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Defining A Stakeholder-relative Model To Measure Academic Department Efficiency At Achieving Quality In Higher Education

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DEFINING A STAKEHOLDER-RELATIVE MODEL TO MEASURE ACADEMIC DEPARTMENT EFFICIENCY AT ACHIEVING QUALITY IN HIGHER EDUCATION

by

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ABSTRACT

In a time of strained resources and dynamic environments, the importance of effective and efficient systems is critical. This dissertation was developed to address the need to use feedback from multiple stakeholder groups to define quality and assess an entity's efficiency at achieving such quality.

A decision support model with applicability to diverse domains was introduced to outline the approach. Three phases, (1) quality model development, (2) input-output selection and (3) relative efficiency assessment, captured the essence of the process which also delineates the approach per tool applied.

This decision support model was adapted in higher education to assess academic departmental efficiency at achieving stakeholder-relative quality. Phase 1 was accomplished through a three round, Delphi-like study which involved user group refinement. Those results were compared to the criteria of an engineering accreditation body (ABET) to support the model's validity to capture quality in the College of Engineering & Computer Science, its departments and programs.

In Phase 2 the Analytic Hierarchy Process (AHP) was applied to the validated model to quantify the perspective of students, administrators, faculty and employers (SAFE). Using the composite preferences for the collective group (n=74), the model was limited to the top 7 attributes which accounted for about 55% of total preferences. Data corresponding to the resulting variables, referred to as key performance indicators, was collected using various information sources and infused in the data envelopment analysis (DEA) methodology (Phase 3).

This process revealed both efficient and inefficient departments while offering transparency of opportunities to maximize quality outputs. Findings validate the potential of the

Delphi-like, analytic hierarchical, data envelopment analysis approach for administrative decision-making in higher education. However, the availability of more meaningful metrics and data is required to adapt the model for decision making purposes. Several recommendations were included to improve the usability of the decision support model and future research opportunities were identified to extend the analyses inherent and apply the model to alternative areas.

This dissertation is dedicated to my family and friends- my mom and dad who raised me to believe that this was possible; my husband Ahmad who supported me; my daughters Amani and Amiyah whom I live to inspire; my late uncle Leverette, who motivated me to fight through anything; my close friend Arnitta who passed during this process and all others that have been instrumental along the way.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
AI	Academic Infrastructure
ANP	Analytic Network Process
AR	Assurance Region
BCC	Banker, Charnes, Cooper Model
BSC	Balanced Scorecard
CCR	Charnes, Cooper & Rhodes Model
CECE	Civil, Environmental & Construction Engineering
CP	Composite Preference
CREST	Costs, Research, Enrollment, Sustainability, Teaching & Learning Model
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DEAHP	Data Envelopment Analytic Hierarchy Process
DMU	Decision Making Unit
DI	Departmental Infrastructure
DQ	Departmental Quality
EECS	Electrical Engineering & Computer Science
FM	Faculty Management
GIS	Graphical Information Systems
GUI	Graphical User Interface
HEI	Higher Education Institutions
IEMS	Industrial Engineering & Management Systems
IO	Input-Output
KPI	Key Performance Indicator
$LIFTS^2$	Learning, Infrastructure, Faculty, Teaching, Students & Sustainability
MMAE	Material Science, Mechanical & Aerospace Engineeing
PI	Performance Indicator
PQ	Program Quality
PS	Program Sustainability
QFD	Quality Function Deployment
SAFE	Students, Administrators, Faculty, Employers Model
SL	Student Learning
SM	Student Management
SWOT	Strengths, Weaknesses, Opportunities, Threats
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TQM	Total Quality Management
USNWR	U. S. News & World Report
VRS	Variable Returns to Scale

CHAPTER ONE: INTRODUCTION

Resources and public trust in higher education have diminished over recent years with the most common causes marked by massification, privatization, globalization, and online education (Altbach, Reisberg & Rumbley, 2009; Sarrico, Rosa, Teixeira & Cardoso, 2010). Governmental funding has decreased, student enrollment in higher education has increased and the number of students needing financial assistance has increased. Institutions are forced to do more with less, thereby increasing the need for efficiency, optimization and quality in its resources and operations.

This task of building and sustaining effective systems and near optimal processes compounds greatly within the context of the university environment. The complexity inherent to such a system is caused by the weakened transparency of the relationships between the components therein. Ultimately, a *University System* is composed of (1) people from different backgrounds that interact with the University and each other at different levels; (2) rapidly changing organizational architectures due to varying needs; (3) a fluctuating physical structure to satisfy current capacity and anticipated demand; (4) social systems bounded by sub-organizations, group behaviors, and student-faculty relationships; (5) services to the professions and the community; and (6) a product (education) which entails teaching, learning and contributing to the overall body of knowledge (research). Funding enters the system in a plethora of forms (i.e. government funding, tuition, fees, activities, research, and gifts) and exits in a similar manner (i.e. overhead, student support, salaries, research expenditures, and physical plant/maintenance).

Trow (1973) notes that changes in higher education impact every part of an institution- its government and administration, finances, the enrollment of students, the curriculum and instruction, and the recruitment, training and socialization of faculty and staff. Therefore, it is crucial to consider the interrelatedness of components to gain insight on the performance of the system (Breneman, 2002; Edmonds, Hernandez & Troitzsch, 2008; Geoffrion, Dyer & Feinberg, 1972; Inbar, 1980).

I. Research into University Dimensions

Three levels of activity exist within the University context- functional, microscopic and universal (Rath et al., 1968). Much of the academic administration research is representative of the functional level, involving the natural view of the systems- students, faculty and similar entities. The two remaining levels are far more complex accounting for human behavior (microscopic) and educational, sociological, political and economic goals (universal). Likewise, there are two dominant philosophies regarding the behavior of systems, namely the positivist view and the social constructivist (or constructionist) view (Remington & Pollack, 2007). The aforementioned views the world as “black and white,” in a sense, failing to acknowledge ambiguities and the unbalanced equity of it components. It considers systems as open and equally accessible to everyone (Remington & Pollack, 2007; Wiseman, 1979). The constructionist view, on the other hand, considers the dynamic and interdependent nature of systems and processes on the overall state of the system (Remington & Pollack, 2007). This research develops based solely on the idea of a dynamic environment.

In Figure 1, the main parts of the University are shown in black text and the interactions between these components are captured using arrows. Blue arrows show a uni-directional relationship while the red arrows indicate a bi-directional flow. Duplicate arrows were found to decrease the readability of this model. It is also important to note that ‘University Revenue’ receives and expends money to many facets that are not directly linked to components within the system due to the assumption that their relationship is either indirect or negligible for the purposes of this representation.

As the figure suggests, significant entities are its people, resources (physical, technological, and service-oriented), products (courses, research and service), and the constant adaptations that occur within. Every change among these components will somehow affect at least one of the other components in either a microscopic or macroscopic manner. Hence, institutions are systems-of-systems that interact continuously, having some effect on the social, structural and physical state of the overall system (Maguad, 2011; Filippakou, 2011). Albert Einstein said it best in that problems cannot be solved at the level at which they occur. Haines (2000) concurs by adding that root causes and ordered effects are typically not linked closely in time or space. In academic institutions there are many components interacting at different levels (granularity); dependent on the problem’s scope, the details and data required to capture such systems can become intractable. Its entities are linked to other systems in a hierarchy or network, establishing the “what” of the component to the “how” of the system (Haines, 2000). Because these entities often have conflicting and competing goals or objectives (Mustafa & Goh, 1996), many effects do not become transparent immediately and intensify the complexity of the overall system.

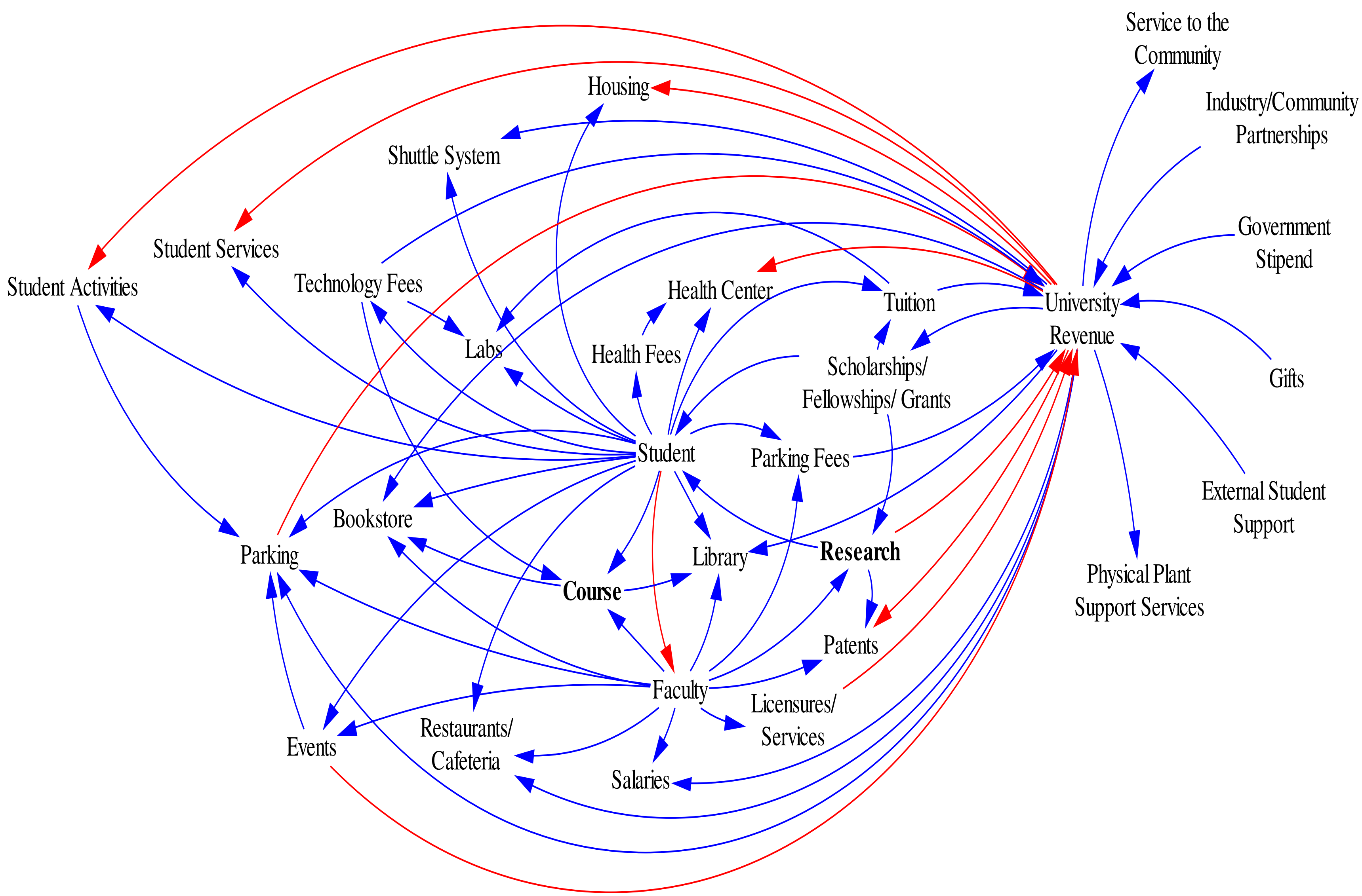


Figure 1: Snapshot of the University System

Jones and Song (2005) weigh the validity of several management theories due to their open-ended indication of when disruptions will occur. The important points these theorists make were that systems are becoming more complex requiring additional consideration of the effects of somewhat “minor” events in order to account for their potential long-term effects. Maguad (2011) counters this claim asserting that variation due to complex interactions occurs so randomly that their combined affects can be considered stable and predictable. While this may be true in some cases, it seems imperative to gain as much information as possible about the interrelatedness of the system to enhance our judgment. Support of theory itself requires an understanding of the cause and effect relationships entailed (Haines, 2000) and hinges on a greater need to understand distinctive system dynamics and use this information to drive the cycle of the system.

Therefore, it is important to understand the dynamic nature of systems so as to maintain an organization capable of effective decision making and dynamic capabilities. This understanding enables rapid adaptation to changes in the internal and external environment (Pavlou & El Sawy, 2011) and increase the permeability to learn, change and grow as an institution (Haines, 2000).

II. Establishing a Need

After thorough review of the higher education and academic administration literature, this dissertation’s focus became quality measurement and efficiency assessment. Quality exemplifies the very dynamics previously discussed. Each component of higher education institutions (HEIs) affects the quality perceived from different stakeholders in the system. A student may perceive the proportion of tuition cost to expenditures per student as indicative of a quality program, whereas faculty may deem a program quality based on the average ratio of teaching hours to research hours per semester. Likewise, administrators may be focused purely on output hence viewing quality as the number of students leaving the program with a degree, while an employer may evaluate the same program based solely on the level of competency of its graduates in performing job duties. Needless to say, quality in HEIs is multi-faceted and stakeholder-relative.

Given the prevailing literature, key stakeholders are initially deduced to students, prospective students, parents, faculty, staff, alumni, administrators, state/national government, special interest groups, local businesses, the community and industry (including future employers). Following further analysis, they are limited to students, administrators, faculty and employers (or SAFE). It is important however, to note that many existing studies that acknowledge the concept of multiple stakeholders in the conception of quality consider mostly the student, faculty and in fewer cases, the employer view (Farid, Mirfakhredini & Nejati, 2008; Grover & Kumar, 2008; Koksal & Egitman, 1998; Owlia & Aspinwall, 1998; Sahney & Karunes, 2004; Singh, Hwarng & Teo, 2000).

Conversely, there are several definitions of HEI quality available (Harvey & Williams, 2010; Srikanthan & Dalrymple, 2002; Tsinidou, Georgiannis & Fitsilis, 2010; Zhang, 2009; Zineldin, Akdao & Vasicheva, 2011), although a crisp definition of quality has yet to reach consensus. The result is an abundance of narrative or reflective papers arguing one alternative over another and a limited representation of data-driven applications. Only 19 of 36 quality articles reviewed were based on either a hypothetical or practical application; the majority of these were of a qualitative nature with respect to the chosen approach.

Fortunately, the introduction of powerful computing capability and the demand for efficiency and effectiveness has given rise to several tools that are capable of highly complex tasks in dynamic environments. This presents opportunities to design and implement effective models for decision support. Cohn et al. (1989) notes the need for a model that considers not only traditional variables that are easily measureable but also factors of quality, institutional structure, fiscal responsibility and more detailed accounts of faculty work.

Researchers' plea for increased simplicity and flexibility in the design of emerging models in HEIs that attempt to capture dynamic capabilities (Pavlou & El Sawy, 2011; Wiseman, 1979). Geoffrion et al. (1972) mentions that future models should "(1) Treat certain parameters as interacting decisions; (2) Use hierarchies; and (3) Expand beyond the functional domain." Newton, Burgess and Burns (2010) point out that future work should identify essential features of the problem, and aim to balance generality, reality and precision in the construction of a model.

III. Objectives

This dissertation is an attempt to marry both qualitative and quantitative aspects of quality. Stakeholder values and input-output measures together result in an assessment of quality that is both multi-faceted and stakeholder-relative. Accomplishing this using a multiple round Delphi study, the analytic hierarchy process and data envelopment analysis ensures that the model is not only qualitative and quantitative, but sensitive to the dynamics of the system. Through four controversial, yet realistic questions, this dissertation:

1. Determines the key attributes of academic departments that identify quality performance;

2. Measures the relative importance of these attributes to stakeholders; and
3. Accounts for the dynamics of the system in the measurement of a unit's efficiency at achieving this stakeholder-relative view of "quality".

IV. Organization of the Dissertation Document

The remainder of this document has been organized in a logical manner. Chapter 2 reveals the literature review, including a comprehensive account of the search strategy. This review covers quality in higher education and the major aspects of the higher education system- including cost management, research, enrollment management, sustainability and teaching and learning. Several existing comprehensive models are introduced, performance measurement is explored and selected tools are described, namely the Delphi method, the analytic hierarchy process (AHP) and data envelopment analysis (DEA).

In Chapter 3 the selected approach is illustrated through a generic model capturing the process and a more implementation-specific adaptation of the model to highlight its application to address the problem. The remaining content is then distributed into three major phases in order to clearly outline the process and capture the output as key deliverables. This chapter concludes with a discussion of the limitations related to the chosen methodology.

Chapter 4 provides the results of the dissertation by stepping through each step in the process. The results are dispersed across 7 sections- (1) Delphi-like Method- Round 1, (2) Delphi-like Method- Round 2, (3) Delphi-like Method- Round 3, (4) Quality Model Verification and Validation, (5) AHP Analysis, (6) KPI Analysis, and (7) DEAHP Analysis.

The final chapter, Chapter 5, summarizes the findings of this dissertation. It highlights the model's utility to university administrator, discusses recommendations, lessons learned, areas of future research and the contribution of the dissertation to the industrial engineering and the overall body of knowledge.

CHAPTER TWO: LITERATURE REVIEW

Limited resources and increasing competition for external resources have created a dire need for institutions to make effective and efficient decisions using more systemically sound approaches (Liberatore & Nydick, 1997). Chapter 1 introduced guiding stimuli to support the importance of this dissertation and its anticipated impact on the literature. High-level components and tasks of HEIs have been framed within the scope of quality measurement as performance measurement stressing the importance of integrating more effective models using variables that consider more than convenient indicators.

This chapter is dedicated to further exploiting this topic, thereby limiting the dissertation's scope. Because institutional structure, fiscal responsibility, faculty work, and student performance are all indicative of quality in higher education this literature review could easily be viewed as very broad. Yet the goal to identify possible performance measures of quality and useful tools and techniques to accomplish the dissertation objectives deems this choice of breadth as satisfactory.

I. Search Strategy

Articles were examined dating back as early as the 1960s to ensure the ability to accurately capture the state of the art. Many earlier articles were excluded if adequate details of their content were available in survey papers.

The search began with a brainstorm of keywords related to the target areas. These keywords (or combination of keywords) were used to search all databases and journals listed on Table 1 in order to generate a list of possible references for further review.

Table 1: Search Keywords

Keywords	Search Boundaries
Organizational Decision Making, University Planning, Institution, Decision Support System, Model, Academic Administration, Higher Education, Multi-Criteria, Cost Model, Assessment, Planning, Management Science, Modeling, Simulation, Efficiency, Enrollment, Social, Multiobjective, Growth, Quality, Data Envelopment Analysis, DEA, Analytic Hierarchy Process, AHP, Analytic Network Process, ANP, Frontier, Non parametric, Weight Restriction *(Combinations of keywords also used)*	Books24x7.com Amazon.com UCF Library Databases *EBSCOhost* *Elsevier Science Direct* *Engineering Research Database* *ERIC* *Google Scholar* *JSTOR* *LexisNexis Academic* *Springer Link*

A. Inclusion Criteria

All articles and books included in this study were published between 1964 and 2011. They were published in English and are available on the UCF Library electronic interface, with the exception of a few titles retrieved from books24x7.com or purchased. All findings were categorized based on eight dimensions- (1) holistic models, (2) quality, (3) cost management, (4) enrollment management, (5) sustainability, (6) analytic hierarchy process, (7) data envelopment analysis, and (8) other or unclassified. They were further categorized as a literature review, commentary, or hypothetical/practical application. The result was 120 works that are cited throughout the remaining sections to initiate a conversation of what has been done in the field of HEI performance measurement and how three distinct, multi-criteria tools may be useful in satisfying the objectives of this dissertation. Figures 2-3 provide a summary of referenced works. Any studies covering multiple dimensions of this classification scheme are counted more than once so the total is slightly more than 120 in Figure 2.

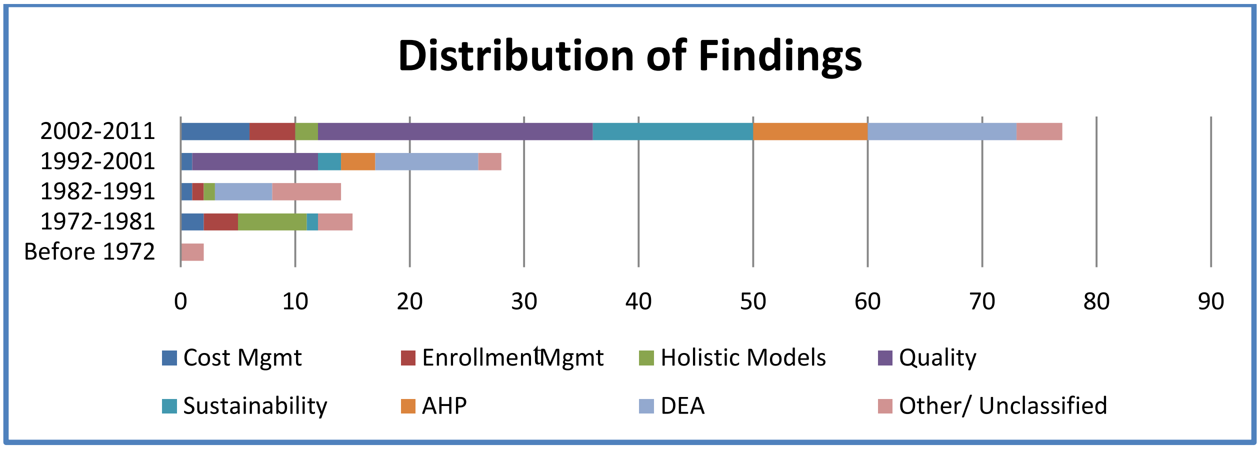


Figure 2: Works Summary

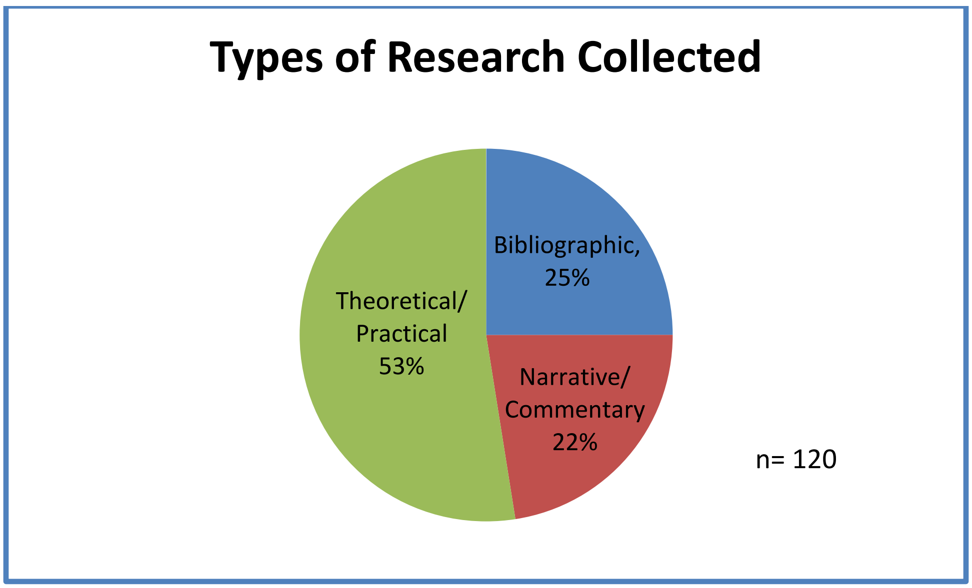


Figure 3: Distribution of Research

B. Limitations

While it is infeasible to exhaust all possible literary works or to analyze all models ever proposed, this study uses several comprehensive databases to attempt to capture the state of the field. It additionally considers sources uncovered from manual searches using the Internet Explorer Web Browser and the Google Search Engine.

C. Summary of Findings

Based on the reviewed literature, this chapter discusses quality in higher education, which instigates a conversation of past studies in various dimensions of performance measurement including comprehensive and generic studies in cost management, enrollment management, sustainability and research, teaching and learning. In introduces the Delphi method, approach to gather qualitative data in a systemic and often confidential manner. It also discusses two prevailing computational tools- the analytic hierarchy/network process (AHP/ANP) and data envelopment analysis (DEA) highlighting their usefulness and limitations in complex systems.

II. Quality in Higher Education

Quality has been a concern in higher education for some time. Cheng (2003) discusses quality assurance in education using three distinct paradigms, which he adds are complementary. The first paradigm focuses on education effectiveness, or quality as an ability to achieve academic goals with respect to teaching, learning and other internal, academic processes. The second paradigm specifically emphasizes institutional effectiveness as education quality, stakeholder satisfaction and market competitiveness. The "triplization" factors guiding the third paradigm, namely globalization, localization and individualization aids in bringing the aforementioned view of quality into a more sustainability-based perspective. Whether its purpose is accountability, improvement or a fusion of the two (Saarinen, 2010), it is a diverse field attracting researchers from many disciplines.

A. The Quality Debate

While the desire to achieve quality is often the case (Filippakou, 2011), there is an overall lack of consensus on what quality is and how it can be measured. A review of 320 articles published in a leading quality in higher education journal asserts that quality is still a highly contested concept and acceptance of this position is what allows for progress in the field (Harvey & Williams, 2010). Many subscribe to the student-centric view of quality which perceives quality as service quality provided to students, thereby discounting the needs and requirements of other stakeholders (Zineldin et al, 2011). This notion is likely one of the primal views of quality in HEI since it emerged heavily in the literature during the maturation of Total Quality Management (TQM). Many studies support this view (Tsinidou et al., 2010; Zineldin et al., 2011) and the similar value-added or transformation approach (Srikanthan & Dalrymple, 2002; Zhang, 2009).

The contemporary view seems to be quality as multi-faceted, multi-dimensional, value-laden and quite elusive (Altbach et al., 2009; Green, 1994; Harvey & Green, 1993; Harvey & Williams, 2010; Law, 2010; Newton, 2010; Sarrico et al., 2010; Singh, 2010; Tam, 2001; Tsinidou et al., 2010). Murias, Miguel and Rodriguez (2008) asserts that quality assessment is synonymous with overall effectiveness, hence performance measurement. A very thorough definition that seems to embody a number of available perspectives was posed by Berquist (1995) and reads:

> *"Quality is the extent to which an institution successfully directs adequate and appropriate resources (input) to the accomplishment of its mission-related outcomes (output) and that its programs make a significant and positive difference in the lives of people associated with it (value-added) and that these programs are created, conducted, and modified in line with the mission and values of the institution (process)."*

More concisely, quality is ‘fitness for purpose and fitness of purpose’ (Sarrico et al., 2010). Albeit some researchers opt to argue quality as a set of dimensions that together define quality- i.e. (1) exceptional, perfection, fitness for purpose, value for money, and transformation (Harvey & Green, 1993); (2) technical quality, functional quality, atmosphere, interaction and infrastructure (Zineldin et al., 2011); and (3) academic, managerial, pedagogic and employment (Brennan & Shah, 2000).

B. Acknowledging Stakeholders

The notion of quality as stakeholder-relative and highly dependent on context seems inevitable. Higher education serves multiple stakeholders with various interests. Students, faculty, administrators, local and state government, industry and society all bear an investment in higher education. The ability to provide ‘quality’ to each entity simultaneously is a complex and daunting task due to the inconsistent and contradictory nature of their expected outcomes.

The key to addressing this challenge is to consider these often competing perspectives and discourses in not only the conception or classification of quality, but also in the way that it is assessed (Green, 1994; Pratasavitskaya & Stensaker, 2010; Sarrico et al., 2010; Tam, 2001). Pratasavitskaya and Stensaker (2010) add that any future applications should make the operations and activities of the University more transparent, accountable and efficient. Table 2 evaluates several articles self-identified as offering quality-based models in HEIs. Their treatment of stakeholders and system dynamics is recognized and the data types employed are disclosed.

Table 2: Key Quality Models

Topic: Multiple Stakeholder Perspectives for Strategic Quality Assessment & Improvement

(Quality Models Only)

**Student (S), Faculty (F), Employer (E), Government (G), Community (C), Administrator (A)*

	Purpose					Stakeholders Views*						Managing Competing Voices					Data Types			
	System Dynamics	Multiple Stakeholders	Prioritization of Quality Factors	Quality Evaluation/ Asessment	Quality Improvement	S	F	E	G	C	A	BSC	QFD	Fuzzy Logic	AHP	DEA	Subjective	Literature Review	Primary/ Secondary Performance Data	None
Existing Models of Quality in Higher Education																				
Farid, Mirfakhredini & Nejati (2008)			X				X					X		X			X			
Singh, Grover & Kumar (2008)		X	X			X	X	X					X					X		
Ibrahim (2001)		X				N/A								X						X
Owlia & Aspinwall (1998)		X	X		X	X	X	X					X				X			
Aydin, Kahraman & Kaya (2012)				X		N/A								X	X		X			
Koksal & Egitman (1998)		X	X			X	X	X					X		X		X			
Jantzen(2000)						N/A													X	
Shelton (2010)				X	X						X	X					X			
Tsinidou, Vassilis & Fitsilis (2010)			X			X								X	X		X			
Zhang (2009)				X		N/A													X	
Hwarng & Teo (2001)		X	X			X	X						X				X			
Sahney & Karunes (2004)			X			X							X				X			
Kennedy (1998)	X			X		X		X	X	X							X			

C. Rankings, Awards & Recognition

The use of rankings to implicate quality institutions is highly controversial (Harvey, 2008) given the common objective of comparing institutions or programs to reveal an ordered "best". Each schema represents a different purpose, employs varied metrics, assigns often biased weights to selected indicators and offers limited usability given alternative scenarios. Consequently, there is no apparent consistency across the different ranking systems (Harvey, 2008). The "best" performer of one ranking could easily become rated an average competitor in a different ranking model. Despite its flaws, rankings represent one of the leading options in the demand for greater transparency in HEIs (Federkeil, 2008).

Rankings typically come under scrutiny for a number of reasons including (1) Most selected measures are typically the result of a priori processes and the weights assigned to them are often determined in a similar manner; (2) Current ranking systems tend to discount the shift to education as global systems; (3) There is an overall lack of systemic and theoretical basis; and (4) Readily available data, usually secondary, publicly available data, is often used as a surrogate of the desired measure (Federkeil, 2008; Harvey, 2008).

In an article by Federkeil (2008), three major suggestions were offered to guide the evaluation of existing rankings or the evolution of a new system of measurement. The first suggests that rankings should find balance between the goal of the instrument and the needs and requirements of HEIs. Next, a broad range of data should be used to enable analysis on various aspects of performance. And lastly, data should be limited to a single field, department or program. This disaggregation helps to take into account the varied operations, needs and requirements of each respective system.

Additionally, Harvey (2008) emphasized six steps to devise rankings or measurement systems (originally offered by Lazarsfeld et al. in 1972): (1) Make a clear statement of what is to be measured; (2) Determine dimensions of the selected measurement; (3) Identify sets of possible indicators for each aspect; (4) Narrow the list of indicators; (5) Theoretically and systemically weigh each indicator's importance given its respective dimension; and (6) Calculate an aggregate index from the derived dimensional weights.

In short, there are several available ranking systems including the Times Higher Education World University Ranking, the Princeton Review, and the Center for Measuring University Performance Report. The Times Higher Education World University Ranking system ranks universities based on 13 performance measures divided into five categories- *Teaching* (30%)- the learning environment; *Research* (30%)- volume, income and reputation; *Citations* (30%)- research influence; *International Outlook* (7.5%)- staff, students and research; and *Industry Income* (2.5%)- innovation. The preferences of the users could be used to alter the weights given to each category.

Alternatively, the Princeton Review offers 62 different rankings of schools by region, based solely on student survey responses. It is compiled annually and discriminates among universities based on demographics, community, academics, politics, extracurricular activities and other categories that may seem relevant to students. The third ranking system listed orders institutions based on the number of times they rank in the top 25 in 9 measures- total research, federal research, endowment assets, annual giving, National Academy members, faculty awards, doctorates granted, postdoctoral appointees, and median SAT scores. Nevertheless, because of their wide usage, the U.S. News & World Report rankings are of greater interest here.

U.S. News & World Report

The decision to consider the U.S. News & World Report Ranking System for Higher Education stems from its quality implications to those who recognize it. The report is issued yearly and ranks institutions in the order of which is 'best'. A close examination of the criteria for ranking the best graduate engineering schools revealed a shocking flaw in the methodology. The criterion for identifying the 'best' institution is highly biased and highly subjective. Based on its methodology, quality of engineering colleges is 40% of the metrics and based solely on the opinions of academic peers and industry recruiters. What's even more surprising is that the specialty rankings within Engineering, both undergraduate and graduate level, are based solely on the opinions of peers. Recognition of these flaws are at the heart of debates on ranking systems.

III. Comprehensive Models in Academic Administration

Much controversy uncovered in the literature debates whether a comprehensive model can be built that accurately represents the dimensions of the system by eluding into its microscopic or even universal realm (Masland, 1983). Haines (2000) seems to agree to some extent, with her notion that systems upon systems are too complex to fully understand. Yet, the key to representing complex systems that can efficiently aid in the decision making process is to find balance between simplicity, flexibility, usability and effectiveness.

There are countless mathematical programming models, statistical designs and small simulations that address specific problems in performance measurement, but as Geoffrion et al. (1972) adds, these models simply do not take an interactive approach to coordinating decisions and estimating tradeoffs between criteria. Few researchers have taken a comprehensive and systemic approach to account for the complexity of the system (Bleau, 1981; Foreman, 1974;

Hopkins, 1979; Kassicieh & Nowak, 1986; Masland, 1983; Schroeder, 1973). Such large scale, implemented models opting to take this approach are summarized in Table 3.

It seems imperative to note the assertion of Plourde (1976) which claims that existing models are sufficient to solve the problems at hand and it is simply a matter of refining those models to meet the times of a given context. Srikanthan and Dalrymple (2002) further this assertion by claiming that a synthesis of available models would make it possible to develop a holistic model addressing at least the educational process.

Alternatively, there is significant concern over the usability of past generic models. Schroeder (1973) notes that the relationships between the inputs and outputs of the educational process are necessary to increase the usefulness of models in academic administration. One survey of 394 schools reported that most institutions that had access to comprehensive models did not use them or in some cases, did not even implement them (Wiseman, 1979). This lack of use has several implications that should be considered in the development of future models:

A. Skepticism of system representation

B. Skepticism of data accuracy

C. Lack of usability- *i.e. interface, reports, other outputs*

D. Goal Misalignment- *i.e. output does not meet needs*

E. Discounting the quality of education

Table 2: Comprehensive Models in HEI Performance Measurement Table

Model Name	Author/ Year	Description	Granularity	Key Variables	Concerns
TRADES or "trade-offs"	Hopkins (1979)	Explorative mathematical programming model to test alternatives iteratively to obtain an improvement in the solution based on user defined values	University/ College	# of tenured and untenured faculty, auxiliary faculty, student levels, tuition, growth-rate of tuition, staff-to-faculty ratio, the degree of liquidity, salary policy, and the funded improvement fraction.	Small scale modeling; most basic capture of interrelationships among minimal planning variables
CAMPUS, Comprehensive Analytical Method for Planning in University Systems	Foreman (1974)	A simulation model showing implications of changed conditions on facility requirements and budgets	Course	Enrollment Inputs & Cost Factors: (I) Indirect Cost; (D) Direct Cost Activity Cost (D), InstructionalSupplies, InstruEquip, FacultySalaries, FringeBenefits, SupportSalaries, FieldWork, Academic Overhead (D), Educational Resources (I), Student Services (I), Administration (I), Plant (I)	Expensive; Large Data Requirement; Computing Requirements
RRPM, Resource Requirement Prediction Model	Schroeder (1973); Hopkins (1979); Masland (1983)	A simulation model that calculates the cost associated with programs and their operating costs	Discipline or Program	Enrollment projections, course demands, support costs, salaries, academic departments, physical constraints	Linearity & stability assumptions; bias; misrepresentation of trends; Inexpensive
SEARCH, Systems for Evaluating Alternative Resource Commitments in Higher Education	Schroeder (1973); Hopkins (1979); Masland (1983)	A simulation model to examine how changes in a factor affects related factors	Discipline or Program	Student sex and class, faculty rank and department, students enrolled by class, total faculty, individual compensation, budget summaries, endowment summaries	Little insight on internal allocation of resources due to adequate cost breakdowns

Model Name	Author/ Year	Description	Granularity	Key Variables	Concerns
Unnamed	Geoffrion, Dyer & Feinberg (1972)	An interactive mathematical programming approach to multi-criterion optimization	Department	# of sections offered at varying levels- graduate, lower undergrad, upper undergrad; # FTE regular or irregular faculty by type- tenured, non-tenured, teaching assistants, lecturers and senior lecturers; # FTE released; # FTE allocated to dept.; student enrollment	No treatment of academic output or interacting decisions
EFPM, Educom Financial Planning Model	Bleau (1981)	Off the shelf, generic version of TRADES used to create models that forecasts budgets and analyze based on user-defined constraints on resources and policy	University/ College	A blank matrix of 560 variables is offered that lets the user create a model based on their needs, establishing the relationships between the variables. Key variables such as faculty size, salary increases, and student enrollment must be initialized and may be projected up to 10 years into the future.	Accessible over dial up server; Not a ready to use model
HELP/PLANTRAN, Higher Education Long-range Planning	Bleau (1981)	Interactive model where the user sets up simulations using a budget rendering a reference matrix and output reports; Revised to an off the shelf version	Department	Budget Variables	Small model

Anderson, Milner and Foley (2008) argue that too commonly researchers discount a phenomenon by observing static snapshots or oversimplifying data at the compromise of usability. In foresight, much of the more recent work avoids these large-scale, generic planning models altogether (White, 1987). McNamara (1971) captures this trend and warns researchers of the risks related to modeling sizeable, generic models, as he suggests that researchers should concentrate on specific problems only. In the following sections, additional research in academic administration has been categorized based on prevailing concerns related to quality as performance measurement- (1) Cost Management, (2) Enrollment Management, (3) Sustainability, and (4) Research, Teaching and Learning.

IV. Cost Management

During a time of decreased government appropriations and declining opportunities for sponsored research, Universities tend to fill the budgetary void with increases in tuition (Bell, 2011; Immerwahr & Johnson, 2010). This is evidenced in many studies included in the survey by Mustafa and Goh (1995). With the exception of the comprehensive cost models in the preceding section, existing research in cost management tends to approach the matter using (1) single-product studies that view the cost yield of an institution as a function of a single outcome or (2) overly simplified multi-dimensional studies like those considering teaching and research as the sole factors affecting higher education (Agasisti & Salerno, 2007; Cohn, Rhine & Santos, 1989).

Hoenack and Pierro (1990) introduced a model of the relationships among several variables used to explain university enrollment and instructional revenue. The model accounted for legislative demand, student demand, and institutional supply but the interpretation of what this model actually achieved is unclear.

However, Agasisti and Bianco (2007) note several cost functions proposed by researchers between 1989 and 2005 and follow by estimating another. Their quadratic cost function takes into account all public, Italian universities with teaching and research responsibilities. It addresses the interaction between teaching and research activities as a possible driver in cost reduction but it does not consider the quality of output or provide any information on cost efficiency. An extension of this work was performed by Agasisti and Salerno later in 2007. It adds to the study using data envelopment analysis to assess cost efficiency and several measures of education and research quality. Although these measures were able to trace directly into the much overlooked area of quality in institutions, the authors conclude with a recommendation to pursue more specialized combinations of output in future studies.

Simon and Ranchero (2010) can attest to this need based on many of the ongoing issues they report in this area. Examples include the ill use of profit-and-loss statements to determine the worth of individual faculty members, funding practices based directly on what students accomplish, and cost-benefit analysis based mostly on the amount of research funds generated and the number of courses taught. Each of these approaches is highly contested and highlights a key concern in cost management, namely the inconsistencies between educational programs at any given institution (Capaldi & Abbey, 2011). Because funds generation and expenditures differ greatly across and within disciplines, by level of coursework and by the original source funding, there is an increased need for consideration of such differences. Without this understanding decision-making capabilities in cost management are at a disadvantage (Rich, 2006).

V. Enrollment Management

Enrollment management is a significant concern in academic administration. In the age of increased enrollment, an increased desire for diversity, and the often observed lag in degree completion, it is important to more closely examine enrollment management.

Doyle and Cicarelli (1980) lead this discussion with the introduction of a regression model of enrollment demand to analyze several variables that affect student enrollment. Two similar studies were later conducted by Jantzen (2000) and Berger and Kostal (2002). Jantzen offered a two-stage least square regression model of enrollment demand that considered factors internal and external to the University (Jantzen, 2000). Although this model considers tuition change, accreditation status and funding sources in its analysis, there were several simplifying assumptions about enrollment trends and other factors, which seem to threaten applicability. Berger and Kostal, on the other hand, considered supply and demand forces to evaluate the determinants of enrollment at the State level. They used secondary data to develop an econometric model that determined the effect of socioeconomics and financial resources on enrollments (i.e. tuition, state and local appropriations, income, labor market conditions). Given the high aggregation of the data used, the study concluded that tuition is the most significant factor in enrollment demand.

In a more complete analysis, DesJardins, Ahlburg and McCall (2006) produced a simulation model that considered student application, admission, financial aid awards and enrollment behavior to determine how these factors affect enrollment and application behaviors. Likewise, Maltz, Murphy & Hand (2007) implemented a predictive enrollment model using a financial aid matrix and the probability of several predictors of student enrollment to determine yield and discount rate. By using neural networks, decision trees, several iterations of the logistic regression function and Microsoft Excel, the researchers were able to optimize enrollment, yet based solely on a financial objective.

A sensible conclusion is that much of the enrollment management research has been focused on students' demand for a University rather than how student enrollment affects the operation of the University. The reality is that increased enrollments causes strain on existing resources- physically, structurally, financially and functionally. This leads to the following discussion of sustainability.

VI. Sustainability

A popular myth in higher education is that growth has an overall positive impact but organizational growth is a multi-dimensional concept. The adaptation of new technology, globalization, multiple interacting processes and numerous forces exerted from internal and external stakeholders (Mihm, Loch, Wilkinson & Huberman, 2010) require organizational balance to support such change. Massification, curriculum expansion and similar implications of growth have been reported to have a negative or adverse effect on measures viewed as important by stakeholders (Altbach et al., 2009; Oppedisano, 2011). This confirms that while growth is often a desired state of an organization, a preceding requirement of complementary resources and the operational capacity to satisfy the new demand must guide. If 1000 students are accepted into a college each year, but the institution has the capacity to serve only 500, continued growth while all other factors remain unchanged would be less than desirable. This overall lack of achieving sustainable growth is the reason many organizations fail (Weinzimmer, 2001).

In "Fast Growth: How to Attain It, How to Sustain It," Weinzimmer lists several relationships that must be balanced for sustainable growth including, *Growth vs. Cost*

Management, Growth vs. Operations, and Resources vs. Capabilities. Significant signs of the imbalance of these components are divided into two categories- functional and infrastructure-related. The *Functional* domain includes (1) Poor Product or Service Quality; (2) Inefficient Procurement and (3) Operational Issues, while *Infrastructure* entails the (1) Misuse of People including inappropriate empowerment; (2) Information Technology Strain, (3) Poor Accountability and (4) Inconsistent Record Keeping. Each of these are detrimental to the state of the institution over time (Weinzimmer, 2001).

Moreover, Alemu (2010) alleges that a "quality higher education largely depends on the qualities of educational inputs (resources such as fiscal, physical, human, curricular, material/equipment) and throughputs (institutional governance that entails accountability, setting and implementing clear standards, and effectiveness)."

VII. Research, Teaching and Learning

There appears to be an overwhelming consensus that research, teaching and learning are the most important responsibilities of HEIs, although the degree of the importance of each may vary among stakeholders and across institution types. As implied in the selection of variables in nearly all past studies reviewed to this point, research tends to be measured on the basis of either quantity or "quality" whereas teaching and learning often lends itself to proxies of output excluding what occurs in the "elusive black box" (Pavlou & Sawy, 2011). The elusive black box refers to the complex internal processes of the education system.

A. Faculty Work

An issue that is commonly avoided is the complexity of faculty work. Aside from teaching and conducting research, individuals are often expected to serve on multiple committees, guide the matriculation of students, participate in special projects and prepare outside of class (O'Meara, Terosky & Neumann, 2008). Simon and Ranchero (2010) reference complaints about how common student-centered metrics and other accountability tools place too little emphasis on what actually takes place in the role of faculty. Hardré and Cox (2009) found evidence to support this perceived inconsistency of needs between departments by investigating the criteria for evaluating faculty work for the tenure and promotional process across an institution.

One notable attempt to account for this extended view of faculty work was presented by Geoffrion et al. in a 1972 article. They introduced a hierarchical model composed of a coordinator and several semi-autonomous operating components that enabled multi-objective decision making capabilities based on the goals of the department. It was an interactive, mathematical program to estimate the tradeoffs between sections offered (by level), teaching assistant time used for support, faculty release for other departmental service duties and an aggregate variable accounting for miscellaneous responsibilities of faculty, yet there was no treatment of academic output or interacting decisions in the model.

B. Student Learning

No person can discount student learning as a dimension of performance measurement in HEIs so the argument therefore lies in how to measure student learning. Is it effective to use student performance indicators such as graduation rates, - grade point average (GPA) or test results to measure student learning? What is the relevance of these measures as a function of student entrance qualifications or the quality of the education provided? Do the most meaningful measures of learning occur at departure from the HEI or upon “successful” employment in the respective field? Each of these scenarios have been examined by researchers (as demonstrated throughout this report), yet an overall tendency is the use of entry qualifications or graduation data to measure student learning. This raises concerns as to the loss of transparency of what factors are affecting student transformations (or lack thereof) in this process.

VIII. Performance Measurement

Ho (2008) recognizes performance measures as one of the "crucial and urgent" tasks in the University. The literature presented to this point has been concerned with performance measurement in the higher education environment as it directly or indirectly relates to different dimensions of quality. Of the numerous techniques and approaches used by researchers, two additional topics are deserving of distinct discussion- performance indicators and input-output measures.

A. Performance Indicators

Performance indicators (PIs) have been criticized in the public sector due to their focus on inputs to the detriment of outputs and the common ad hoc process of indicator selection which complements them (Avkiran, 2001). "Studies of performance indicators have raised doubts about their relevance and validity as measures in isolation" (Johnes & Taylor, 1990) because comparisons have shown that different indicators produce highly varied evaluations of the same units (Johnes & Taylor, 1990). The central objection is their inability to capture the interaction among the various inputs and outputs (Avkiran, 2001). Nevertheless, Law (2010) concludes that the employment of PIs under adequate conditions can be a notable contribution to the field. The difficulties arise when determining accurate and meaningful measures.

In addition, a number of studies using PIs employ only proxy measures of educational processes and its inputs and outputs due to the inability to secure the necessary data (Sarrico et al., 2010). This usually results in the use of simpler studies using highly aggregated data that is incapable of capturing the interrelatedness discussed throughout this review. A recent study developed a quality scorecard using the Delphi method. It features many pre-existing and original quality indicators weighed by a 'panel of experts' to assess the quality of online education programs (Shelton, 2010). This study is of a qualitative nature but the overall methodology offers much value.

B. Inputs & Outputs in Higher Education

Many higher education studies state the task of explicitly selecting the inputs and outputs of education as an issue. A resource is generally an input used to produce outputs (Avkiran, 2001). Although this is a simple concept at the most basic level, the complexity of the higher education system as evidenced by the inconsistency of input-output (IO) selection across the literature suggests this to be a very difficult task. Johnes and Taylor provides a survey of performance indicators in higher education (1990) where the input known to have the greatest positive effect on degree results, for example, is the quality of students upon arrival to the University (Johnes, 2006a). Another study by Usher and Medov (2010) uses IOs to evaluate indicators of accessibility and affordability as output and the data required to estimate those indicators as inputs.

Appendix B is an exhaustive attempt to capture IOs and performance indicators used in the literature to directly measure "quality". It shows the stakeholder perspectives considered in each study and the approaches utilized. This table is extended by Table 7, where the inputs and outputs used in Data Envelopment Analysis studies in HEIs are also considered.

IX. Tools for Complex Systems

Academic institutions are using computer-based tools to better structure and understand the effects of changes on the overall organization (Masland, 1983). The field of Operations Research (OR) has stemmed from early works in operations management, which was mostly composed of descriptive research until the 1960s (Buffa, 1980). Operations Research has shifted from its initial motivations of solving real-life problems in operations management to the need to develop both explanatory and predictive models (Bertrand & Fransoo, 2002).

More generically speaking, operations research is the use of mathematical modeling techniques to address both simple and complex problems. Simple problems are commonly well-structured problems so almost always choice problems, while complex problems are usually ill-structured problems, most often resulting in a design problem (Grunig & Kuhn, 2009). This warrants the discussion of descriptive versus prescriptive models in operations research.

The task of distinguishing between the two is sometimes rather complicated as evidenced in model interpretations found in the literature (Hansson, 2005). This is more apparent in OR than many other disciplines. The sections below attempt to define descriptive models and prescriptive models as either normative or prescriptive models due to the debate in the literature as to whether the two are interchangeable.

A. Types of Models

Descriptive Models

Descriptive models, often representative of work in the social sciences, are concerned with the how and why of problems, involving mathematical modeling and statistical analysis. It is empirically indebted and often involves clinical activity like surveys. Bell and Raiffa (1980) define the purpose of these models as *describing*, without trying to modify, influence or moralize such behavior. The authors also offer a list of questions that helps to conceptualize the types of models included in this domain. For example,

1. How do real people think and behave?
2. How do they perceive uncertainties, accumulate evidence, learn and update perceptions?
3. Can people articulate the reasons for their actions?
4. What are the differences in types of thought patterns for people of different cultures, of different experience levels?
5. How can approximate real behavior be described?
6. How good are mathematical models in predicting future behavior?

Normative Models

Some researchers use the terms normative models and prescriptive models interchangeably as evidenced in Bertrand & Fransoo's (2002) reference to normative research which says that such models are primarily for the purpose of "developing policies, strategies, and actions to improve..., to find optimal solutions for a newly defined problem, or to compare various strategies for addressing a specific problem." Since this seems to harbor the essence of both normative and prescriptive models, this section deciphers normative models as those dealing with logical, rational or intelligent behavior as explained by axioms, basic principles or a similar transitive basis; therefore, its value becomes dependent on the "empirical verification" of the behavior, whether actual or as perceived by the decision maker (Bell & Raiffa, 1988). These models are primarily interested in analyzing an abstract system to understand and explain the characteristics of the model (Bertrand & Fransoo, 2002).

Moreover, normative models answer questions regarding how decisions should be made in order to be rational and how to coordinate these decisions over time (Hansson, 2005). The end result is a dynamic interaction between the real world, a perception of the world and the abstract mathematical representation of the world. (Bell & Raiffa, 1988).

Prescriptive Models

The third class of models, prescriptive models contain instructions for action for rational decisions (Grunig & Kuhn, 2009). It may combine both descriptive and normative models to the accomplishment of this purpose and typically deal with intransitive preferences such as non-stationary preferences, stochastic and the balancing of attributes (Bell & Raiffa, 1988). This domain satisfies the paraphrased statement by Kirby (2007) that argues that "objectivity cannot be the absence of value judgments in purposeful behavior- because purposeful behavior cannot be free from value." Key questions answered by prescriptive models are:

1. What should an individual do to make better choices?
2. What modes of thought, decision aids, and conceptual schemes are useful for real (and diverse) people?

Model Type Summary

Bell and Raiffa (1988) comments that each of the three models can be better deciphered by its criteria of evaluation:

Descriptive models- Empirical validity (extent to which they correspond to observed choices)

Normative models- Theoretical adequacy (degree of acceptable idealization or rational choices)

Prescriptive models- Pragmatic value (ability to help people make better decisions)

Classification of Models

Each of the higher education conceptual and implemented models referenced in this dissertation are classified based on the three model types (Figure 4). Appendix C includes a more detailed taxonomy. These classifications are limited in several ways including, (1) They are based only on the information presented in each article, which may not be a complete account of methods/approaches used; and (2) Models are classified without consideration of user interaction, therefore some models noted as used or interpreted for prescriptive purposes are not specified as such.

Nevertheless, the figure clearly shows an over-emphasis in the higher education literature on empirical methods for the purpose of explanation or description. Even if we combine the normative and prescriptive models (as some researchers suggest), descriptive models would remain dominant.

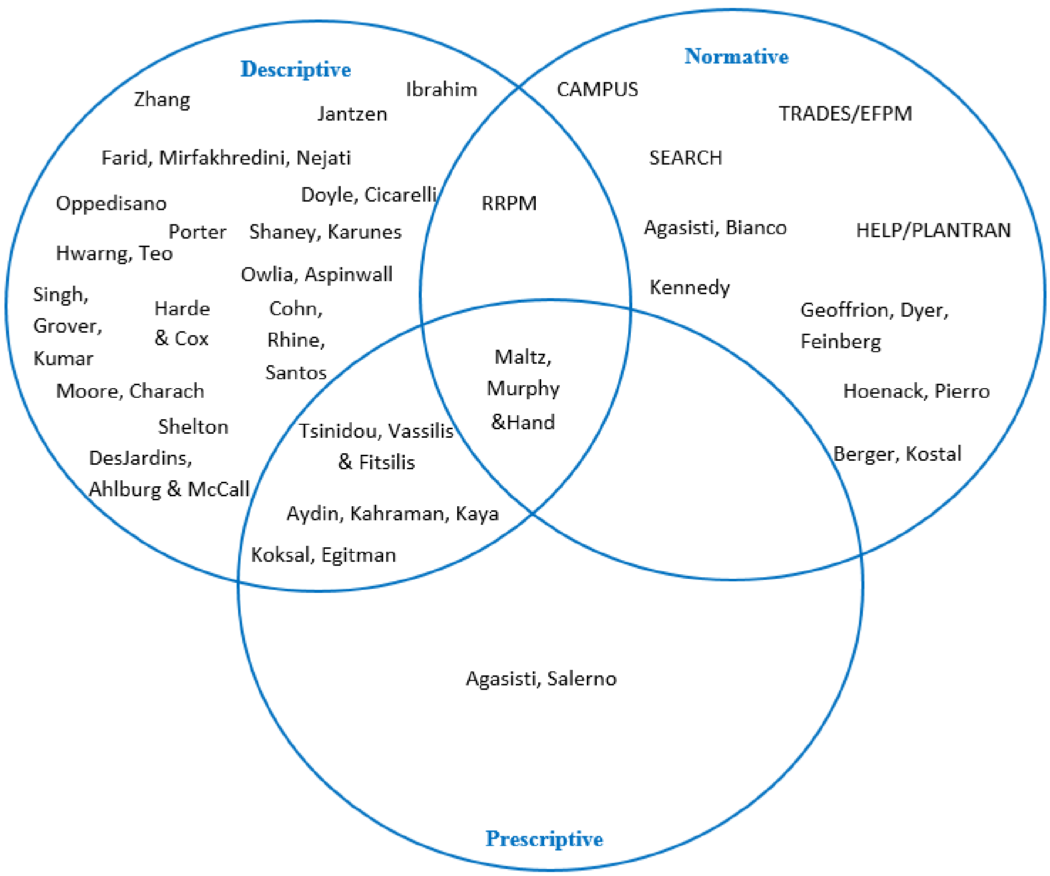


Figure 4: Classification of Reviewed Higher Education Models

Other Findings

Rath et al. (1968) offer a small compilation of the use of management science in University operations. Schroeder (1973) builds on this knowledge as he classifies literary trends using four primary decision making methods- mathematical models; resource allocation models; planning, programming and budgeting systems; and management information systems.

Additionally, White (1987) classified 146 studies using a comprehensive taxonomy that showed the common level of model design as being for *University Level* decision making (80%). A closer look at the models revealed that their primary purpose were in either planning or resource allocation tasks. Operations research methods and management science techniques were predominantly employed and the common factors of faculty, students and facilities were the most considered parameters.

An overall dominance seems to belong to mathematical programming. White (1990) cites 504 references that use mathematical programming methods for complex systems. The depth of the information provided is minimal; yet the magnitude of sources listed provides an ideal starting point for future researchers interested in past mathematical programming applications. Moreover, linear programming is traditionally an approach used to achieve desirable outcomes, given constraints and an objective function. It has been extended quite notably by multiple or competing criteria methods, or MCM (Geoffrion et al., 1972; Mustafa and Goh, 1996; Evans, 1984). One study used MCM to assist in departmental resource allocation decisions. The model was structured to provide users with value tradeoffs within institutional and resource constraints (Schroeder, 1973). A second study used MCM to study the influence of numerous determinants of service quality from the student perspective (Tsinidou et al., 2010).

In a more summative fashion, Mustafa and Goh (1996) supplement these accounts with a review of 62 application papers on multi-criteria decision models in academia and classify their purpose, technique, and whether they were hypothetical or practical in nature. All models reported by the publication date were for the purposes of resource allocation, budgeting, evaluation, scheduling, and/or planning with many models satisfying the criteria of multiple purposes.

In the following sections, the Delphi method is introduced and two approaches in the mathematical programming and multi-criteria modeling literature are discussed- the analytic hierarchy/network process (AHP/ANP) and data envelopment analysis (DEA).

B. The Delphi method

The Delphi method offers a systemic and widely used approach to group problem solving, decision-making and forecasting (Landeta, 2006; Okoli & Pawlowski, 2004; Pill, 1971). Its mid- twentieth century roots trace back to a military application to reach consensus (or a convergence of opinions) given a small group of experts through an iterative series of controlled communications (Hsu & Sandford, 2007; Landeta, 2006; Okoli & Pawlowski, 2004).

Today, there are several variations of this method, illuminated in vast applications found in the literature- i.e. Derivation of alternatives; Exploration of underlying assumptions and theory; Gathering information related to the respondent group; Correlation of informed judgments; Creation of awareness related to the diversity of perspectives; Identification of research topics and questions; Selection of variables of interest; and Delineation of relationships (Hsu & Sandford, 2007; Okoli & Pawlowski, 2004).

The Delphi method can be characterized by four major attributes- (1) The process is iterative over time; (2) Anonymity is present among participants, minimally extended to anonymity in respondent feedback; (3) Controlled feedback ensures that previous data is communicated through later rounds; and (4) Group statistical response to provide a quantitative and more systematic function of the analysis (Hsu & Sandford, 2007; Landeta, 2006; Pill, 1971).

The literature exposes several strengths, weaknesses and opportunities of utilizing the Delphi method. Of these, the reduction in the psychological effects related to attaining group consensus in a non-anonymous setting is a key driver. The ability to share true opinions and later refine those opinion based on insight from the group is an invaluable feature of the approach. However, concerns have been raised as to other factors including low participation rates, the time commitment required for participation, the selection of "experts", the deterioration of the quality of responses over time, and the heavy reliance on written and virtual communications (Landeta, 2006).

Given the nature of the approach, the sample size does not conform to statistical power estimates. Instead, the method stresses the overall group dynamics and suitability of respondents as “experts” based on the researcher’s needs (Okoli & Pawlowski, 2004).

As a consequence, expert selection has been noted as the most important consideration in the Delphi method, as it ultimately determines the level of confidence in the representative nature of the results (Hsu & Sandford, 2007; Okoli & Pawlowski, 2004). An “expert” can technically be anyone capable of contributing relevant input (Pill, 1971), therefore researchers should pay careful attention to the potentially ill suitability of these selections.

Additionally, many variations exist to conduct a Delphi study but two approaches are described here. The ranking-type approach involves 3 steps: (1) brainstorming for important factors; (2) narrowing down the original list to the most important ones; and (3) ranking the list of important factors (Schmidt, 2001). The second, more generic approach can be described as several rounds:

Round 1 consists of open-ended responses or a more structured questionnaire based on the literature or other pre-existing knowledge of the researcher (Hsu & Sandford, 2007). Round 2 would then offer a more structured questionnaire and challenge respondents to refine their judgments. Respondents may also be asked to rank order components (Hsu & Sandford, 2007) if determining the group’s view of the relative importance of items under interest is desired (Okoli & Pawlowski, 2004). The goal of Round 3 is to conduct further analysis of the information and ranked order, yet researchers have reported only a slight increase in the degree of consensus at this stage and beyond.

Researchers may opt to continue to additional rounds being cognizant of the time commitment required. Ultimately, this decision is at the discretion of the researcher and depends on the degree of consensus sought. All rounds following the first round provide respondents information on ratings and majority/minority opinions to gain final refinements to their judgments (Hsu & Sandford, 2007).

Hsu & Sandford (2007) mentioned the recommendation of 2 weeks for respondents to respond to each round of the study. Considerable time may be expended between each round of the study, collecting data, developing a new instrument, gaining approval (as needed) and administering the new round. Therefore the temporal burden is not only on the respondent, but also the researcher. The type of data used to assess when consensus is reached is often flexible (Hsu & Sandford, 2007), possibly involving a combination of qualitative and quantitative data.

Nevertheless, Pill (1971) warns that the Delphi method should not be considered in isolation, but rather fused with other approaches to fully exploit the potential to solve diverse and complex problems.

C. Analytic Hierarchy Process

The analytic hierarchy process (AHP) was developed by Thomas Saaty in the early 1980s to tackle issues related to decision making for complex problems. It organizes problems into a multi-level hierarchy, rendering element and sub-elements based on a global goal. Each element is assumed independent and unidirectional, with respect to the preceding level. The generic hierarchical structure shown in Figure 5 depicts the framework of an AHP model, yet the information required at each level varies based on the needs of the user and the design of the problem. Similar to the process offered by Ho (2006), Figure 6 captures the AHP process adding additional steps for group aggregation purposes.

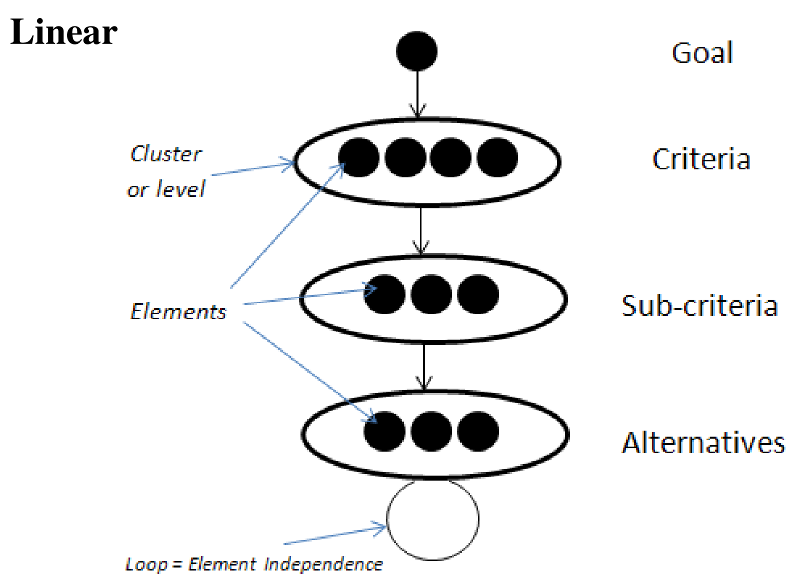


Figure 5: Analytical Hierarchy Process Model

The hierarchy undergoes pairwise comparisons at each level to determine priorities or weights among elements based on a 9-point ratio scale (See Table 3). This allows for the derivation of ratio-scaled weights of the relative importance of each criterion using objective and subjective judgments (Lee, 2010). Several variations have been noted in applications, including a partial ratio scale, using only 1, 3, 5, 7 and 9 to make the comparisons. In these cases, researchers assume that inclusion of the additional options does not change the overall preferences derived. It should also be noted that the definition of each point on the scale varies based on what the researcher is comparing. The consistency, however, is that the lowest end of the scale (or 1) represents the equivalency of the pair.

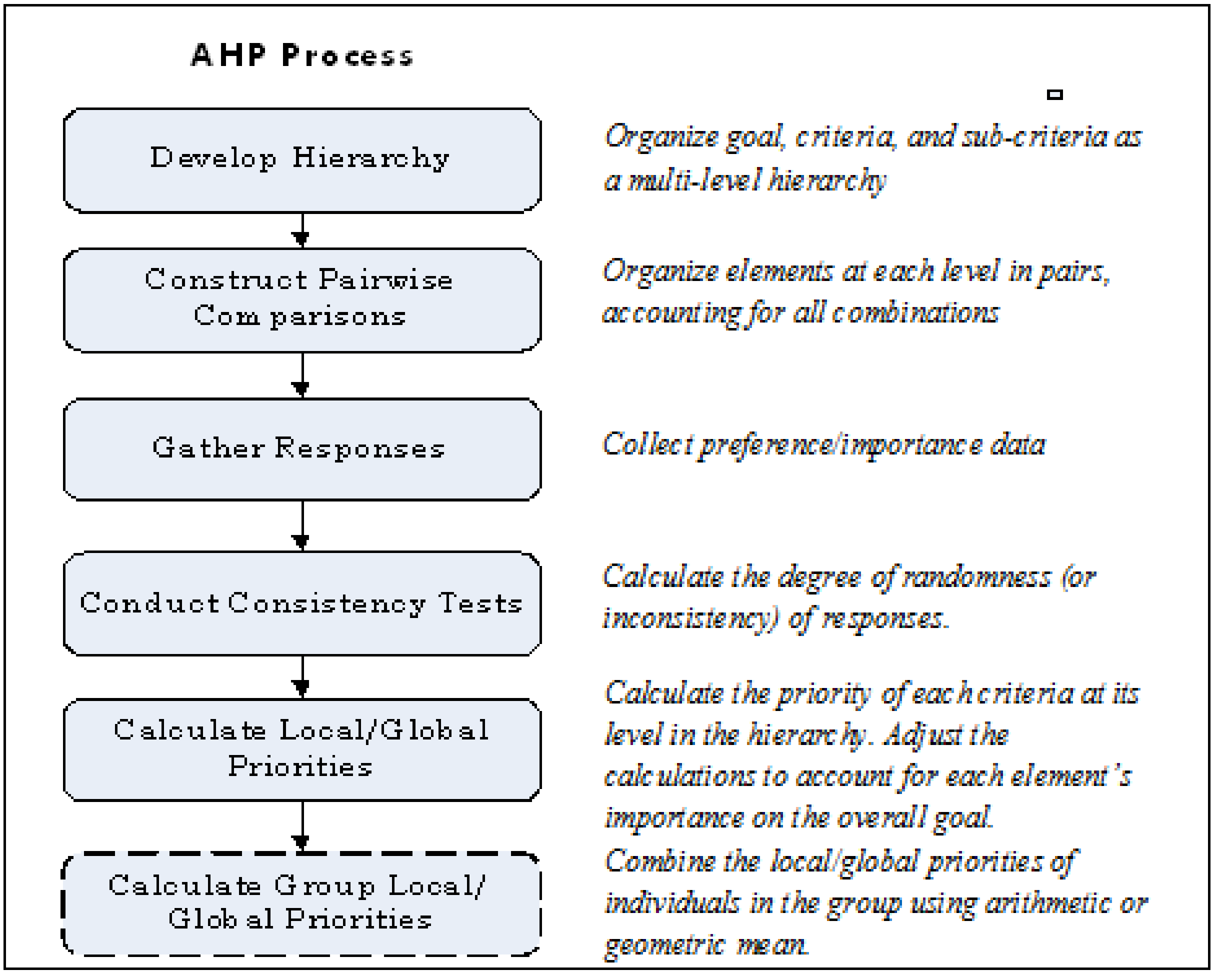


Figure 6: AHP Process

Table 3: Ratio Scale

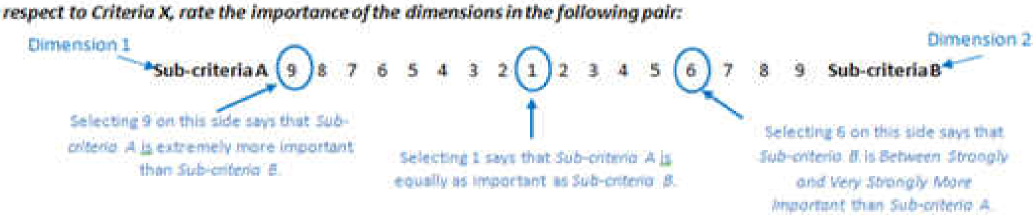
1	*Equally as Important*
2	*Between Equally and Moderately More Important*
3	*Moderately More Important*
4	*Between Moderately and Strongly More Important*
5	*Strongly More Important*
6	*Between Strongly and Very Strongly More Important*
7	*Very Strongly More Important*
8	*Between Very Strongly and Extremely More Important*
9	*Extremely More Important*

Questions are presented to the decision maker in a way that captures the relative judgments of each pair of elements. For example, *with respect to Criteria X, what is the relative importance of Sub-criteria A when compared to Sub-criteria B?* Or in a simpler survey form,

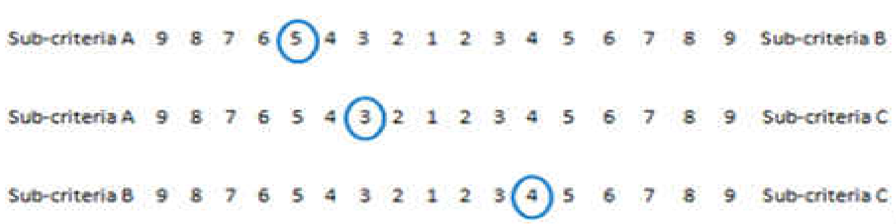
Sub-criteria A 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Sub-criteria B

Consider the following scenario assuming the selected importance rating is always denoted closer to the dimension of dominance (Figure 7). As the figure shows the judgments can be captured as a matrix, using the ratio form of each relationship to complete the matrix.

With respect to Criteria X, rate the importance of the dimensions in the following pair:



Assume a respondent made the following selections:



These responses could be translated into matrix form.

	Sub-criteria A	Sub-criteria B	Sub-criteria C
Sub-criteria A	1	5	3
Sub-criteria B	1/5	1	¼
Sub-criteria C	1/3	4	1

Inverse of Ratio

-Or-

$$\begin{vmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/4 \\ 1/3 & 4 & 1 \end{vmatrix}$$

Figure 7: AHP Example

The steps to calculate local weights from these judgments and ensure their suitability for use are as follows:

(1) Find the local preference weight, P_t using the nth root of the products of each row in Matrix X_t. Then sum all derived roots to find the proportion of preference per criteria (Equation 1).

$$P_{t(1,..n)} = \frac{\sqrt[n]{\prod_t^r X_r}}{\sum \sqrt[n]{\prod_t^r X_r}}, \textit{ where n= \# of criteria, r = row number, t = rater number}$$

(1)

The result is a vector of weights expressing the relative importance of each criteria and sub-criteria to the overall goal and most traditionally, the alternatives in the problem (Yang & Kuo, 2003). To calculate the global weights, each sub-criteria weights are multiplied by the respective criteria weight.

(2) Multiply the paired comparisons Matrix X_t by the priority vector P_t. The resulting vector is then divided by P_t, component by component. The average of the resulting vector form a single eigenvalue (λ_{max}) used to compare to *n* to determine whether the results should be checked for errors (Equation 2). This is commonly referred to as a sanity check so the result should reflect $\lambda_{max} > n$. If this is not the case, there may be errors in the calculations or the judgments are highly inconsistent.

$$\lambda_{\max(1,\ldots t)} = \overline{\left(\frac{X \times P_t}{P_t}\right)}$$

(2)

(3) Check the consistency of judgments. The consistency index (CI) is derived first using equation 3. The resulting value is compared to the random CI (RI) derived based on Saaty's

work for a sample size of n (see Table 4) using the relationship shown in Equations 3 and 4 (Alonso & Lamata, 2006). Typically, any consistency ratio (CR) > .1 implies that the judgments are at or beyond the limit of consistency. A value more close to 1 indicates that the judgments are nearly random.

$$CI_t = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

Table 4: Saaty's Random Index

	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
RI	.58	.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

$$CR = \frac{CI}{RI} \tag{4}$$

It is not uncommon to accept slightly more inconsistency, dependent on what the researcher is willing to accept in any given scenario.

In cases where multiple raters provide input, an additional step is often required to aggregate preferences, forming a group preference. The composite preference for each attribute *i* (CP_i) can be calculated using several techniques including the arithmetic mean, although the geometric mean of the judgments have been reported to increase accuracy. For this dissertation, the arithmetic mean of the preferences was used (Equation 5); *N* represents the total number of raters.

$$CP_i = \frac{\sum_{(1,\ldots N)} W_{i,t}}{\mathrm{N}}, \text{ where } W = AHP \text{ weight for Attribute } i \text{ from Rater } t \tag{5}$$

This process would be repeated for each attribute/criterion. The result is a single, aggregate preference for each attribute, representative of the entire group's perspective.

Applications in Higher Education

AHP is employed with a number of objectives in mind, including determining the best alternative, rankings and preference analysis. Much of the popularity of AHP stems from its ease of use and its ability to use objective and subjective considerations in the process (Ho, 2008; Lee, 2010). Despite the complex nature of the University environment, Vaidya and Kumar (2006) found numerous accounts of AHP applied to the field of education. Ho (2008) reported an increasing trend of integrated-AHP, where the methodology combines the strengths of AHP with that of tools like mathematical programming, SWOT analysis (strengths, weaknesses, opportunities and threats), quality function deployment (QFD), meta-heuristics and data envelopment analysis (DEA). Similarly, Sipahi and Timor (2010) reveal analytic hierarchy and network processes as most commonly integrated with methods like genetic algorithms, fuzzy logic, factor analysis, balanced scorecards, the Delphi method, data envelopment analysis, goal programming, technique for order of preference by similarity to ideal solution (TOPSIS), simulation, graphical information systems (GIS) and SWOT analysis.

Notably, Liberatore and Nydick (1997) described several existing AHP applications in higher education, including faculty evaluation, strategic planning, budgeting, curriculum redesign, program selection and career choices. Their unique contribution utilized AHP to rank research papers for an annual award. A small committee of judges ranked the importance of several criteria individually resulting in a comparison matrix based on geometric means. The authors also introduced a more incomplete example using a 3-level structure for strategic planning purposes.

Koksal and Egitman (1998) used the House of Quality tool in conjunction with AHP to derive relative weights for the student, employee and faculty stakeholder groups. Five members from each group weighed the importance of several education design requirements for industrial engineering quality. Each group's respective matrix was aggregated into a composite stakeholder preference matrix but no findings were reported in this paper. Similarly, Raharjo, Xiw, Goh and Brombacher (2007) proposed a methodology to integrate quality function deployment and AHP to develop an effective strategic plan based on multiple stakeholders. Like most researchers facing group decision making using AHP, the authors aggregated judgments for each group.

Lastly, Armacost, Hosseini & Pet-Edwards (1999) introduced a two phase AHP approach to solicit the relative importance of several criteria of a decision problem and utilized that information to determine relevant alternatives for further comparison in a second iteration of AHP.

Limitations of AHP

(1) *Exhaustive Exercise:* AHP can become a very exhaustive exercise as the number of judgments required increases (Ramanathan, 2006). Because the method uses pairwise comparisons at each level, the number of required judgments increases rapidly.

(2) *Rank reversal:* Rank reversal is the potential effect of adding or deleting alternatives or criteria. This may result in variations in the resulting rankings or preferences. Several modifications have been suggested to address this concern, including its integration with other techniques.

From AHP to the Analytical Network Process (ANP)

A similar methodology developed by Saaty in response to the need to model problems closer to their natural state is the analytical network process (ANP). Most real world problems defy the assumptions related to modeling in hierarchical structures (Karsak, Sozer & Alptekin, 2002). Researchers often discount hierarchical models with linear top to bottom structures not being suitable for complex systems (Chung, Lee & Pearn, 2005) yet AHP generally dominates over ANP with respect to quantity of practical applications. This is due to decreased data and analysis requirements and greater transparency. However, unlike AHP, ANP allows for interdependencies between any components and levels of the problem and uses a "systems with feedback" approach (Karsak et al., 2002; Mikhailov & Singh, 2003). It replaces hierarchies with networks (Lee, 2010), showing relationships using arcs in the direction of dependence and looped arcs among clusters indicative of inner dependencies (Lee, 2010). This feedback is thought to improve the priorities derived from judgments and make predictions more accurate. Figure 8 below summarizes the ANP structure.

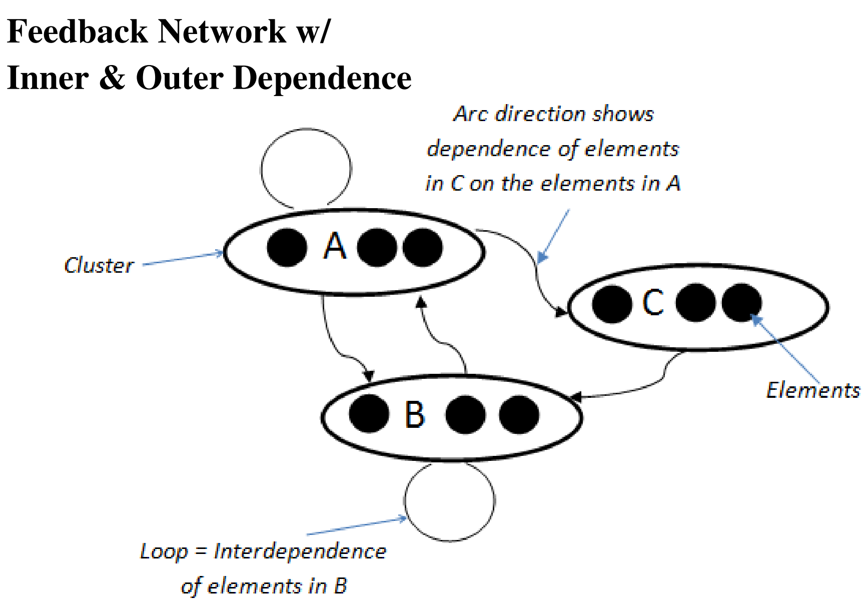


Figure 8: Analytical Network Process

The analytic network process is accomplished using seven steps: 1. Organize the properties or criteria; 2. Prioritize them into the framework of a control hierarchy; 3. Perform comparisons; 4. Synthesize to obtain the priorities of these properties; 5. Derive the influence of elements in the feedback system; 6. Weight the resulting influences; and 7. Obtain the overall influence of each element (Lee, 2010; Vaidya & Kumar, 2006).

It is important to note here that numerous studies have reported that the results obtained from ANP do not differ greatly from those found using the simpler AHP. These studies question the trade-off between the slightly more accurate results and the resources required to obtain such results. For this reason, ANP is not considered in this dissertation. Future research may challenge this decision by employing ANP to compare the results.

D. Data Envelopment Analysis

Data envelopment analysis (DEA) was first introduced in Farell's work in the 1950s but reached its present popularity several decades later given efforts by Charnes, Cooper and Rhodes (1978). It is a non-parametric, multi-criteria approach by which inputs and outputs of a process are used to directly determine the relative efficiency, performance or productivity of a decision making unit (DMU). A decision making unit is a near homogeneous entity under comparative review in DEA.

This is accomplished using linear programming methods to derive weights from input-output measures (Johnes, 2006c) which are sometimes controlled using weight restrictions. The efficiency of each unit is measured as a ratio of weighted output to weighted input, and is bound by the requirement of first explicitly identifying its inputs and outputs. Although this may seem to be a very difficult task in highly variant and complex problems (Avkiran, 2001), no assumptions are required as to the relationships among these factors. Given the overall lack of transparency of interrelatedness in the context of complex organizations, this characteristic often constitutes DEA as the approach of choice.

Data envelopment analysis applications have been uncovered in a range of areas, yet detailed coverage of such applications is beyond the scope of this paper. Nevertheless, there are two dominant classifications of DMUs in the higher education literature specifically- (1) DMUs as institutions or (2) DMUs as departments, either inter-institutional or across multiple institutions. Institutional studies typically experience higher efficiency (Johnes, 2006a) which is suspected to be due to the level of aggregation in the data. Athanassopoulos and Shale (1997) report that DEA is more commonly applied at the department-level which seems logical in light of the suggestions of some DEA models (namely, the constant returns to scale model) that DMUs are near homogeneous units, performing nearly the same tasks for nearly the same objectives (Ramanathan, 2006). Ramanathan (2006) and Sinuany-Stern, Mehrez & Barboy (1994) confirm that the inputs and outputs of each DMU should be uniform, with the only exception being related to the intensity and magnitude of those factors.

Cooper, Seiford and Tone (2006) offer for considerations for understanding inputs and outputs and DMUs of DEA models- (1) Data capturing each input and output should be available and be positive for all DMUs; (2) Selections should reflect the decision-makers interest; (3) Smaller input values and larger output values should be reflected in the data; and (4) The measurement units may vary.

Gattoufi, Oral and Reisman (2004) outlined DEA considerations and processes in a taxonomy consisting of four key components- Data, Envelopment, Analysis and Nature and Methodology of Study. Table 5 provides high level information about the aspects of each component although much greater detail is provided by the authors.

Table 5: DEA Taxonomy

	S1-Data	S2- Envelopment	S3- Analysis	S4- Nature & Methodology
L1	Sources of data	Stochasticity of the Frontier	Purpose	Nature
L2	Degree of Imprecision in the Data	Special Restrictions	Time Horizon	Methodology
L3		Orientation and Returns to Scale	Efficiency	
L4		Convexity of the Mathematical Model	Level of Aggregation in the Analysis	
L5		Solving Method	Sensitivity Analysis & Robustness	
L6		Efficiency Measures	Techniques for Sensitivity & Robustness	

Types of Data Envelopment Analysis

Traditional DEA defines the relative efficiency of DMUs as a weighted sum of outputs divided by the weighted sum of inputs, $Technical\ Efficiency = \frac{weighted\ sum\ of\ outputs}{weighted\ sum\ of\ inputs}$ (Flegg Allen, Field & Thurlow, 2004). All efficiencies are derived as a percentage, with a maximum assignment of 100% efficiency. In order to maximize efficiency of each DMU, weights are derived dependent on whether the primal or dual form is employed. Two common approaches assume either constant returns to scale or variable returns to scale but several extensions of each exist. For example, benchmarking enables further analysis by calculating the amount of inefficiency of inefficient DMUs.

Constant Returns to Scale (CRS)

Charnes, Cooper & Rhodes (1978) introduced a fractional programming model commonly referred to as the constant returns to scale (CRS) model. Synonymous with the CCR model which incorporates the first initial of each author, CRS assumes that DMUs are able to linearly scale its inputs and outputs without increasing or decreasing efficiency (Smith, 1990).

Let n= number of DMUs. Each DMU_i (i=1, …, n) uses *m* inputs, x_{ij} (j= 1, …, m) to generate *s* output, y_{ik} (k=1,…, s). For example, x_{12} denotes the amount of input *2* used by DMU *1*. The input and output weights become v_j and u_k, respectively. The model would run n times, with the DMU being evaluated during any iteration of the linear program represented as DMU_0.

Given an input-oriented model where the goal is to minimize inputs, the relative efficiency, ε_0 can be found by solving the primal form of the CRS model illustrated by the linear program in Equation 6:

$$\varepsilon_0 = max \sum_k u_k\, y_{0k}$$

$$s.t. \qquad \sum_j v_j x_{0j} = 1$$

$$\sum_k u_k\, y_{0k} - \sum_j v_j x_{0j} \le 0 \qquad \forall_i$$

$$u_k, v_j \ge 0 \qquad \forall_{j,\ k}$$

(6)

The dual form of this equation in Equation 7 yields equivalent information, yet requires a different interpretation of the results. It evaluates the column form of the data rather than the rows and show changing variables as λ_i, the weight derived for each DMU.

$$
\begin{aligned}
&\min \ \theta \\
&s.t. \\
&\qquad \sum \lambda_j x_j - \theta X_0 \ \leq \ 0 \\
&\qquad \sum \lambda_k y_k \ \geq \ Y_0 \\
&\qquad \lambda_i \geq 0 \qquad\qquad\qquad\qquad \forall_i
\end{aligned}
\tag{7}
$$

The results of both models are data-driven input, output or DMU weights that maximize the efficiency score for DMU_0. A score of θ =1 declare a DMU as efficient relative to all other DMUs. A score of less than one implies that DMU_0 is inefficient relative to other DMUs.

Conversely, the output-oriented model would assume a near opposite form and seeks to maximize outputs with the current level of input. The goal of the linear program in Equation 8 is to illustrate the dual, minimization problem:

$$
\begin{aligned}
&\min \sum v_j x_{0j} \\
&s.t. \quad \sum u_k y_{0k} = 1 \\
&\qquad -\sum u_k y_{0k} + \sum v_j x_{0j} \ \geq 0 \\
&\qquad u_k, v_j \ \geq 0
\end{aligned}
\tag{8}
$$

This model would run *n* times so as to reveal the relative efficiency of DMU_i .

One extension of data envelopment analysis is a longitudinal efficiency model referred to as window analysis or modified window analysis (Talluri, 2000). This approach allows consideration of DMUs over time, where the number of time periods, t, increases the number of DMUs in the model to $n * t$. This can be a highly beneficial approach, especially when the number of DMUs is relatively small.

Variable Returns to Scale Model (VRS) or BCC Model

The variable returns to scale model or its alternative reference of the BCC model (coined after researchers Banker, Charnes, Cooper), relieves the assumption of a common scale of operations among DMUs. In this case, the decision to use an input or output-oriented model affects the derived efficiency scores (Note: This is not the case in CRS). The input-orientation uses fixed outputs to explore the possibility of a proportional reduction in inputs, vis a vis for the outputs orientation, where an expansion of outputs are desired (Johnes, 2006c).

Assuming the output-orientation approach the linear programming model in Equation 9 would be solved:

$$\begin{aligned} Max \quad & \theta_0 + \varepsilon \left(\sum_{k=1}^{s} s_k + \sum_{j=1}^{m} s_j \right) \\ s.t. \quad & \theta_0\, y_{ik} - \sum_{j=1}^{n} \varphi_i\, y_{ik} + s_k = 0 \\ & x_{ij} - \sum_{j=1}^{n} \varphi_i\, x_{ij} - s_j = 0 \qquad \forall_i \\ & \sum_{i=1}^{n} \varphi_i = 1 \\ & \varphi_i , s_j , s_k \geq 0 \qquad \forall_{j,r,i} \end{aligned} \tag{9}$$

In this form, the newly introduced variables of s_j and s_k are the slack variables assigned to the input and output respectively. The variables φ_j represents weights of the inputs and outputs for each DMU. The technical efficiency could be calculated as the reciprocal of θ_0.

In VRS, a DMU is deemed efficient if its efficiency score is 1 and all the slack variables are zero. The results of this model have been known to increase efficiency scores (Smith, 1990) but offers opportunities to integrate the results derived from the CRS model to additionally determine the pure technical efficiency and scale efficiency of each DMU.

Applications

DEA is highly useful when the user is interested in understanding performance based on the conversion of inputs into outputs. It has been used to not only amplify relative efficiency among DMUs but also as a reference for improvement (Avkiran, 2001). Some applications have been input-oriented, while others have been more output-oriented. Some applications focus on increasing or decreasing returns to scale, while others are interested in constant returns to scale (Sinuany-Stern et al., 1994). Other popular models are variations of the additive and multiplier models, which are not discussed in this report.

One of the earliest reviews in the DEA literature cited over 400 articles written between 1978 and 1989 (Seiford, 1989). He added to this account in 1996, offering a more recent snapshot of the state of the art. Although the author provides a laundry list of a bibliography in this contribution, proving a sizeable existence of DEA literature, it is somewhat difficult to navigate the list due to its lack of organization (alphabetized only). More than a decade later, Emrouznejad, Parker and Tavares (2008) conducted a survey of DEA literature over a thirty year period. They reported on over 4000 articles excluding only unpublished works. They record nearly exponential growth of DEA applications, with an estimate of its maturity phase beginning around 1995. Interestingly, they found that 22% of all papers were written by the top 12 authors (given about 2500 authors).

Research efficiency seems to be a very popular domain in the DEA in academia literature. Johnes and Johnes (1995) investigated the technical efficiency of multiple University economics departments on the basis of research activity. They chose to control for the inter-institutional differences in input by deriving a measure of technical efficiency that "provides information about the standards a department could expect to sustain given that it has the same levels of transferable resources as every other department." Beasley (1995) used a non-linear approach to apportion shared resources between teaching and research, while also incorporating value judgments.

Table 6 compiles several DEA models in higher education that disclosed the inputs and outputs used in their analysis. It is important to note that many studies provide minimal insight as to what these variables are and how they were selected. Yet, the common approach among those with full disclosure seems to be the use of personal knowledge or expert groups.

Table 6: HEI DEA Models, Input-Output Selection

Researchers (Yr)	Type	Inputs	Outputs
Bessent (1983)	CRS	# contact hours, physical facilities (in sq. ft), direct costs	State allocation, # of graduates employed in their profession to the satisfaction of their employer
Subhash (1985)	CRS	# of courses, index of involvement in community	Average student grades
Sinuany-Stern, Mehrez & Barboy (1994)	CRS	Operational expenditures, faculty salaries	Grant money, # publications, # graduate students, # credit hours given by department
Beasley (1995)	CRS	General expenditure, equipment expenditure, research income	# undergraduates, # taught post graduates, # research postgraduates, research income, rating of research activity
Athanassopoulos &	CRS/	*Cost efficiency Model*- general	# of successful leavers, # higher

Researchers (Yr)	Type	Inputs	Outputs
Shale (1997)	VRS	academic expenditure, research income *Outcome Efficiency Model-* # of FTE undergraduates, # FTE postgraduates, # FTE academic staff, mean A-level entry score, research income, expenditure on library and computing services	degrees awarded, weighted research weighting
Avkiran (2001)	CRS/ VRS	FTE Academic Staff, FTE Non-Academic Staff	*Overall Performance Model-* Undergraduate Enrollments, Postgraduate Enrollments, Research Quantum *Performance on Delivery of Educational Services Model-* Student retention rate, student progress rate, graduate full-time employment rate *Performance on fee paying enrollments Model-* Overseas fee paying enrollments, non-overseas fee paying post graduate enrollments
Rouyendegh & Erol (2010)	CRS	# of professor doctors, # of associated professors, # of assistant professors, #instructors, budget of departments, # f credits	# of alumni, evaluation of instructors, # of academic congeries, # of academic papers
Murias, Carlos de Miguel & Rodriguez (2008)	CRS	*(No separation of input/output provided)* Full time teaching staff/student ratio, students that graduate within a "suitable" length of time, students enrolled on their chosen course, exchange students, per-researcher income from research, doctoral these per PhD, postgraduate students, beds available for student accommodation, library seats per student	
Flegg, Allen, Field, Thurlow (2004)	CRS/ VRS	# of staff, # of undergraduate students, # of postgraduate students, aggregate departmental expenditure	Income from research and consultancy, # of undergraduate degrees awarded, # of post graduate degrees awarded
Kuah & Wong (2011)	CRS	*Model of Teaching Efficiency-* # of academic staff, # of taught course students, avg. student qualifications, university expenditures *Model of Research Efficiency-* University expenditures, # of research staff, avg. research staff qualifications, # research students, research grants	*Model of Teaching Efficiency-* # graduates from taught course, avg. graduate results, graduation rate, graduate employment rates *Model of Research Efficiency-* # of graduates from research, # of publications, # awards, # intellectual properties
Johnes (2006)	VRS	#undergraduates/avg. A-level pts for first year FTE students, # FTE postgraduate students, # FT faculty,	# degrees weighted by classification, # higher degrees awarded, value of recurrent research grants by HEFCE

Researchers (Yr)	Type	Inputs	Outputs
		total depreciation and interest, total expenditure excluding academic staff costs and interest payable, expenditure on central administration and central services	

Using multiple DEA Models

Some researchers elect to calculate relative efficiency using different models, representing different dimensions of performance. This seems to increase the usability of the results, as decision makers are provided more delineated information that typically is more representative of the problem. This enhances the ability to make improvements on specific dimensions of the problem (Nunamaker, 1985).

In Avkiran's model (2001), three models of university efficiency are used- an overall performance model, performance on delivery of educational services model and performance on fee-paying enrollments model. Kuah and Wong (2011) distribute their analysis to performance on teaching efficiency and performance on research efficiency. They self-identified as the first study in higher education to use a large of number of inputs/output measures (16) given a small sample size (30). Despite researchers' claim of weakening discriminatory power associated with a large number of IOs, the model produced discriminatory results.

Data Aggregation

Due to concerns over applying aggregated data to DEA, some researchers have explored the use of individual data (Ahn & Seiford, 1990; Johnes, 2006a). For example, Johnes (2006a) explored the use of individual student data to measure the efficiency of departments. These results were compared to those derived from aggregate data. The results suggested that "aggregate level DEAs provide efficiency scores which reflect the efforts and characteristics of the students as well as those of the department or institution to which they belong." Likewise, DEA was also found to be insensitive to the aggregation and disaggregation of variables in a different study (Ahn & Seiford, 1990).

Weight-Restriction in DEA

In cases where the significance of differentiating between the importance of criteria and the capacity of alternatives is high, the impetus to incorporate additional weights to these variables is substantiated. Ramanathan (2006) adds that this introduction should always be analyzed parallel to the same model without constraints.

Athanassopoulos and Shale (1997) utilized value judgments to account for prior knowledge regarding the relationships among certain inputs and outputs. This introduction of preference weights across several models resulted in an overall decrease in the number of efficient universities, with one run revealing nearly half the amount derived in the comparable un-weighted form. Kabnurkar (2001) used both crisp absolute weights and fuzzy absolute weights in his application of DEA. Similarly, Murias, de Miguel and Rodriguez (2008) used DEA with weight restrictions to facilitate aggregation and the weighting of the data used to construct a synthetic indicator for the selection of facility layouts.

There are several reasons or approaches in the imposition of weight restrictions which was summarized very precisely by Kabnurkar (2001):

(1) Direct restrictions on the output weight value: The use of absolute limits or assurance regions to restrict the value of any input or output weight is increasingly popular (Cooper, Park & Yu, 1999). Absolute weights are imposed constraints on the upper and lower limit of the input-output weight. As an alternative to the former, Athanassopoulos and Shale (1997) describe

the process of using assurance regions (ARs). ARs are typically of three types- those used to incorporate the relative importance of input-outputs ratios (Type 1) and those linked by upper and lower bounds using the ratios of output weights to input weights (Type 2) (Kabnurkar, 2001). Type 3 ARs allow for the importance of inputs or outputs as a proportion of total output or input for that DMU, within an upper and lower bound, A_{ik} *and* B_{ik} .

(2) Restricting weight flexibility by restricting the weighted IOs: In this case, researchers view the local weight b_m for each input m as a multiplier of the weight derived for that criterion for a specific DMU v_{mi}, for instance. The same would be true for each output. Therefore the global weight, v_{mi} becomes $v_{mi} = b_m * v_{mi}$.

(3) Adjusting the observed input-output measures to capture value judgment using cone ratios and ordinal relationships.

Limitations of DEA

(1) *Balancing DMUs & Input-Output:* A major concern in using DEA is the limited number of input-output factors that can be considered because of the effects of too many factors while the sample size is small. One rule of thumb is that three times the sum of the number of inputs and outputs should be less than the number of DMUs (Sinuany-Stern, Mehrez & Barboy, 1994). The second commonly accepted constraint is that the number of DMUs be greater than the product of the number of inputs and outputs (Avkiran, 2001). Therefore, as the number of inputs and outputs increase, more DMUs should be considered or the overall number of efficient units is expected to increase (Johnes, 2006a; Ramanathan, 2006). Ramanathan also recognizes the existence of several DEA applications that disregard this rule and employ small sample sizes, yet

fail to disclose examples. One such example was found in Kuah and Wong (2011), where researchers were able to produce satisfactory results despite discounting this rule.

(2) *Choosing Inputs-Outputs:* The selection of appropriate inputs and outputs is sometimes difficult to achieve within the recommended bounds. Luckily, correlation tests on pairs of inputs or outputs may assist in eliminating the number of IOs required (Sinuany-Stern et al., 1994).

(3) Rank Reversal: There is a lot of conversation about rank reversal, or the sensitivity of the choice of inputs and outputs in DEA (Ramanathan, 2006). Johnes and Johnes (1995) noted the substantial impact of the addition of inputs on the dispersion of efficiency scores. Nunamaker (1985) concluded that variable addition cannot cause an already efficient DMU to become inefficient regardless of the intensity of the correlation among the variables. Yet Sinuany-Stern et al. (1994) tested the opposite scenario, deleting a variable that seemed universally efficient, and found that this may cause efficient DMUs to become inefficient.

(4) Computational Intensity: The level of computational intensity can quickly increase with the number of DMUs selected. Since each DMUs efficiency score is derived using its own linear program, the number of DMUs equals the number of linear programs required.

(5) *Noise*: Due to the nature of DEA, extremities in the data (i.e. errors and unique occurrences) can cause significant issues. It can skew the results of the entire analysis.

(6) *Relative vs. Absolute Efficiency*: The purpose of DEA is to derive relative efficiency rather than absolute efficiency. The estimates represent performance with respect to all other DMUs considered.

(7) *Validity & Significance:* Since DEA is a nonparametric technique, statistical hypothesis tests are difficult. Some tests have been introduced in the literature to overcome this limitation, i.e. Pastor, Ruiz and Sirvent Test (2002) and the Bootstrapping Approach (Simar & Wilson, 2004).

E. Integrating AHP and DEA

Given the strengths and weaknesses of both the analytic hierarchy process and data envelopment analysis, a marriage of the two is sensible. The acronym DEAHP was realized in Ramanathan (2006) to denote the combined method as the data envelopment analytic hierarchy process. One author reported very limited applications of this method, with 4 of 66 cases being applicable (Ho, 2008). None of the cases in this review were concerned with issues in higher education.

An inclination exists to agree with the notion that the DEAHP literature is limited (Yang & Kuo, 2003). Common approaches use AHP to either derive values to serve as DMU data, or to use AHP to derive weight restrictions. The former uses AHP to handle subjective factors and to generate a set of numerical values; then uses DEA to identify efficiency scores based on the entire data set, including the values rendered in AHP. The latter approach uses AHP to introduce preference information into DEA calculations, offering subjective weights. The common approach is using the AHP-derived weights to define the assurance region (Seifert & Zhu, 1998;

Takamura & Tone, 2003). Some researchers have even applied both methods and compared their output.

Sinuany-Stern et al. (1994) used DEAHP to evaluate of relative performance of academic units within a single University. It relieved the common subjective bias of a priori processes by applying a systemic approach. Sinauny-Stern et al. (2000) extended DEA using AHP to offer a full ranking of academic units. Additionally, Rouyendegh and Erol (2010) introduced a two stage model to rank organizational departments where each department had different inputs and outputs. DEA was used to formulate the problem and separately formulate each pair of units. Then the pairwise evaluation matrix from the first stage was utilized to fully rank-scale the units under the processes of the Fuzzy-Analytic Network Process. The result was a rank order of the alternatives using actual data, completely eliminating subjectivity from the process.

X. Conclusion

Given the escalating strain on higher education and its resources, it is imperative to investigate how certain decisions affect the University System. Because this involves multiple stakeholder requirements, changing demands, various fields and synchronous and asynchronous education a highly complex situation prevails. Athanassopoulos and Shale (1997) stress that stakeholder requirements in HEIs require satisfactory performance, although the basis of these judgments may be unclear.

With the evolution of technology and tools, such as the systems thinking paradigm, an opportunity to advance our knowledge in this area has been uncovered. In this chapter, the topic of quality in higher education has been explored, research in existing models for performance measurement in higher education (holistic and specialized) was unveiled and tools for complex systems were discussed, including Delphi method, AHP and DEA. In the next chapter, a detailed methodology is disclosed and the use of specific tools to accomplish the objectives is revealed.

CHAPTER THREE: METHODOLOGY

Quality in itself is a multi-faceted and stakeholder-relative concept. The importance of understanding customer needs and requirements is a pre-requisite to providing, accessing and improving quality (Raharjo, Xiw, Goh & Brombacher, 2007). Even more, determining who to consider as stakeholders in the analysis can become quite daunting.

I. The Decision Support Model

In order to account for various stakeholder views in the definition of quality and the assessment of how well decision making units achieve quality, a three phase model is described in Figure 9. The model begins with initial design decisions to clearly identify DMUs and determine the number of DMUs under consideration over a set time period, as well as the identification of key stakeholders. These selections not only limit the model, it may raise additional considerations of confounding factors and similar.

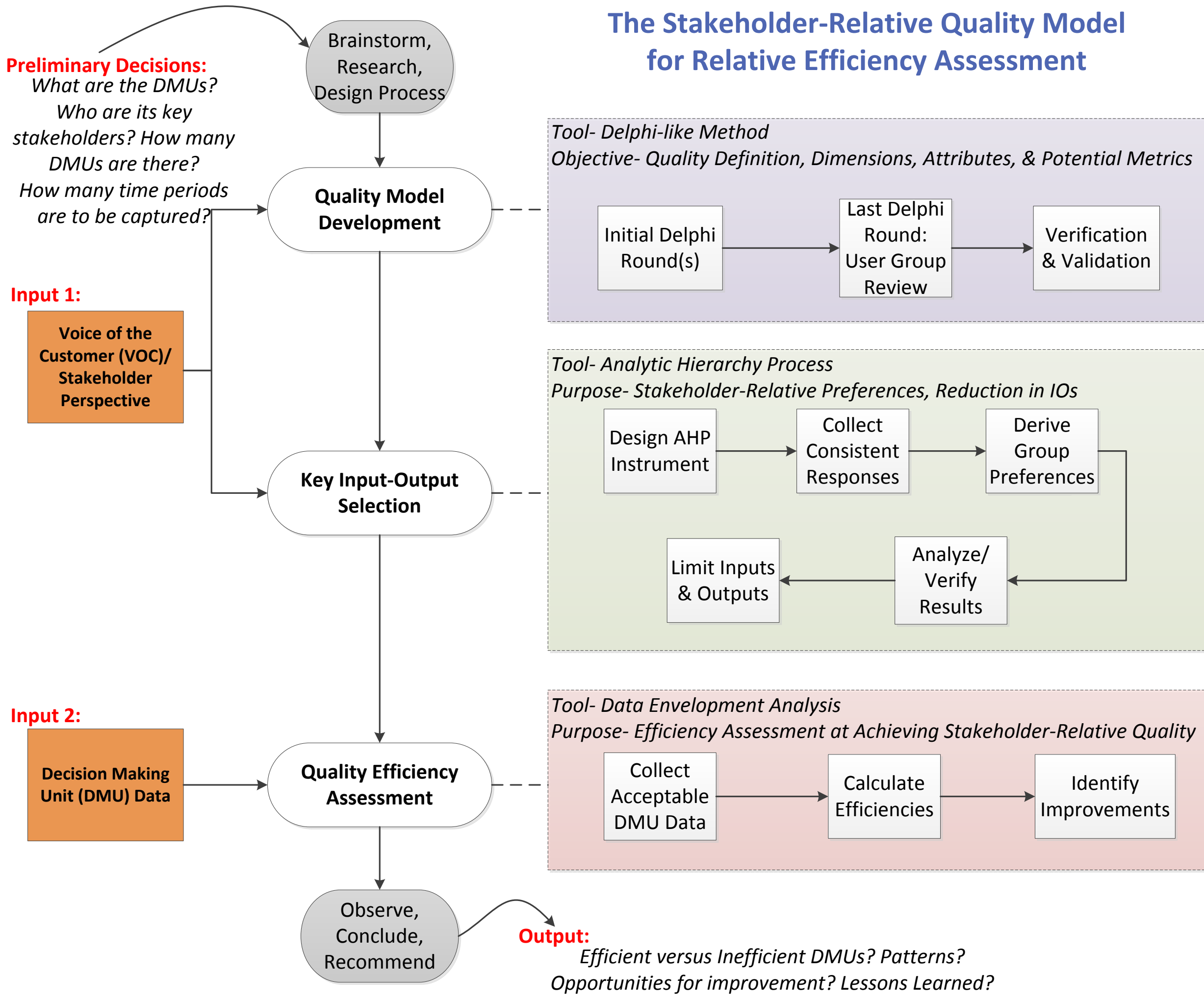


Figure 9: Decision Support Model

Phase 1 is a four step process that uses the voice of stakeholders to derive a definition of quality, and determine the areas (or dimensions) of quality and attributes of those dimensions. The steps are multiple Delphi rounds querying feedback from the selected stakeholder group(s), while the final round specifically requests feedback from the user group. The goal of the latter, is to use feedback from the intended user of the model proposed by the collective stakeholder group, as to the reasonableness and feasibility of the derived model. The final step of this phase is to identify a widely accepted or recognized quality criteria to use to verify that areas and components deemed quality indicators in the model are present, at a minimum in the derived model.

Phase 2, Key Input-Output Selection, also utilizes the voice of stakeholders to derive stakeholder perspectives as to the importance of each dimension and attribute to overall quality. A survey should be developed with an understanding of the analytic hierarchy process and the requirements of any overseeing body such as the Institutional Review Board (IRB). Stakeholder responses are collected and utilized only if responses are consistent enough, as defined by the researcher. *Note: The consistency ratio is usually .10.* If the number of participants is more than 1, one of several approaches are needed to render group preferences. Two options are taking the geometric mean of judgments during the analysis or taking the arithmetic mean of the resulting preferences. Moreover, several inferences and conclusions are privy to this point in the analysis; based on these preferences and adhering to the number of input-output constraints inherent to data envelopment analysis, the number of inputs and outputs are reduced.

The last phase, Phase 3, is intended to evaluate each decision making units' effectiveness in using available resources to maximize the output produced. Historical data for DMUs represent input and output values and are analyzed to determine similarities and relationships among the variables. Then, a linear program is run for each of the DMUs to determine the relative efficiency of that unit. If a unit shows a 100% efficiency score and zeros for all slack variables, that DMU is efficient. Otherwise, the DMU is inefficient, and opportunities for improvement exist.

By going through this process, transparency of the values of stakeholders is gained. Additionally, efficiency assessment based on these values are achieved. Not only are DMUs deemed efficient or inefficient, patterns are identified and opportunities to improve the DMUs, the model and the process are identified and valuable lessons learned are gained.

A. Limitations of the Model

Quality Model Development

(1) The sample size tends to be small in the Delphi-like approach. The objective is to get the "right" people, or individuals who may be deemed experts in the topic or at least have a sufficient understanding of the topic. Dependent on the screening and recruitment strategy for participation, this may or may not be the case.

(2) Participants may or may not be representative of the stakeholder group's needs and requirements. Personal experiences and current role has an impact on an individual's view of quality. The result may be outliers in the group's perspective. Dependent of the sample size, the outliers may be consciously accepted as representative or go undetected.

(3) Depending on the application of the model, identification of an acceptable instrument or criteria to use for model verification and validation purposes may be complex. The goal is to identify a criteria from a recognized and accepted body that can be cross-referenced with the derived model.

(4) The resulting hierarchy may be unbalanced. The tendency to compare global rather than local priorities resulting from AHP can cause higher attribute preferences in those dimensions with less attributes. The effect can be illustrated in the following comparison, A dimension is 30% of the total preference and has 3 attributes weighted equally for simplicity (10% each,

global preference). A second dimension is also 30% and has 5 attributes weighted equally (6% each, global preference). In this example, the same 30% of preference is spread across more or less variables, therefore creating a sense of one group being more important. Careful attention is required in the model development phase to balance the quality hierarchy as best as possible.

Key Input-Output Selection

(1) The model suggests that every stakeholder be viewed equal, although this may not be ideal in many scenarios. The goal here is to develop a baseline model that can be used in more detailed ways as more information becomes available.

(2) There are several risks of using the most important variables identified by AHP- A. Both inputs and outputs may not be present; B. Minimum variability may be present among selected metric for the variable; and C. Less meaningful relationships may be inherent to the prevailing inputs and outputs.

(3) Reasonable data may not be available to capture the intent of the selected attribute. In such cases, proxy measures of that data may be acceptable but special attention may be necessary to ensure the intent remains evident.

(4) The proposed model does not utilize the full capability of the analytic hierarchy process, and eliminates the bottom level of the hierarchy (i.e. not consideting alternatives).

Efficiency Assessment

(1) Although near homogeneous units are important for an accurate assessment of relative efficiency of DMUs, too much homogeneity may reduce the ability to discriminate among efficient and inefficient units.

(2) The use of data envelopment analysis limits the number of inputs and outputs under evaluation based on the number of decision making units under review. It may not be feasible to incorporate desired numbers of inputs or outputs unless window analysis is used to view each DMU over time. Given this constraint, one metric per attribute is recommended unless the numbr of DMUs can be increased to an amount that satisfies DEA constraints (i.e. 3(inputs + outputs) and (inputs x ouputs) should be less than the number of DMUs).

(3) The decision to use a constant returns to scale model versus a variable returns to scale model may impact the results. CRS tends to be less conservative in that less units are efficient and efficiency scores span across a larger range. However, the analysis is based on the assumption of proportionate changes among the inputs and outputs. Given the need to do more with less, relaxing this assumption seems inevitable, hence the need to utilize the variable returns to scale model.

II. Model Implementation

Initiated by a desire to understand HEI quality using multiple measures of performance, the decision support model was used to address quality in academic departments at the University of Central Florida. The initial task was to determine the aspects of quality, while further partitioning those components into attributes that are contained within each major dimension. This was accomplished using a three-step, Delphi-like approach. Then the analytic hierarchy process was undertaken to reveal stakeholder preferences and used to limit the Inputs-Outputs of the DEA model. Data envelopment analysis enabled quality output, optimization-based assessment.

The somewhat homogeneous existence of departments in only one College supports the UCF's College of Engineering & Computer Science (CECS) as a favorable project scope. Differences across multiple colleges or universities increases the impact of data aggregation, cross functionality, and overall conflicting meanings in the data collected.

The purpose of this implementation of the decision support model is to test the methodology to reveal perspectives of quality specific to key stakeholder groups and use that insight to drive efficiency assessment of academic departments. The output reveals transparency of metric and data requirements to better supplement College-level, administrative resource allocation-related decision making efforts.

A. The SAFE Approach

In academic administration, studies focus on an array of individuals or groups and sometimes use questionnaires, quality function deployment, affinity diagrams, stakeholder analysis or focus groups to account for the Voice of the Customer. Figure 10 captures 12 stakeholders common to the academic administration literature. It is in no way all inclusive, but serves as a starting point to identify key stakeholders in higher education.

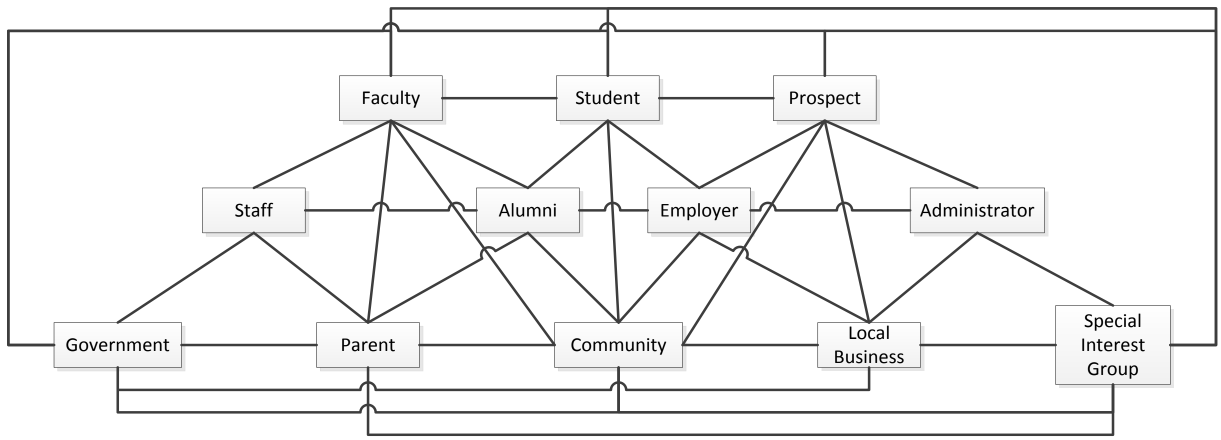


Figure 10:Stakeholders in Academia

In order to approach quality assessment assuming the multi-faceted, stakeholder- relative view, stakeholders have been limited to those highly concerned with the quality of higher education. While the choice of considering only students, administrators, faculty and employers may be debated, their competing requirements are assumed to encapsulate a broad range of concerns that are also representative of other groups.

Table 2 implied that many studies seem to overlook the administrator's view but this study uses the role of administrators to represent the interests of the University at all levels. The Student, Administrator, Faculty and Employer (SAFE) approach coined in this dissertation (Figure 11) suggests that the majority of common stakeholders are generally viewed as internal customers, while the employer is traditionally external (with a two-way relationship). However, as Koksal and Egitman (1998) warn, the placement of stakeholders as internal or external customers is highly dependent on the stages of the educational process being evaluated.

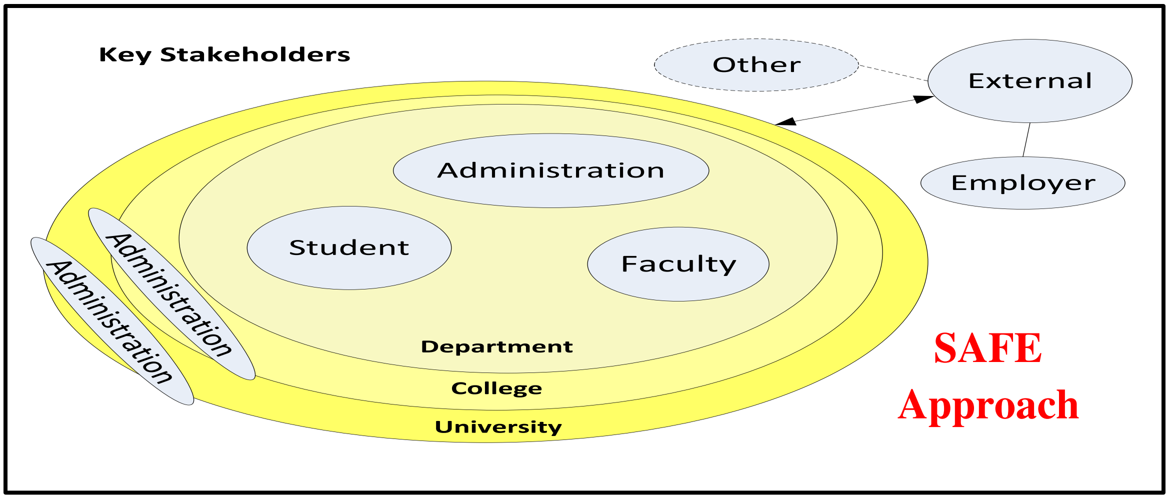


Figure 11: Key Stakeholders Map- SAFE Approach

In the SAFE approach, **S**tudents are classified as undergraduate and graduate students in the College of Engineering & Computer Science, including master degree prospects and doctoral students. **A**dministrators are identified as department chairs, associate deans and deans within the College of Engineering & Computer Science. **F**aculty were full-time faculty (tenure, tenure-earning or visiting professor) and instructors and lecturers for CECS, not including adjunct instructors. **E**mployer/Industry Partners is composed of typical employers of the CECS's graduates and industry partners collaborating with the College on different projects, grants and initiatives.

B. Approach Overview

Figure 12 shows the steps of the dissertation and is expounded upon in the following sections using the three major phases of the decision support model- (A) Quality Model Development, (B) Key Input-Output Selection and (C) Quality Efficiency Assessment.

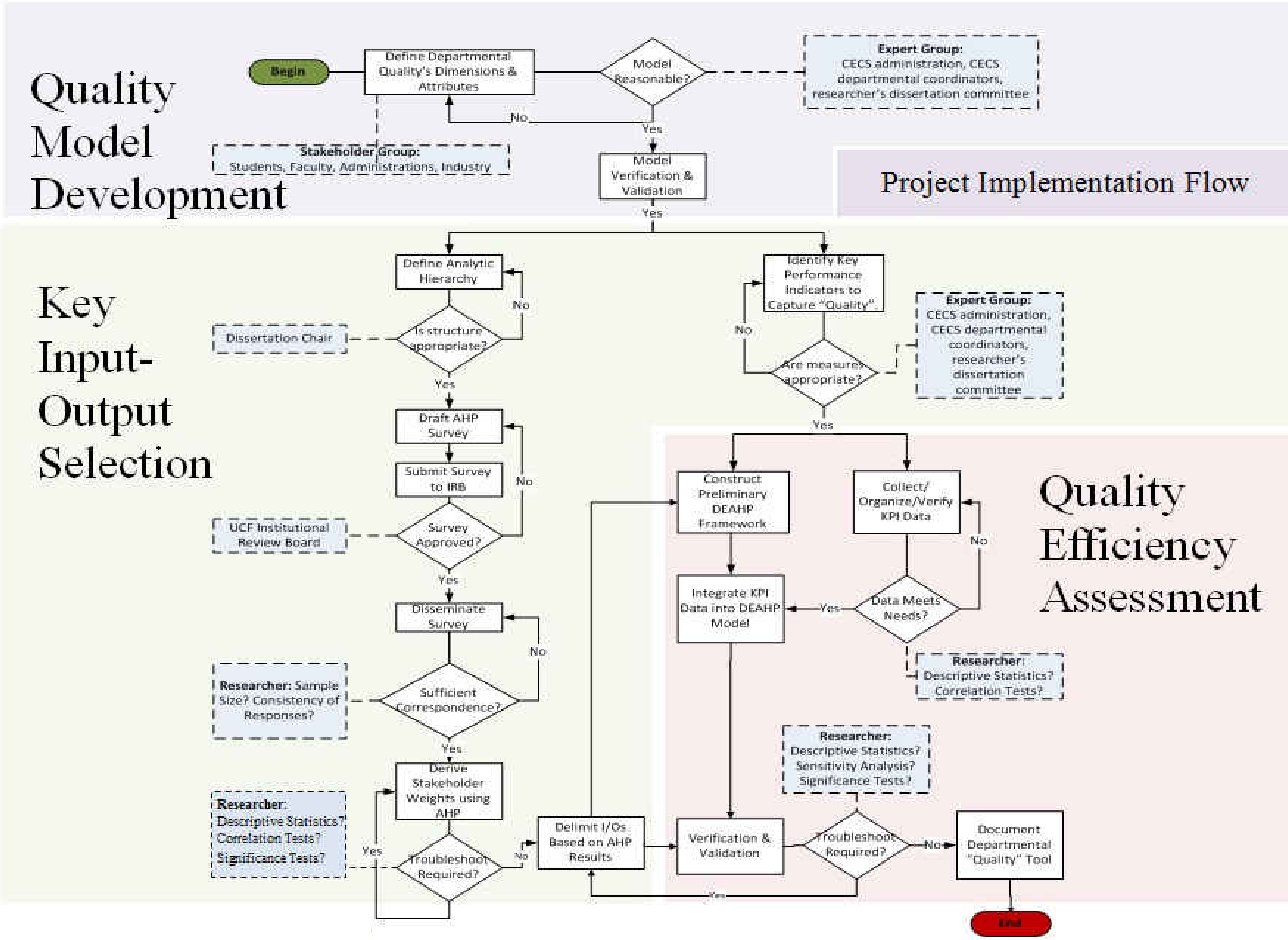


Figure 12: Implementation Process Map

C. Quality Model Development

In order to define quality, stakeholder input is crucial. A three stage, Delphi-like study, which included a review session with representative users of the decision-making model was proposed. The Institutional Review Board (IRB) approved the study in several iterations due to the evolutionary nature of the instrument's content (Appendix D).

Survey 1, Est. Population Size= 8,190, N= 73

In survey 1, the objectives were to (1) Gather unique definitions of program quality; (2) Identify key areas of programs that implicate quality; and (3) Highlight potential performance indicators to capture key areas. The survey instrument is located in Appendix F.

Participation requests were emailed to a sample of 73 individuals with at least one representative of each stakeholder group. An online link was attached to the email along with a participant identification number for tracking purposes. A reminder email was sent to non-respondents as necessary. The email invitations are included in Appendix E.

The only students contacted were leaders of CECS organizations. Faculty and administrators were composed of a random sample among those listed on public department websites as full-time faculty. Employers of CECS graduates and its Industry Partners were limited to those contacts provided by CECS.

The survey was distributed on the SurveyMonkey.com server and all resulting data was organized into high-level components (dimensions or criteria), sub-components (attributes or sub-criteria) and possible indicators of those measures using affinity diagrams. This task was complemented by findings from the literature review.

Survey 2, Est. Population Size= 8,190, N= 73

In survey 2, the objectives were to (1) Critique the current quality model structure; and (2) Rank performance measures. The survey instrument is in Appendix G.

Participation requests were emailed to the same SAFE stakeholder sample of 73 individuals. The only students contacted were leaders of CECS organizations. Faculty and administrators were composed of a random sample among those listed on public department websites as full-time faculty. Employers of CECS graduates and its Industry Partners were limited to those contacts provided by CECS.

The email invitation included a copy of the most current draft of the quality model as an attachment. A participant identification number for tracking purposes was also included. A reminder email was sent to non-respondents as necessary.

The survey was distributed on the SurveyMonkey.com server and all resulting data was used to edit the dimensions/attributes and reduce possible metrics to one key performance measure per attribute. The minimization of inputs and outputs is ideal for the future application in DEA. The actual "best" performance measure that capture each attribute was transparent from the Delphi-like rounds. While the argument can be made that no single performance measure would be able to capture the information necessary to determine whether a department is of quality, best effort was placed on identifying measures that capture reasonable signs of quality and are meaningful to college-level administrators.

User Group Review, Population Size= 13, N= 13

In this Delphi-like round, the objectives were to (1) Query appropriateness of model architecture; (2) Verify/Improve performance indicators (PIs) based on administrative concerns; and (3) Identify data feasibility conflicts.

Participation requests were emailed to all CECS administrators and the dissertation committee members, including the most current draft of the quality model. The dissertation committee were also included because the majority of the committee members were also University administrators. A reminder email was sent to non-respondents as necessary.

The PowerPoint Presentation used for facilitation of this round was delivered to confirmed participants prior to the meeting to provide reference material for the meeting (See Appendix H).

The meeting was held on campus to discuss the model and propose any changes. Electronic feedback was also requested from those who could not attend, yet feedback was not received until after this phase of the data collection had closed. However, all feedback gained through this model review was used to edit and finalize the quality model architecture from the SAFE perspective.

Quality Model Validation

Criteria proposed by ABET, known as the Accreditation Board of Engineering & Technology until 2005, were used to ensure that the quality model covered at minimum, the areas accepted by the University of Central Florida as quality indicators. ABET is the formal governing body assessing the suitability of engineering programs. One of its prime missions is to assure quality and the stimulation of innovation in engineering, applied science, computing and engineering technology programs. ABET assesses programs based on 8 main areas- Students, Program Educational Objectives, Student Outcomes, Continuous Improvement, Curriculum, Faculty, Facilities and Institutional Support. See Appendix I for the full ABET Criteria.

Based on any identified disparity, the quality model was adjusted prior to finalization.

Phase 1 Deliverable

The resulting architecture was a three-level hierarchy with departmental quality residing as the primary objective. The components on level two represent the major categories and the components of level three represent the major attibutes within each category. As shown in Figure 13, levels two and three of the hierarchy were expected to have 3-6 components each.

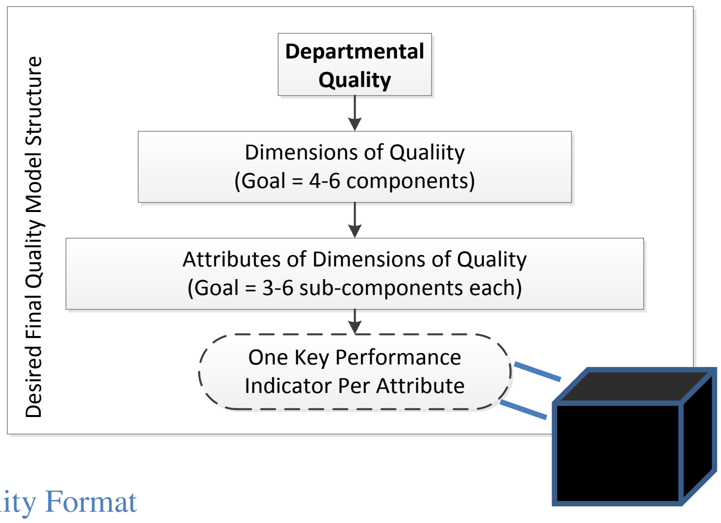


Figure 13: Ideal Quality Format

D. Key Input-Output Selection

To reduce the number of inputs and outputs, the analytic hierarchy process was applied to acquire stakeholder preferences and reduce the model to a short list of key performance indicators.

Capture Stakeholder Preference

The goal of using AHP was to derive an aggregate group preference in order to limit the number of attributes to be included in the efficiency model. The initial step was to define the unstructured problem, which was assumed synonymous with the Quality Model derived in Phase 1. The resulting three level quality definition referenced in Figure 13 was translated into a linear hierarchy, representative of Overall Quality at Level 1 (Goal), Dimensions of Quality at Level 2

(Criteria) and Attributes of the Dimensions of Quality at Level 3 (Sub-criteria) as shown in Figure 14.

This hierarchy was mapped to the AHP framework nearly 1 to 1 as implied in Figure 14 and depicted in survey form for dissemination to stakeholders using Saaty's complete, 9-point ratio scale.

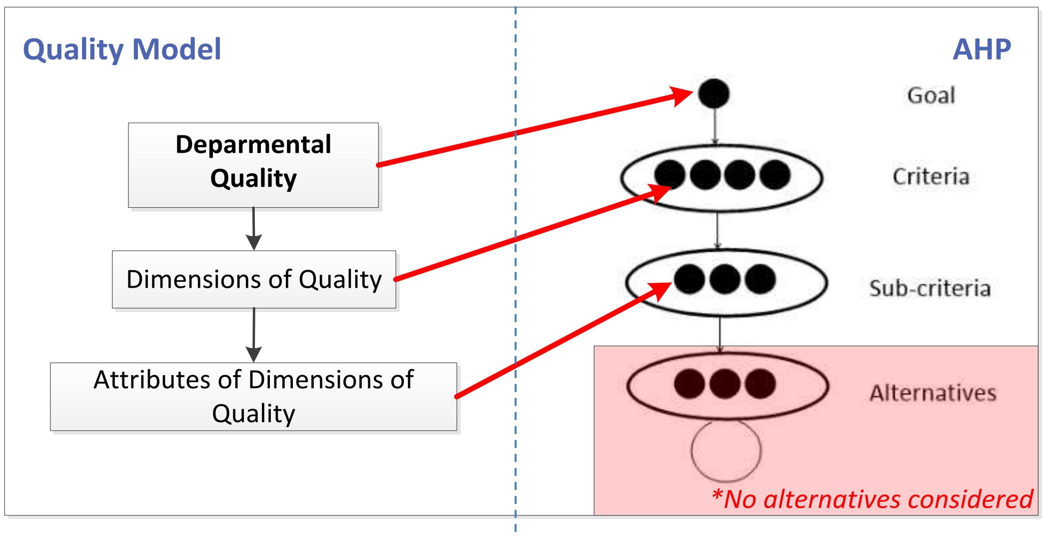


Figure 14: Quality Model to AHP Transition

It was crucial to be cognizant of the number of comparisons required in the AHP analysis due to the exhaustive burden that often results. The number of comparisons were determined to be 55 using Equation 10, where *n* is the number of components in each cluster:

Dimension Level –

$$\frac{n\,(n-1)}{2} = \frac{6\,(6-1)}{2} = 15$$

Attribute Level -

$$\sum \frac{n\,(n-1)}{2} = \; = 5\,x\,\frac{4\,(4-1)}{2} + \frac{5\,(5-1)}{2} = 40$$

Total Number of AHP Comparisons = 15 + 40 = **55**

(10)

The AHP survey was developed as an Adobe Acrobat form and approved by the UCF Institutional Review Board (See Appendices D & J). It was distributed among the SAFE stakeholder groups using electronic and non-electronic mediums and targeted all four stakeholder groups for participation.

AHP Sample Size Determination

Two parameters were determined to calculate the number of surveys needed to satisfy the desire for a representative sample- confidence level = 95%, margin of error = .15. The confidence level represents how often the true percentage of the population would pick a response that lies within the bounds of the confidence interval, or the amount of certainty in the results. The margin of error (or confidence interval) is the amount of error deemed acceptable. Since more information was not available as to spread of responses, the most conservative assumption for the distribution of responses was assumed, 50/50 or p= .50.

Based on a normal distribution, the sample size, *n,* was calculated using Equations 11, where Z= standard normal coefficient (or 1.96 for 95% confidence level), p= .5 is the conservative distribution of response, σ = .15 is the margin of error or confidence interval.

$$Sample\ Size, n = \frac{Z^2 * p(1-p)}{\sigma^2} \tag{11}$$

$$Sample\ Size, finite\ population = \frac{\frac{Z^2 * p(1-p)}{\sigma^2}}{1 + \frac{\frac{Z^2 * p(1-p)}{\sigma^2}}{N}}, where\ N = population\ size \tag{12}$$

Table 7 shows the sample sizes derived from the generic size formula in Equation 11 as well as the results based on accounting for the size of each stakeholder group (Equation 12). The number of CECS employer/industry partners were estimated. The table shows that 43 responses are ideal when not considering the segregation of the participants into groups yet, 105 distributed across its respective stakeholder groups may be a more appropriate target. Therefore the acceptable sample size range was between 43 and 105 responses.

Table 7: Approximate CECS Populations & Sample Need

	Population	Sample
Infinite Sample	NA	43
Students	8,008	42
Administrators	9	8
Faculty	123	32
Employer/Industry Partner	50	23
	Total	**43-105**

CECS **S**tudents: A sample of CECS students was targeted among CECS Student Organization Leaders and students enrolled in either a Senior Design Course or a Graduate Research Course during the spring semester of the 2012-2013 academic year.

CECS **A**dministrators: All CECS administrators listed on the public CECS website at the time of the survey were targeted for participation.

CECS **F**aculty: All full-time faculty, instructors and lecturers listed in public UCF websites was targeted for participation. Additional participants were identified by designations listed on faculty offices in UCF's Engineering Buildings I, II & III.

CECS **E**mployers: A short list of industry partners was provided by CECS. These individuals were targeted for participation.

Stakeholder Preference Data & Validation

A submission link was embedded into the electronic Adobe survey that allowed automatic upload to the Adobe Cloud technology. All other submissions were enabled by email or in-person. Each person's responses were checked for completeness and any data that did not satisfy the initial AHP consistency threshold of 25% was excluded from the composite preferences calculations. After all acceptable responses were compiled at the individual and then stakeholder group level using the arithmetic mean of the derived preferences, an aggregate score for all stakeholder groups combined was derived as depicted in Figure 15.

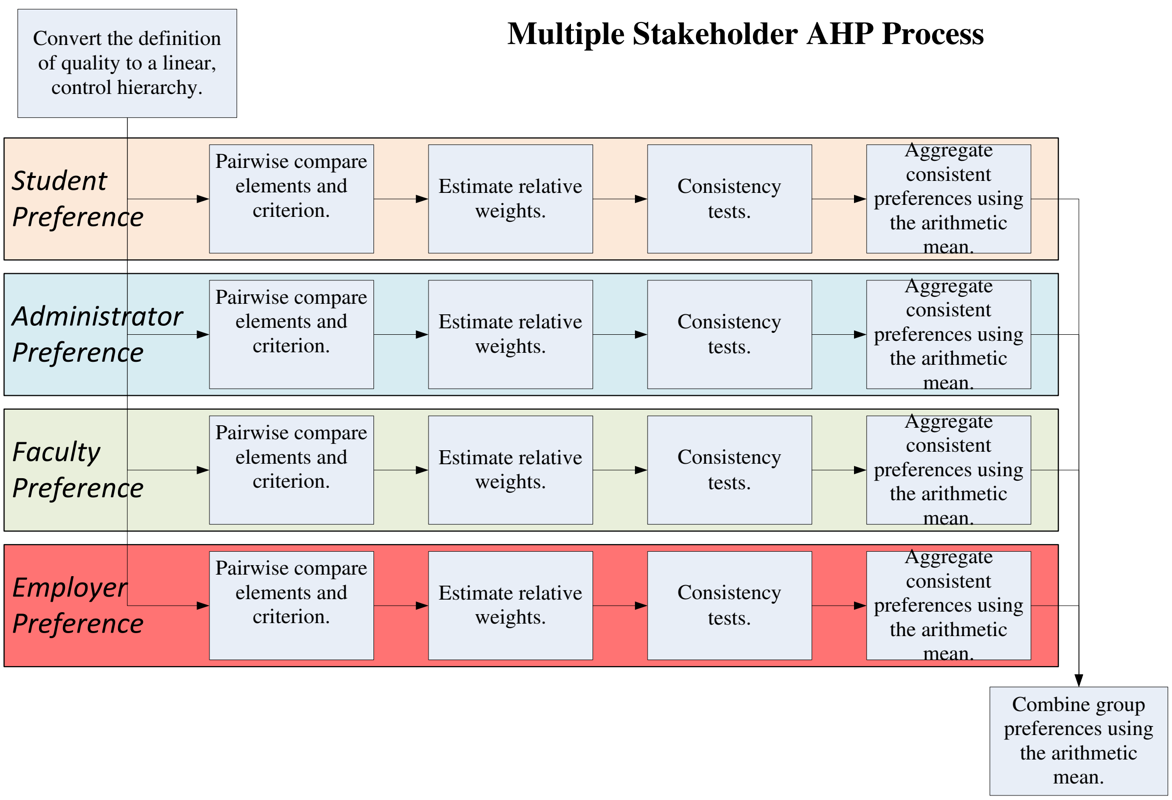


Figure 15: AHP Process

Verification of Results

In an effort to verify that the results are appropriate for the purpose of this project, three statistical analysis tools were utilized to determine the relationships among stakeholder groups, the dimensions and the attributes- i.e. Descriptive Statistics, Correlation Analysis and Significance Tests.

Descriptive Statistics

Descriptive statistics were used to provide information about the spread of the data. The mean, median, standard deviation and range showed the general distribution of the data and highlighted any initial conclusions.

Correlation Analysis

Correlation Analysis, specifically the Pearson product-moment correlation coefficient, or Pearson coefficient was used to show the predictive relationship between (1) pairs of dimensions and (2) SAFE groups at the dimension and attribute level. This was computed by dividing the covariance of the two variables by the product of their standard deviations as shown in Equation 13, where X and Y are random variables with expected values μ and E, and standard deviations, σ.

$$\rho_{X,Y} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E\ [(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y} \tag{13}$$

Significance Tests

Two non-parametric tests were used to evaluate the significance of the prevailing results. The Friedman 2-way ANOVA by ranks test (or Friedman Test) was used to test the significance of (1) preference distributions among all stakeholder groups simultaneously, as well as (2) the difference between the distributions of each dimension of quality. The Wilcoxon Signed-Rank

Test Matched Pairs Test was used to test scenarios where the difference between each pair of groups or dimensions was assessed.

The Friedman Test is a nonparametric test that treats each row as a subject. To compute the test statistic, Q, the different values in each row were rank ordered from low to high. The sum of the new ranks become the R value for the *i*th group in Equation 14. The ranked scores were summed for each column and squared, or $\sum R^2$. The last step was to plug the values into the equation to solve for Q, where N is the number of subjects, and k is the number of groups (or treatments).

$$Q = \frac{12}{Nk(k+1)} \sum_{i=1}^{k} {R_i}^2 - 3N(k-1)$$

(14)

The Wilcoxon Signed-Rank, Matched Pairs Test was the nonparametric test used to assess the each stakeholder group's preference at the attribute level. The null hypothesis (H0) is that the difference between the medians of a pair of groups, X and Y, equals 0. For each record, the difference d was computed by subtracting Y from X and taking the absolute value. All nonzero absolute values were sorted in ascending order and ranks were assigned as R_i. In the cases of ties, the average rank was utilized.

The test statistic W was calculated using Equation 15 which is the absolute value of the sum of the signed ranks.

$$W = |\sum_{i=1}^{N_r} [\mathrm{sgn}(x_{2,i} - x_{1,i}) \cdot R_i]|$$

(15)

Phase 2 Deliverable

The expectation at Phase 2 was stakeholder input and derived preferences for the composite group. The performance indicators were reduced to include those indicators determined to be of highest importance to the composite stakeholder group, herein referred to as key performance indicators. A data needs worksheet was organized to include several proxy/alternative measures given the risk of data inaccessibility or non-availability (formatted like Table 8). The table describes the variables as an input or output, its source for retrieval, the format of the data, including the level of aggregation. It identifies a point of contact or "owner" of the data and any unique processes needed to acquire the data.

Table 8: Data Needs Worksheet

	I/O	Data Location	Data Format	Aggregation	Contact Person	Contact Information	Data Retrieval Needs
X							
Y							

E. Relative Quality Efficiency Assessment

Each department in CECS was defined as a decision making unit (DMU), for an initial total of 4 units. It may have been possible to view each program as a DMU but more information was required to enable discrimination among data for the programs. By adhering to both IO limitation equations (i.e. three times the sum of the number of inputs and outputs should be less than the number of DMUs and the product of the number of inputs and outputs), this small number of decision making units confines the acceptable number of inputs and outputs included in the model. As a precaution, window analysis was incorporated to increase the number of DMUs by the multiple of 6 time periods (or 24 DMUs).

Following the taxonomy introduced in Table 5, several design decisions were made under the four major steps of the DEA methodology. Appendix Q also captures these decisions:

Step1- Data: Sources of data (Real World Data collected from CECS Academic Affairs, Financial Aid, Office of Institutional Research); Degree of Imprecision in the Data (Single-valued, cardinal data using three significant digits from multiple sources aggregated at the program and departmental level).

Step 2- Stochasticity of Frontier (Deterministic); Special Restrictions (7 Inputs-Outputs due to number of DMUs); Orientation and Returns to Scale (Output-oriented, Variable Returns to Scale and Constant Returns to Scale); Convexity of the Mathematical Model (Continuous and Discrete linear programming model); Solving Method (Exact Method using Frontier Analyst); Efficiency Measures of Solution (Single value efficiency measures).

Step 3- Analysis: Purpose (Descriptive - Department efficiency calculations and identification of potential areas of improvement; Time Horizon (Time window of 6 years); Efficiency (Technical Efficiency, θ); Level of Aggregation in Analysis (Department Level within UCF CECS); Sensitivity Analysis and Robustness (Effect of input or output deletion); Techniques for Sensitivity Analysis and Robustness (Variable Deletion).

Step 4- Nature and Methodology: Nature (Real-world application in Education); Methodology (DEA combined with OR/MS, Statistics and other methods).

Given these methodological decisions, a minimum of *nt* linear programs need to be performed, where n is the number of DMUs and t is the number of time periods. This number was doubled because the model was calculated assuming both variable and constant returns to scale. This choice compelled the use of Frontier Analyst to reduce manual overload.

Equation 8 was employed to compute the CCR model since orientation was irrelevant. The selected BCC VRS, output-oriented, maximization model follows Equation 16 below, which features a convexity constraint $\sum \varphi_i = 1$. The variables are $1/\theta_0$ = technical efficiency score, s_k = output slack variable, s_j= input slack variable, x_{ik}= input for DMU I, input j, y_{ik}= output for DMU i, input k, φ_i= weights of the inputs and outputs for each DMU.

$$Max \quad \theta_0 + \varepsilon \left(\sum_{k=1}^{s} s_k + \sum_{j=1}^{m} s_j \right)$$

$$s.t. \quad \theta_0\, y_{ik} - \sum_{j=1}^{n} \varphi_i\, y_{ik} + s_k = 0$$

$$x_{ij} - \sum_{j=1}^{n} \varphi_i\, x_{ij} - s_j = 0 \qquad \forall_i$$

$$\sum_{i=1}^{n} \varphi_i = 1$$

$$\varphi_i\,, s_j\,, s_k \geq 0 \qquad \forall_{j\,,r,i}$$

(16)

Model Verification and Validation

Sensitivity analysis were used to test and validate the resulting model and to test the effects of varying input-output combinations to evaluate the effects of variable deletion and transfer. Two alternative scenarios were considered: (1) Deletion of 1 output; and (2) Deletion of 1 input and 1 output.

Phase 3 Deliverable

The output of Milestone 3 was the relative efficiency of CECS Departments in achieving quality. The model also shows potential areas of improvement for each department.

F. Implementation Limitations

Several factors limit the scope of this implementation:

(1) *Varying data aggregation levels within departments*. Data is captured and aggregated at the levels needed for current accountability methods. This variation introduces data inconsistency issues and degrades transparency of departmental operations.

(2) *Cross functional use of faculty across programs.* Some College of Engineering & Computer Science (CECS) departments are multidisciplinary such as the merger of Computer Engineering and Electrical Engineering into one department. Given common coursework at the foundational level, complexity is introduced when trying to discriminate among two programs sharing resources. For example, how should teaching faculty and enrolled students be counted in these shared courses? How should the allocation of shared resources be distributed?

(3) *Degree of homogeneity among UCF CECS departments enable discriminatory power among the limited number of units.* By limiting the scope to a single College, the leadership, interests and operations are more similar. However, the magnitude of homogeneity may also be so high that the differences among the departments may seem near negligible, causing more departments to be deemed efficient.

(4) *Individuals serving as the Voice of the Customer are assumed reasonable representatives of their respective stakeholder group.* Study participants are recruited on a voluntary basis and their individual bias are affected by varying factors not accounted for in this model.

(5) *Undergraduate student enrollment in UCF CECS is open, pending only acceptance into the University.* The University of Central Florida accepts undergraduate students irrespective of their prospective disciplines. Also "Direct Connect" students gain entrance to the University as Florida Community College graduates irrespective of their preparation as a condition of state law. This enrollment strategy dilutes the possibility of controlling some student-related inputs at the undergraduate level.

(6) *College Restructuring.* As of 2012-13 school term UCF CECS has extended its number of departments from 4 to 5. MMAE was divided into MSE (Materials Science & Engineering) and MAE (Mechanical & Aeronautical Engineering). Therefore, the data collection was conducted using data prior to the current school term.

(7) *Stakeholder Group Importance.* All stakeholder groups' opinions will be weighted equally due to the desire to create a baseline model. The amount of importance decision makers give to each group may be dependent on the type of decision being made. By creating a more generic model, the decision maker is provided the results given minimal subjective bias and customization.

III. Conclusion

The approach introduced in this chapter should attract attention from a range of groups because defining and quantifying quality has been a controversial issue for decades. The relative quality measurement derived from this approach would not only satisfy the stakeholder-relative view of quality whose importance is supported by the literature, but also the multi-faceted nature of the concept itself. The model enables derivation of the dimensions and aspects of quality from the top-down. The value of these components to key stakeholders were taken into account using representation from each group. These views of importance determine the variables under consideration in the measurement of the relative efficiency of departments. The results of implementing the decision support model not only provides clarity as to how to identify a quality department, but also aids decision makers in balancing the inputs of the system in efforts to maximize output. The outcome of this study can be a notable contribution to the field and stimulates future opportunities in the area of systemically assessing efficiency at achieving quality in higher education.

CHAPTER FOUR: RESULTS

The results of the approach described in Chapter 3 are organized in 8 sections- (I) Delphi-like Study- Round 1, (II) Delphi-like Study- Round 2, (III) Delphi-like Study- Round 3, (IV) Quality Model Verification and Validation: ABET, (V) Analytic Hierarchy Process, (VI) Performance Indicator Analysis, (VII) Metrics Development, and (VIII) Data Envelopment Analysis Hierarchy Process.

I. Delphi-like Study, Round 1

Seventy-three individuals representing all four stakeholder groups were contacted in Round 1. Seven people responded, yielding nearly a 10% response rate. Given the qualitative nature of the questionnaire, quantity expectations were low but the minimum requirement of 1 representative per stakeholder group was met. The distribution was 1 Student, 2 Administrators, 2 Faculty and 2 Employers/Industry Partners.

After several weeks of collecting data on the Survey Monkey server, the results revealed that quality is indeed a widely conceived concept. Participants provided varied definitions to delineate quality programs:

(1) "A quality academic program combines education in key technology concepts and principles with research into new and emerging areas of technology."

(2) "A quality academic program is one where a high level of dissemination and learning of knowledge are being produced. This can be measured through student job placement, and publication of scholarship."

(3) “A quality program produces graduates who are capable of performing the basic technical functions of the job; but just as importantly, who have learned how to learn.”

(4) “An academic program is high quality if it has a 1. high retention and graduation rates, 2. If its’ graduates students are successful in their professional pursuits (get jobs), 3. the faculty are current and experts in their field, and 4. the program is high quality measured through accreditation or program reviews. A Department is high quality if 1. its degree programs are high quality, 2. the faculty are successful (publish, generate creative works, get national awards, and obtain research funding), and the department provides service (active in the professional organizations, provides service in the community).”

(5) “A quality academic program is one that does impactful research and which consistently demonstrates excellence in both research and teaching.”

Each of these definitions illuminates the vast range in interpretation of quality in academic programs and departments. While some stakeholders may take a more narrow view considering only typical outputs of the system, other stakeholders may be concerned with the intricacies of not only outputs, but also the inputs, processes and confounding factors that affect the ability to derive outputs.

Based on these findings and the literary review results, the definition of quality derived was as follows: *Quality is an academic department’s ability to efficiently attain, allocate and utilize infrastructure, technology, fiscal and human resource inputs to maximize positive output and effectiveness in the novelty of research conducted, the delivery of sound teaching practices and the creation of valuable knowledge among its diverse and competing stakeholders.*

When queried about the specific attributes or aspects of an academic program or department that is indicative of a quality program, participants provided a laundry list in a number of different formats. After combining similar responses, Table 9 lists all participant feedback. The bottom portion of the list was drafted based on literary findings prior to survey dissemination and merged in the task of refining the model.

Table 9: Aspects of Quality, Survey 1

Survey 1 Quality Factors	
National Reputation	Employment Rates
Performance of Grad at Workplace	Entrance into Grad Program
Student Job Placement	Students obtaining national scholarships
Research Publications	Patents
Research Funding	Faculty National Awards/Honors
Industry/Government Research Presence	Student National Awards/Honors
Strength of Post-grad Program (rankings, papers	Accreditation
Faculty-to-student ratios	External Reviews (Program Reviews)
Faculty teaching in specialty (rather than across multiple classes)	Honors (membership in national academies)
Faculty Reputation- papers produced	Student Success Post Degree
Relevant teaching (quoted in literature)	External Funding
Retention Rates	National Exam Score of Students
Relevant resources (facilities- labs, computers, building infrastructure)	Department's service to the community
Participant referenced GMAC: which includes (1) Curriculum: (a) content, (b) delivery, and (c) program structure; (2) Faculty: (a) qualifications, (b) research, (c) teaching, and (d) overall quality; (3) Placement: (a) alumni network, (b) career services, and (c) corporate/community relations; (4) Reputation: (a) perceptions of program quality; (5) Student learning and outcomes: (a) personal competency development, (b) student career consequences, (c) economic outcomes, and (d) learning outcomes; (6) Institutional resources: (a) facilities, (b) financial resources, (c) investment in faculty, (d) tuition and fees, and (e) student support services; (7) Program/institution climate: (a) diversity and (b) educational environment; (8) Program student composition: (a) the overall makeup and quality of students; (9) Strategic focus: (a) the quality of the articulated institutional mission and strategic plan.	
Pre-Survey Literary Compilation	
Cost Management	Student Performance
Academic Expenditures	Reputation
Non-Academic Expenditures	Industry Partnerships
Income	Faculty Productivity
Research	Affordability
Publications	Teaching & Learning
Student Financial Support	Environment
Intellectual Property	Facilities & Maintenance
Research Income	Information Infrastructure
Enrollment Management	Student Support Services
Diversity & Demographics	Technology & Equipment
Convenience	Alumni Relations
Competitiveness	Program Relevance
Sustainability	Faculty Development & Training
Evaluations	Student Employability
Accessibility	Program Demand

The factors in Table 9 and the factors present in the quality models captured in Appendix B were organized using affinity diagrams similar to that shown in Figure 16. These diagrams were created by grouping similar concepts and initially trying to amplify possible sub-categories by delineating among the different stakeholder groups.

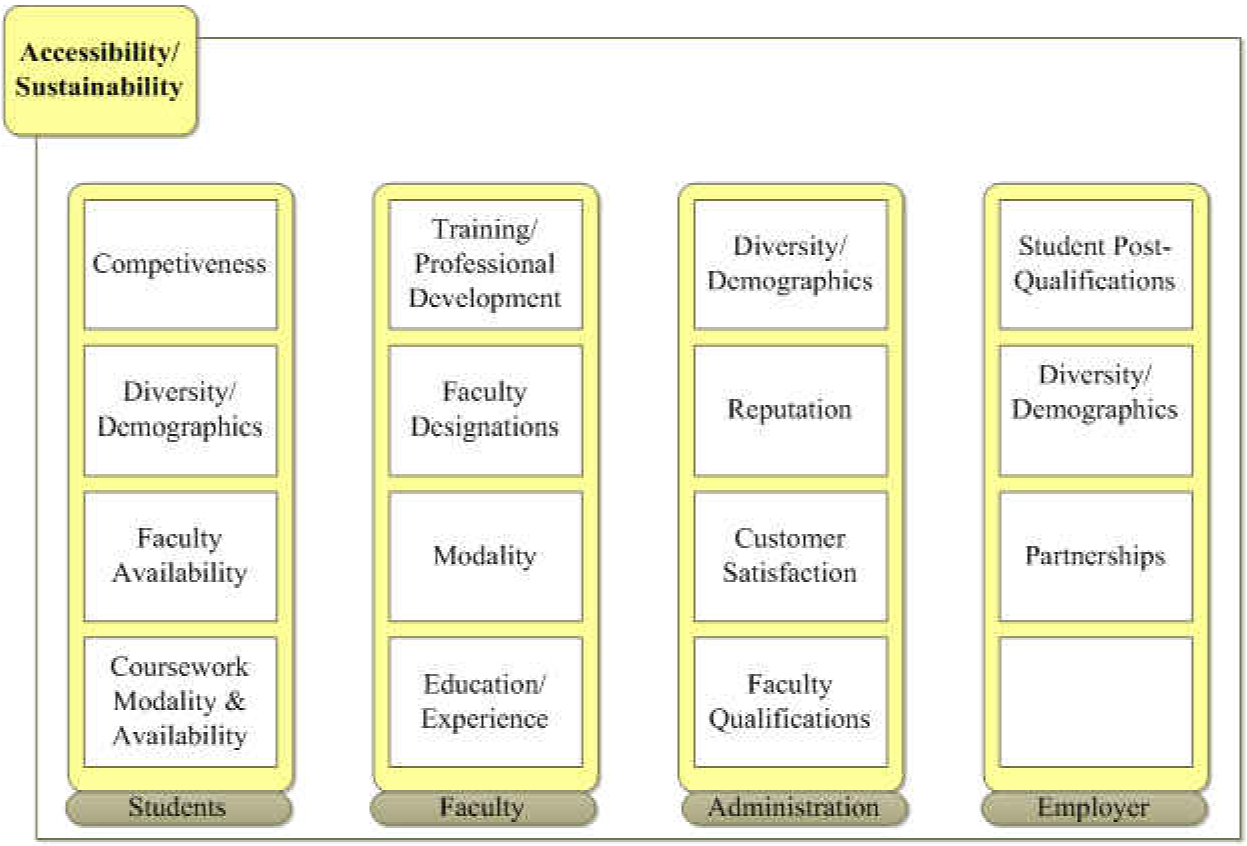


Figure 16: Example Affinity Diagram

The result of this iterative and exhaustive process was the first draft of the quality model shown in Figure 17. This model was comprised of 5 dimensions and 30 attributes, ranging from 4 to 8 attributes per dimension.

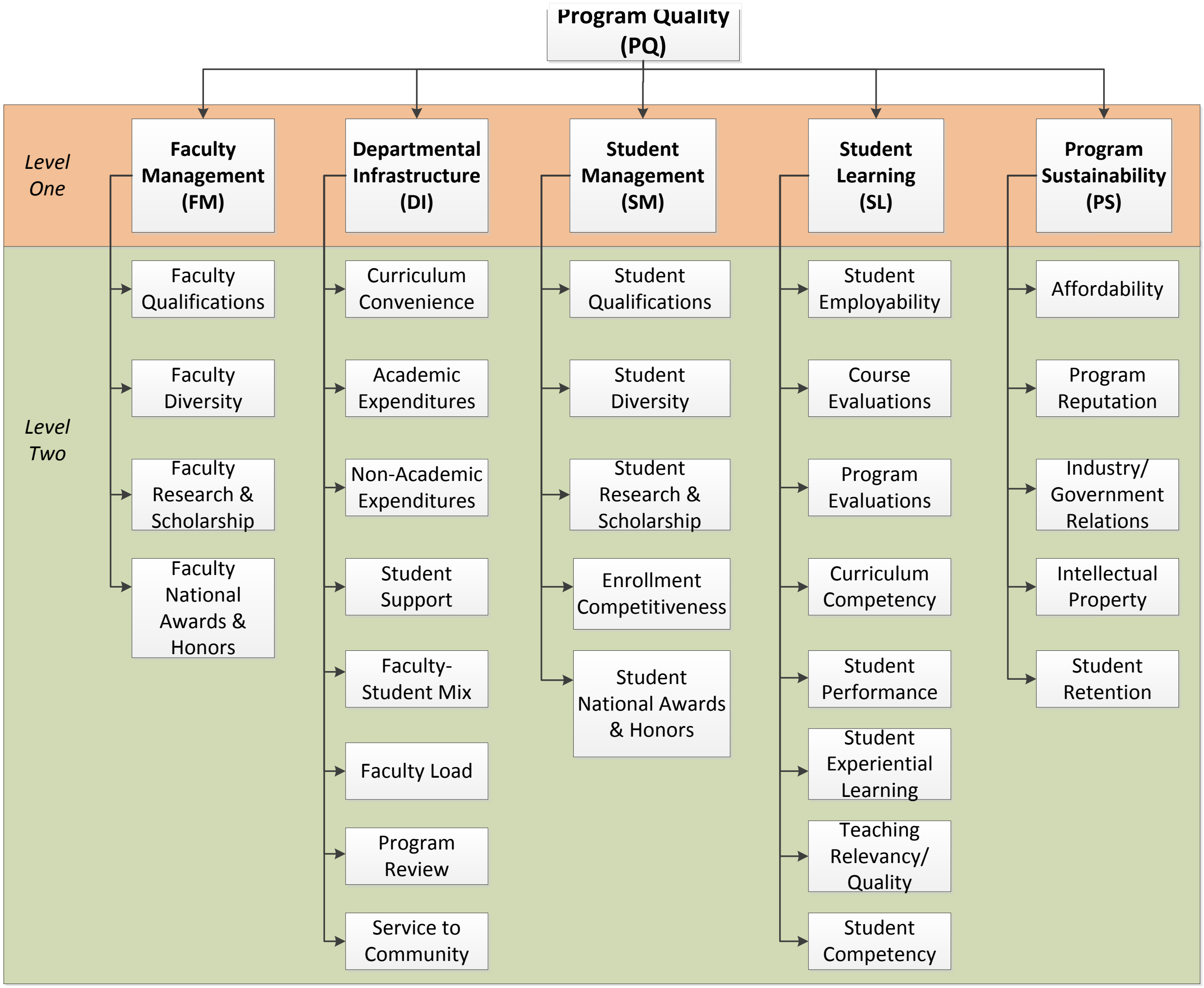


Figure 17: Quality Model- Version 1

The results also revealed 1-4 performance indicators to describe each attribute (Table 10). It also captures the initial definition drafted for each attributes.

Table 10: Performance Indicators- Round 1

	Attribute	Definition	Potential Indicator(s)
Faculty Management	Faculty Qualification	Suitability of faculty-credentials, experience	#Full-time faculty / # part-time faculty
	Faculty Diversity	Demographic mix of faculty	Custom Derived Diversity Factor
	Faculty Research & Scholarship	Presence of faculty in academic research	(Metadata) Avg. # of citations
			# of publications (journals, books, chapters)/#FTE
			# of publications in a A-tier source/# FTE
	Faculty Service	Faculty's service to the community	# Service hours to the community/#FTE
	Faculty National Awards & Honors	Faculty receiving national awards and honors	# of national awards and honors received/#FTE
Departmental Infrastructure	Curriculum Convenience	Level of "flexibility" in program curriculum	% of required courses offered via alternative delivery
			% of curriculum that are electives (restricted/non-restricted)
	Academic Expenditures	Budget resources allocated to academic expenditures	$ of academic expenditures/program budget
	Non-Academic Expenditures	Budget resources allocated to academic expenditures	$ of non-academic expenditures/program budget
	Student Support	Level of financial support provided to students during matriculation	% of students grad students receiving UCF supported fellowships/assistantships

	Attribute	Definition	Potential Indicator(s)
			% of students grad students receiving internal/external fellowships/assistantships Amount of graduate student support
	Faculty-Student Mix	Distribution of faculty among its students	Ratio of FTE faculty to students (UGRAD + grad)
	Faculty Load	Balance of faculty responsibilities	Average # of courses taught per FTE
	Program Review	Internal evaluation of program	Overall program evaluation rating
	Service to the Community	Amount of service provided to the community	# Service hours to the community/#FTE
Student Management	Student Qualifications	Preparedness of students-credentials, experience	Avg. Entering GPA % of students in Top 10% of High School Class
	Student Diversity	Demographic mix of students	Custom Derived Diversity Factor
	Student Research & Scholarship	Presence of students in academic research	(Metadata) # of citations # of publications (journals, books, chapters, conference papers, conf presentations)
	Enrollment Competitiveness	Admissions competition	# of applications/# of students accepted Avg. GRE score of Grad student accepted Avg. entrance GPA of verified UGRAD students accepted
	Student National Awards & Honors	Students receiving national awards and honors	# of national awards and honors received

	Attribute	Definition	Potential Indicator(s)
Student Learning	Student Employability	Students ability to secure employment post-graduation	Percentage employed within 1 year of graduation
			Percentage employed in field within 1 year of graduation
	Course Evaluations	Comprehensive course evaluation provided by enrolled students	Course evaluation rating
	Program Evaluations	Comprehensive evaluation of a program by its graduates (at all levels)	Program evaluation rating
	Curriculum Competency	Relevancy of the curriculum content to the field	Percentage of student passing national exam
			Curriculum-related student course evaluation rating
	Teaching Relevancy/Quality	Relevancy/quality of teaching delivered	Average # of courses taught by per FTE
			Teaching-related student course evaluation rating
	Student Performance	Student academic performance in the program	Undergrad student course performance (any student enrolled in program's course)
			Confirmed undergrad student's non-GenED GPA

	Attribute	Definition	Potential Indicator(s)
	Student Experiential Learning	Student participation in recognized practical experiences while matriculating through program.	% of UGRAD graduating with experiential learning experience (not counting capstone exercise) Avg. amount of experiential experience at UGRAD exit
	Student Competency	Exemplification of mastery of topics related to discipline	Percentage of student passing national exam
Program Sustainability	Affordability	Overall program affordability to its students	Graduate student debt at graduation UGRAD student debt at graduation Overall student debt at graduation UGRAD student debt at graduation/salary after graduation
	Program Reputation	National reputation of program	US News & World Report Score
	Industry/Government Relations	Program presence in Industry/Government	Research $ from industry/government
	Intellectual Property	Any patents, licensures or other intellectual property held by the program	$ Value of intellectual property
	Student Retention	Program's ability to retain its students up to graduation from the program	% of students completing UGRAD program in 5 years % of students transitioning from UGRAD to grad

II. Delphi-like Study, Round 2

In Round 2, the same 73 individuals across all stakeholder groups were contacted to participate in the survey. Ten people participated yielding nearly a 14% response rate. Five of the seven individuals from the Survey 1 were present in this round. Therefore, five new people were present in the second round.

Given the intensive nature of the questionnaire, the quantity of responses was not as important as getting quality responses. The feedback elicited from each participant was both time consuming and mentally demanding. The distribution was 3 Students, 2 Administrators, 3 Faculty and 2 Employers/Industry Partners, thereby meeting the minimum target of 2 representatives from each stakeholder group.

More than 100 descriptive and unique comments were obtained at all levels throughout the model (objective, dimension and attribute levels). The comments ranged from generic reasoning, renaming, adding, deleting and rearranging components. Figure 18 captures several participant comments obtained in this Round of the study to serve as a representation of the nature of the comments provided.

In order to assist in limiting the number of performance indicators to one "best" option per attribute, the results also show a ranking based on quantitative responses. In some instances, comments were made to consider alternative performance indicators. These recommendations were added to the results. Figure 19 is an extraction of the results fully captured in Appendix M.

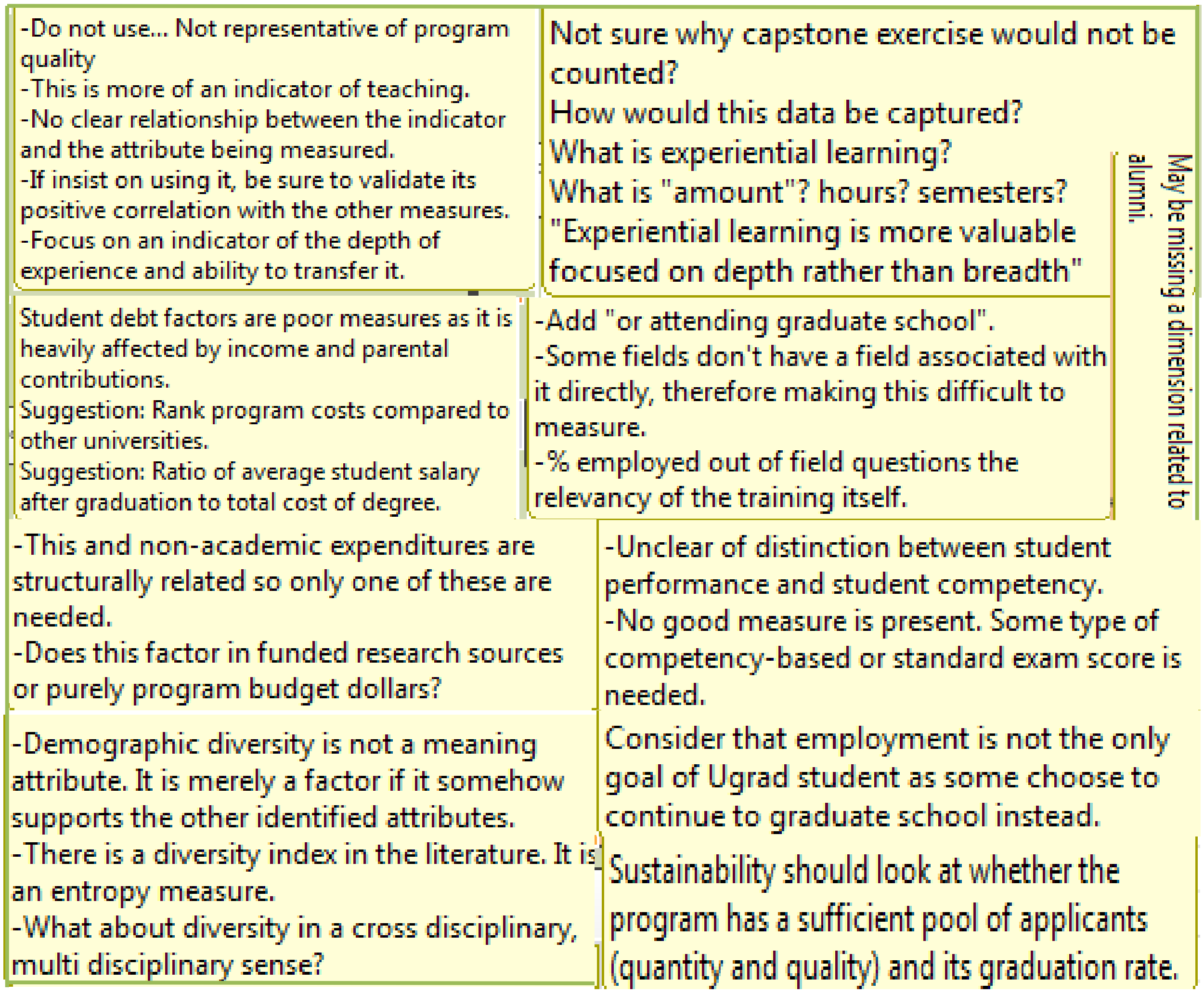


Figure 18: Comment Extraction

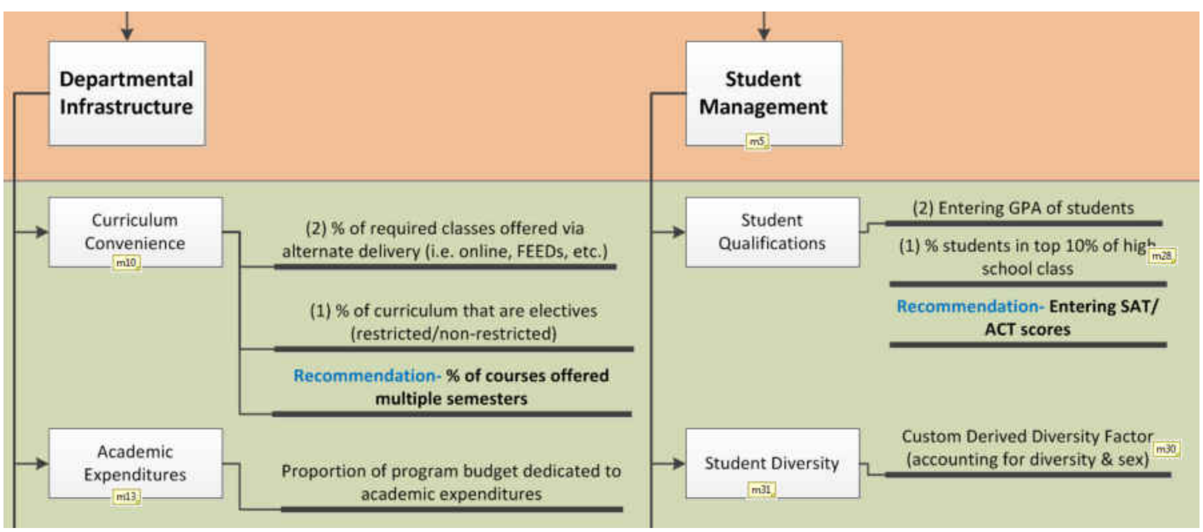


Figure 19: Survey 2 Results Extraction

The following section shows all performance indicators considered in ranked order, as applicable. Any suggested alternatives are also listed.

1-Given the Faculty Management Dimension:

1.1 Faculty Qualifications

Single PI. Ratio of FT to PT Faculty

Alternative. % with a terminal degree in the discipline

1.2 Faculty Diversity

Single PI. Custom Derived Diversity Factor (accounting for diversity & sex)

1.3 Faculty Research & Scholarship

Tied Ranked 1. Metadata on # of citations of faculty research

Tied Ranked 1. # of publications in an A-tier source per FTE

Ranked 2. # of publications per FTE

1.4 Faculty National Awards & Honors

Single PI. # of national awards & honors received per FTE

2-Given the Departmental Infrastructure Dimension:

2.1 Curriculum Convenience

Ranked 1. % of curriculum that are electives (restricted/non-restricted)

Ranked 2. % of required classes offered via alternate delivery (i.e. online, FEEDs)

Alternative. % of courses offered multiple semesters

2.2 Academic Expenditures

Single PI. Proportion of program budget dedicated to academic expenditures

2.3 Non-Academic Expenditures

Single PI. Proportion of program budget dedicated to non-academic expenditures

2.4 Student Support

Ranked 1. Avg. amount of graduate student support per graduate student

Ranked 2. % of graduate students receiving internal/external fellowships/assistantships

Ranked 3. % of graduate students receiving UCF supported fellowships/assistantships

2.5 Faculty-Student Mix

Single PI. Ratio of FTE faculty to students (UGRAD + GRAD)

Alternative 1. FTE classroom to students (undergrad + grad)

Alternative 2. Project specific hours to students (undergrad + grad)

2.6 Faculty Load

Ranked 1. Avg. # of courses taught per FTE

Alternative 1. Avg. # of credit hours taught per FTE

Alternative 2. Avg. # of credit hours taught per FTE

2.7 Program Review

Single PI. Overall program evaluation rating given in departmental reviews

Alternative. Licensure exam results

2.8 Service to Community

Single PI. # of service hours to the community per FTE

3-Given the Student Management Dimension:

3.1 Student Qualifications

Ranked 1. % students in top 10% of high school class

Ranked 2. Entering GPA of students

Alternative. Entering SAT/ACT scores

3.2 Student Diversity

Single PI. Custom Derived Diversity Factor (accounting for diversity & sex)

3.3 Student Research & Scholarship

Ranked 1. # of publications per student

Ranked 2. Metadata on # of citations of student research

Alternative. % of students with publications

3.4 Enrollment Competitiveness

Ranked 1. Ratio of grad students accepted to total grad student applications

Ranked 2. Avg. entering GPA of UGRAD students

Ranked 3. Avg. GRE score of accepted grad students

Ranked 4. Avg. entering GPA of accepted grad students

3.5 Student National Awards & Honors

Single PI. # of national awards & honors received per student

4-Given the Student Learning Dimension:

4.1 Student Employability

Tied Ranked 1. % employed within 1 yr of graduation

Tied Ranked 1. % employed in field within 1 yr of graduation

4.2 Course Evaluation

Single PI. Course evaluation rating

4.3 Program Evaluation

Single PI. Program evaluation rating

4.4 Curriculum Competency

Ranked 1. % of students passing the national exam

Ranked 2. Curriculum-related student course evaluation rating

Alternative 1. # of years since last major curriculum revision

Alternative 2. Survey by employers of new hire preparedness

4.5 Student Performance

Ranked 1. Ugrad student course grade (any student enrolled in program's course)

Ranked 2. Confirmed Ugrad student's non general education GPA

4.6 Student Experiential Learning

Ranked 1. % of Ugrad students graduating with experiential learning experience (not counting capstone exercise)

Ranked 2. Avg amount of experiential experience at Ugrad exit

4.7 Teaching Relevancy & Quality

Ranked 1. Teaching-related student course evaluation rating

Ranked 2. Avg. number of courses taught per FTE

4.8 Student Competency

Single PI. % of students passing national exam in field

5-Given the Program Sustainability Dimension:

5.1 Affordability

Ranked 1. Grad student debt at graduation

Ranked 2. Ugrad student debt at graduation

Ranked 3. Avg. of all student's debt at graduation

Ranked 4. Ratio of student salary at graduation to student debt at graduation

5.2 Program Reputation

Single PI. U.S. News & World Report Score

5.3 Industry/Government Relations

Single PI. Total research dollars from industry and government

5.4 Intellectual Property

Single PI. Dollar value of intellectual property

Alternative. # of patents per faculty

5.5 Student Retention

Ranked 1. % of graduates receiving a degree in 5 years

Ranked 2. % of students transferring internally from Ugrad to Grad program

Alternative 1. 1^{st} yr retention rates

Alternative 2. 6 yr graduation rates

The result of Round 2 was a refined quality model comprised of 6 dimensions and 27 attributes, ranging from 4 to 5 attributes per dimension (see Figure 20). The Departmental Infrastructure dimension was renamed as the Academic Infrastructure dimension. The ranked performance indicators and all suggested alternatives were considered in order to reduce the number of performance indicators from 1 to 4 per attribute down to 1.

The purpose of this reduction was to continue to control the number of inputs and outputs included in the model. Data envelopment analysis works best with a minimal number of inputs and outputs; given the presence of 25 attributes, more than 1 metric per attribute quickly increases the number of inputs and outputs, thereby decreasing the number of attributes that can be considered in DEA.

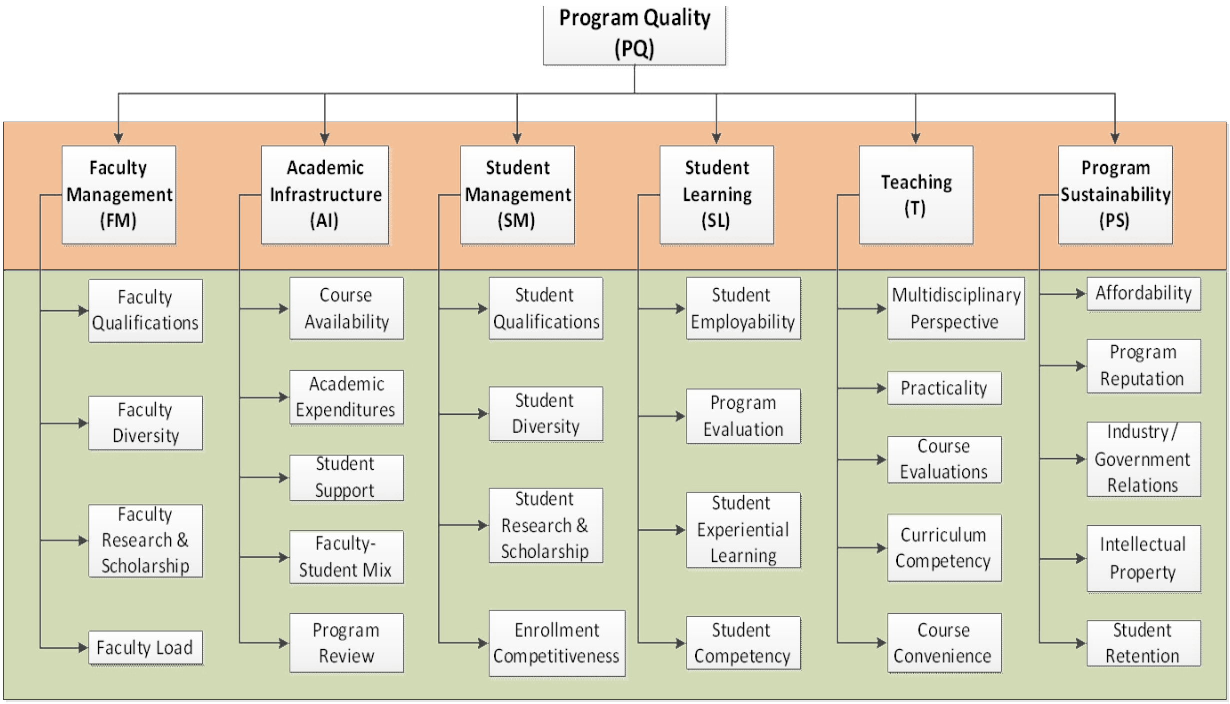


Figure 20: Quality Model, Version 2

III. Delphi-like Study- Round 3

The invitation to attend the User Group was sent to CECS administrators and the dissertation committee members since most of them were University administrators (or 13 people). Only three individuals participated, yielding nearly a 23% response rate. One and a half hour was used gather as much feedback as possible on the model's structure, potential data concerns and alternative performance indicators.

The presentation slides in Appendix H were used to facilitate this session. All data was transcribed during the session and later used to further refine the model. The result of Round 3 was a refined quality model comprised of 6 dimensions and 24 attributes, ranging from 3 to 5 attributes per dimension (Figure 21). The name of the objective level was converted from program quality to departmental quality, because to date the two had been used interchangeably.

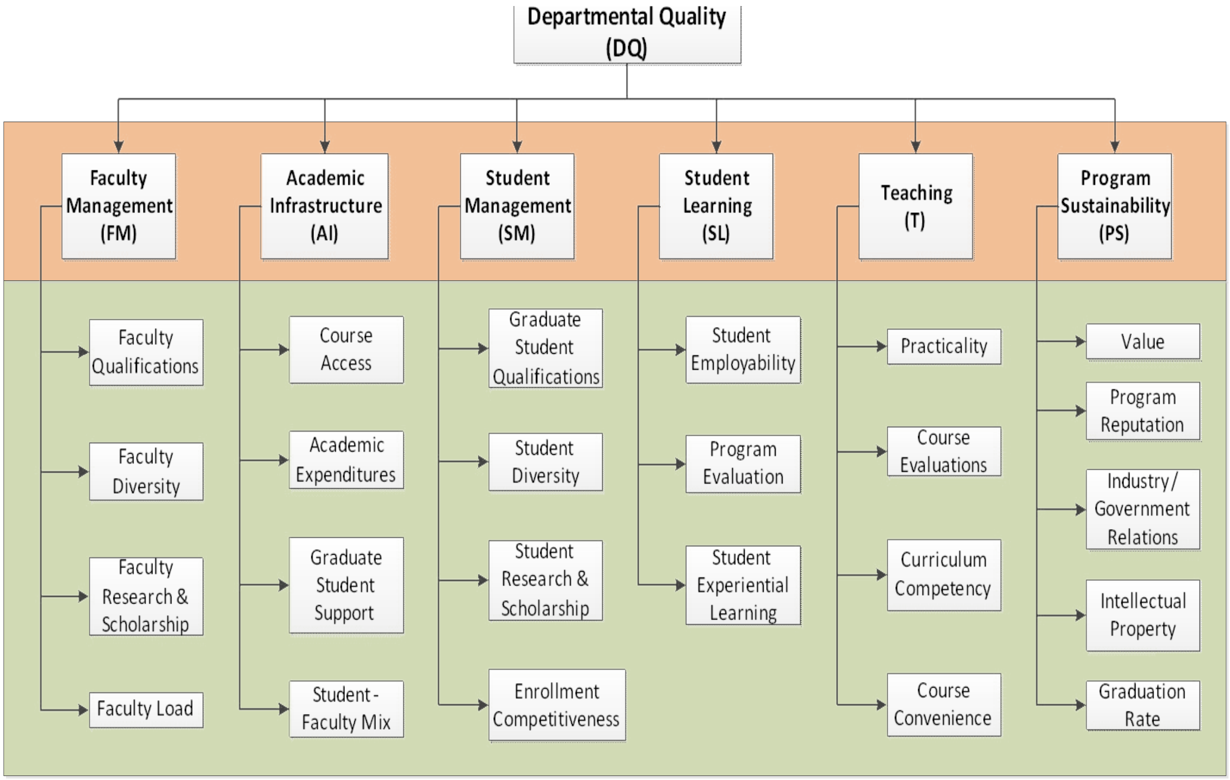


Figure 21: Quality Model, Version 3

IV. Quality Model Verification and Validation: ABET

The purpose of the model verification and validation process was to assess whether aspects of the engineering departments that are widely accepted as key to quality are included in the derived model. The best source identified was the ABET Accreditation Criteria (Appendix I). Detailed Model to ABET mapping is found on the rightmost column of Appendix N and also in Figure 22.

An attribute level evaluation found that all high-level model components were addressed by the derived quality model with the exception of *Facilities and Equipment*. Although *Intellectual Property* could be argued as a proxy of modern tools and equipment, it was not accepted as a direct measure of facilities and equipment. Therefore, this new attribute was added to the dimension of academic infrastructure.

An area not specifically addressed by ABET but included in the quality model was incoming student qualifications, or *Graduate Student Qualifications*. ABET criteria 1d assesses the policies for accepting new or transfer students which may be implied by accepted student's qualifications but the relationship was determined to be indirect. This attribute was preserved.

Interestingly, the derived model introduces three new criteria, *Faculty Diversity*, *Student Diversity* and Program Costs to Students (or *Value*).

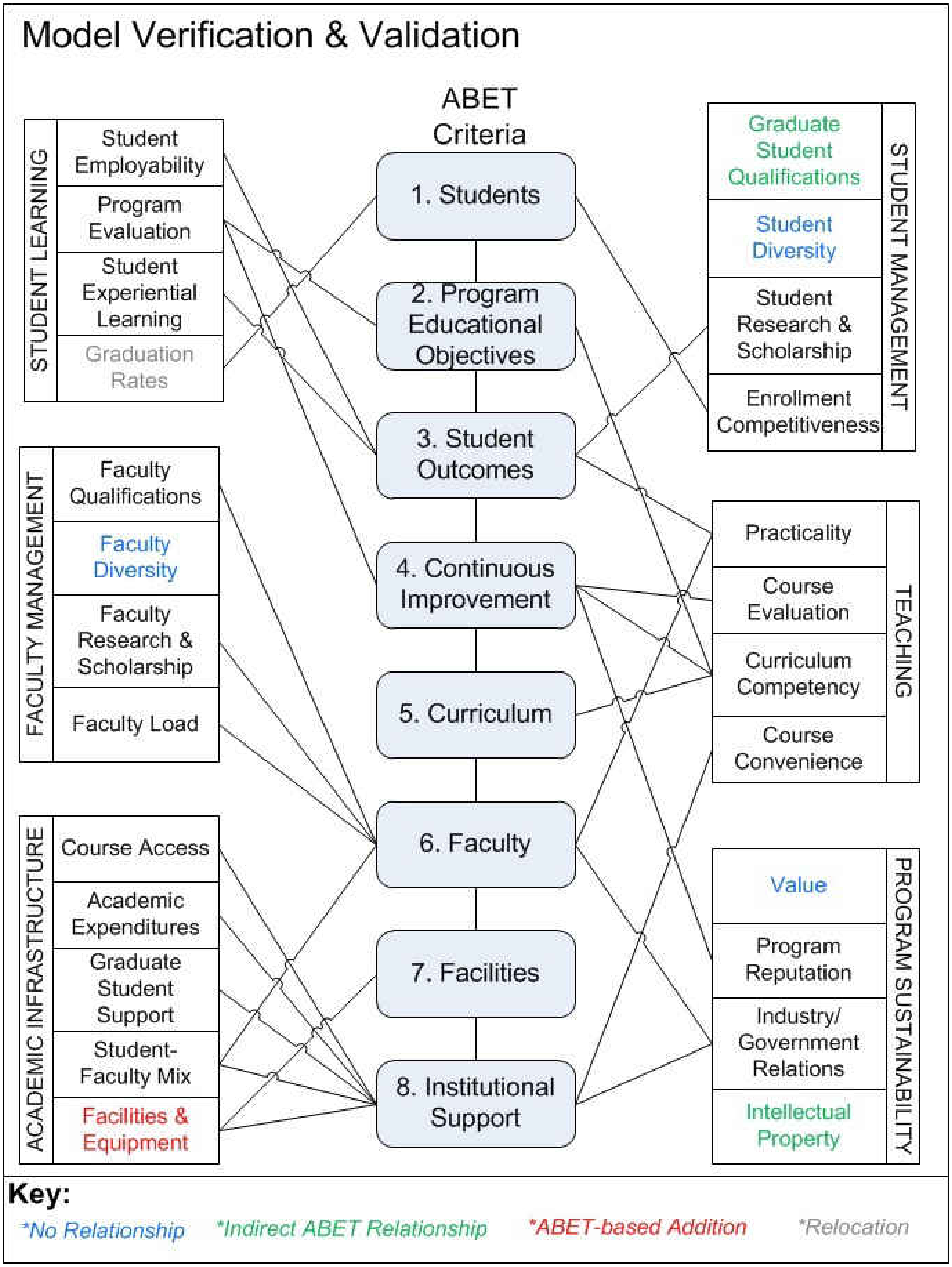


Figure 22: Model Verification & Validation

The result of the verification and validation process was the final quality model used as the basis for the remainder of this dissertation. As shown in Figure 23, the model is comprised of 6 dimensions and 25 attributes, ranging from 4-5 per dimension and only 1 performance indicators for each attribute. For more details, see Appendix N.

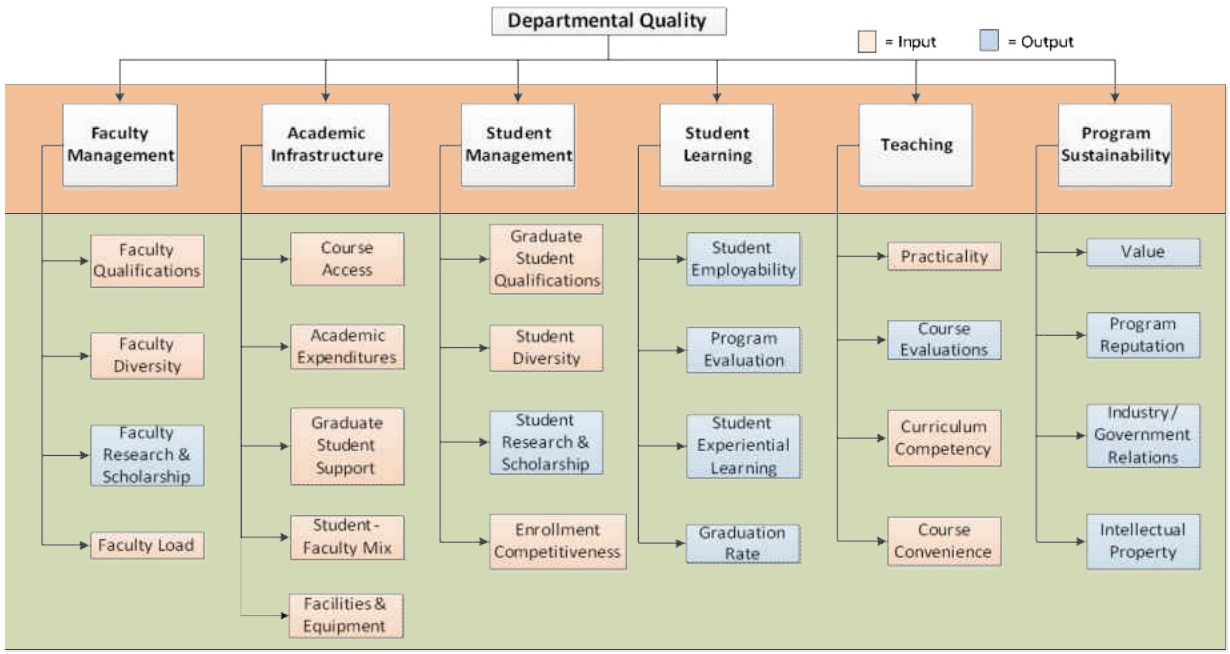


Figure 23: Final Quality Model

The final quality model has been coined as the LIFTS[2] model, as it dimensions can be viewed as **L**earning, **I**nfrastructure, **F**aculty, **T**eaching, **S**tudents and **S**ustainability in short form.

V. Analytic Hierarchy Process

Participation rates in the AHP survey varied among stakeholder groups. The student stakeholder group met its goal of 42 participants, while all other group samples could not be deemed a representative samples (n < goal sample size). Table 11 shows the number of surveys received, the suggested sample size, the number of surveys 100% complete and the max number of surveys that are consistent at each level of the analysis.

Table 11: AHP Responses

	Total Received	Goal	Complete	Max # Consistent
Students	60	42	53	44
Administrators	1	8	1	1
Faculty	9	32	8	7
Employers	3	23	3	3
Unknown	1	0	0	----
Total	***74***	***(43-105)***	***65***	***55***

Table 12 provides more detail into the level of consistency inherent to each group at the dimension level (DQ) and all the groups of attributes (Faculty Management (FM), Student Management (SM), Academic Infrastructure (AI), Teaching (T), Student Learning (SL) and Program Sustainability (PS)). The results show that all groups average around 10% consistency ratio, with the exception of the Administrator group. The most inconsistent overall area was Teaching followed by Program Sustainability. It is important to note that the average consistency ratio for all dimensions are below the 10% threshold, only when the administrator perspective is removed.

Table 12: Average Consistency Ratios

	DQ	FM	SM	AI	T	SL	PS	Avg.
Student	0.1167	0.0988	0.0873	0.1087	0.0899	0.0921	0.0992	0.1012
Admin	0.1378	0.0043	0.1074	0.1648	0.5556	0.1309	0.1986	**0.1856**
Faculty	0.1021	0.1357	0.1063	0.0841	0.1090	0.0531	0.0917	0.0974
Employer	0.0952	0.0642	0.1179	0.0675	0.0254	0.1004	0.1305	.0859
Avg.	**0.1130**	0.0758	0.1047	0.1063	**0.1950**	0.0941	**0.1300**	**0.1175**
Avg., Excluding Admin	0.1047	0.0996	0.1038	0.0868	0.0748	0.0819	0.1071	.0948

The steps in the Analytic Hierarchy Process were programmed in Matlab in order to minimize the repetitive nature of AHP computations. The code for computing the Student Group's preference for the high-level dimensions of quality is provided in Figure 24. All other levels follow similar calculations and remaining stakeholder group calculations are near identical.

```
%Departmental Quality, Student Perspective
P=2; SDQ=[1; 1; 1; 1; 1; 1]; SDQCR=[1];

for P = 2:54
   DepQual= xlsread('Survey4DataStudent2.xlsx',P,'C2:H7');

   %Perform AHP on Departmental Quality Dimensions at Level 1.
   n1=6;
   root=nthroot(prod(DepQual,2),n1);
   sumroot=sum(root);
   Pref=root/sumroot;
   Check=sum(Pref);
   c=DepQual*Pref;
   d=c./Pref;
   e=mean (d);
   CI=(e-n1)/(n1-1);
   CR=CI/1.24;

   %If CR > .25, add preference vector as a new column in a super
   stakeholder vector. Also, add the consistency ratio to a super
   vectors.
   if CR <= .25
       SDQ=[SDQ Pref];
       SDQCR=[SDQCR CR];
   end
   %Assuming sheet number increases by 1 each iteration, increase sheet
   number with each iteration.
end

%Delete the extra column for acceptable student preferences.
 SDQ(:,1)=[];     SDQCR(:,1) = [];        AvgSDQCR= mean(SDQCR)

 %Calculate the arithmetic mean for student stakeholder group.
 y=size(SDQ);     z=size(SDQCR);
 z=z(:,2);        y=y(:,2)
 StudDepQualPrefAM= mean(SDQ,2)

 %Feasibility Check (AM Preferences should sum to 1)
 TotStudDQPrefAM= sum(StudDepQualPrefAM)
```

Figure 24: AHP Matlab Code Extraction for Student Group

The results of the dimension level analysis are shown in Table 13 and Figure 25. Complete preferences are captured in Appendix O. In Table 13, each SAFE stakeholder group share a common mean of overall dimension level preferences due to the ratio nature of the data. The standard deviation from the mean is least for Faculty and Students (approximately 6% and 11%, respectively) and greatest for Administrators and Employers (15% and 11%, respectively). This implies that there exist the greatest variability in Administrator and Employer's view of the importance of each dimension. Figure 25 better depict these relationships. Most groups demonstrate a similar view of the importance of each dimension, with the exception of the Administrator group. Faculty Management and Program Sustainability represent very important dimensions for administrators.

Table 13: Descriptive Statistics at the dimension level (SAFE)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Student	6	.1667	.1112	.0655	.3357
Administrator	6	.1667	.1536	.0205	.4142
Faculty	6	.1667	.0643	.0632	.2455
Employer	6	.1667	.1384759	.0503	.4021

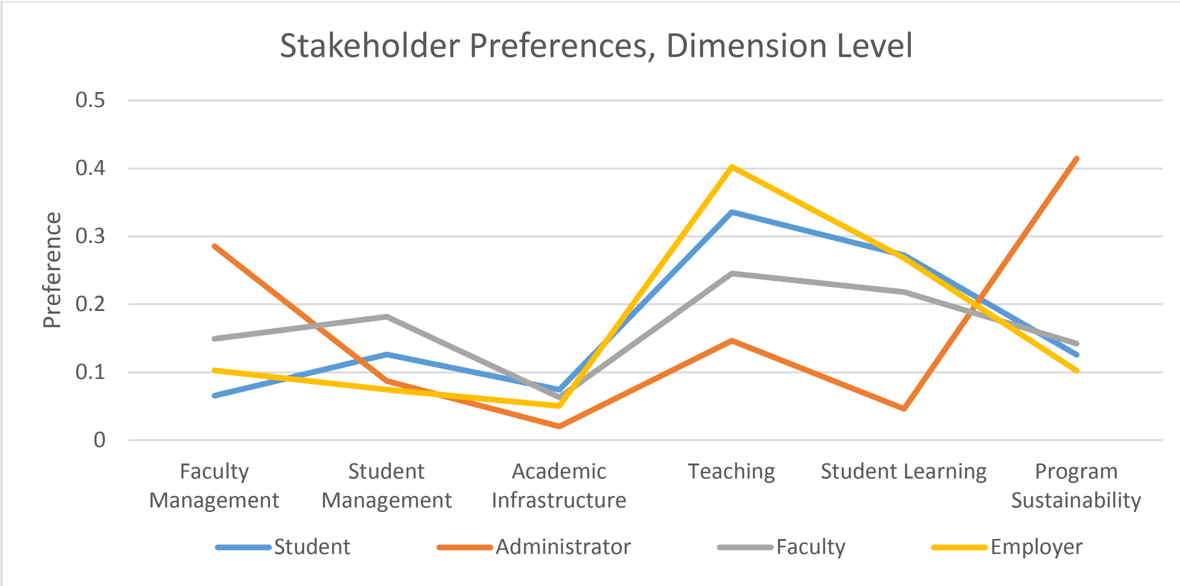


Figure 25: Dimension Level Preferences (by Dimension)

To test the hypothesis that all distributions among stakeholder groups are the same across all dimensions (H0), the related samples Friedman's two way ANOVA by ranks test revealed a significance of .659. Therefore, H0 was not rejected.

The associated correlations at the dimension level (across stakeholder groups) are shown in Table 14. All correlations are significant at either α = .05 or .01 in the positive direction except those involving the Administrator group. Administrator preferences pose a negative relationship with all other stakeholder groups and the relationship is not significant.

Table 14: SAFE Correlations at the dimension-level

	N=6	Student	Administrator	Faculty	Employer
Student	Pearson Correlation	1	-.253	.853*	.962**
	Sig. (2-tailed)		.629	.031	.002
Administrator	Pearson Correlation	-.253	1	-.040	-.152
	Sig. (2-tailed)	.629		.940	.774
Faculty	Pearson Correlation	.853*	-.040	1	.833*
	Sig. (2-tailed)	.031	.940		.039
Employer	Pearson Correlation	.962**	-.152	.833*	1
	Sig. (2-tailed)	.002	.774	.039	

VI. Performance Indicator Analysis

In order to get more information about the relationship between the different attributes, additional analysis was performed.

By transposing the data from Section V so that the dimensions are under review, the least important dimension is academic infrastructure (5% ± 2) and the most important dimension is teaching (28% ±11). Teaching and Program Sustainability shares a similar range for the Administrator group only (19% ± 15). See Table 15 below.

Table 15: Descriptive Statistics at the Attribute Level

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
FM	4	.1507	.0962	.0655	.2855
SM	4	.1175	.0481	.0747	.1817
AI	4	.0521	.0232	.0205	.0743
T	4	.2824	.1111	.1463	.4021
SL	4	.2012	.1061	.0464	.2723
PS	4	.1962	.1462	.1024	.4142

As implied by Figure 26 Students, Faculty and Employers follow a similar distribution. Administrators show a significantly different view (see Pearson correlations). Faculty Management and Program Sustainability are very important to administrators but not as important to the other groups. To test this difference (H0: The distributions of FM, SM, AI, T, SL and PS are the same across stakeholder groups), the related samples, Friedman's two way ANOVA by ranks test revealed a significance of .049. Therefore, the null hypothesis was rejected. The null hypothesis is not rejected if the Administrator group (actually one person) is excluded from the comparison.

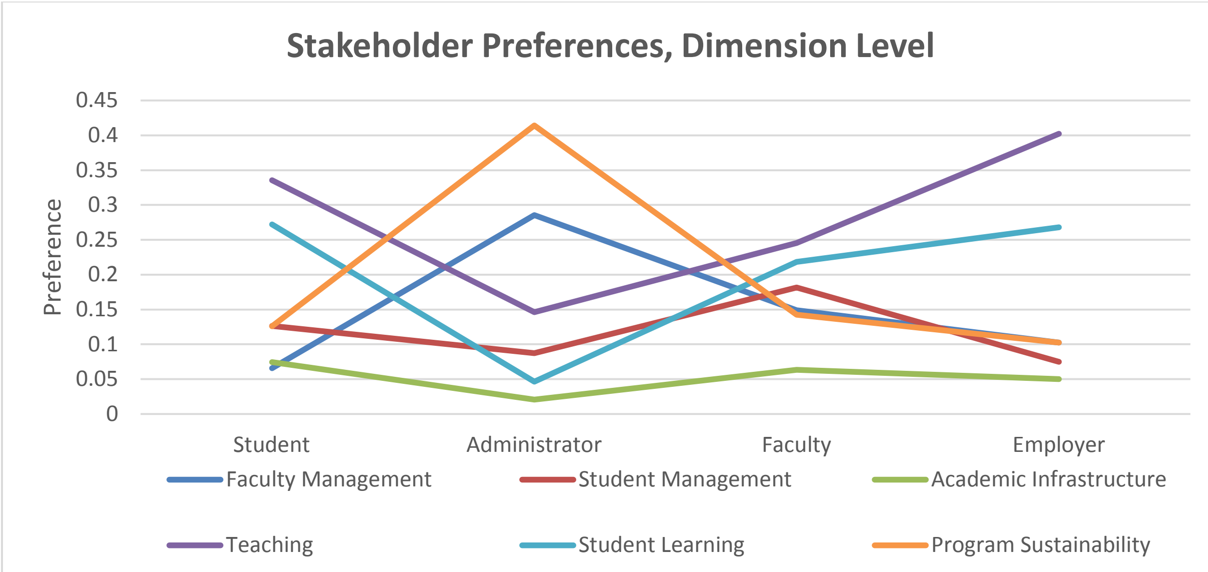


Figure 26: Dimension Level Preferences (by Stakeholders)

Table 16 shows the significant difference between each of pair of dimensions and the significance of the correlation coefficient. Four of 15 pairs revealed a significant difference in preferences- Student Management to Academic Infrastructure, Academic Infrastructure to Teaching, Academic Infrastructure to Student Learning and Teaching to Student Learning.

In addition, three of 15 pairs demonstrate a significant correlation- Faculty Management to Student Learning, Faculty Management to Program Sustainability and Student Learning to Program Sustainability. This implies that as the importance of faculty management increases, the importance of program sustainability increases. Conversely, as the importance of faculty management increases, the importance of student learning decreases and vice versa. The same negative relationship is present between the preferences given to Student Learning and Program Sustainability.

Similar analysis was conducted among the attributes. The distributions of each group are shown in Figure 27. The preference scale varies on each chart to better reflect the data therein.

Table 16: Dimension Level Paired Samples Significance & Correlation

Paired Samples Test

		Paired Differences					t	df	Sig. Diff (2-tailed)	Paired Samples Correlation	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					Pearson Correlation	Sig.
					Lower	Upper					
Pair 1	FM - SM	.0332000	.1161457	.0580729	-.1516138	.2180138	.572	3	.608	-0.208	0.792
Pair 2	FM - AI	.0986250	.1176427	.0588214	-.0885709	.2858209	1.677	3	.192	-0.908	0.092
Pair 3	FM - T	-.1317000	.2016089	.1008044	-.4525047	.1891047	-1.306	3	.283	-0.891	0.109
Pair 4	FM - SL	-.0504750	.2014754	.1007377	-.3710673	.2701173	-.501	3	.651	-0.985	0.015
Pair 5	FM - PS	-.0455250	.0631578	.0315789	-.1460232	.0549732	-1.442	3	.245	0.947	0.053
Pair 6	SM - AI	.0654250	.0394934	.0197467	.0025822	.1282678	3.313	3	.045	0.58	0.42
Pair 7	SM - T	-.1649000	.1288312	.0644156	-.3698992	.0400992	-2.560	3	.083	-0.18	0.82
Pair 8	SM - SL	-.0836750	.1057754	.0528877	-.2519872	.0846372	-1.582	3	.212	0.233	0.767
Pair 9	SM - PS	-.0787250	.1677801	.0838901	-.3457006	.1882506	-.938	3	.417	-0.316	0.684
Pair 10	AI – T	-.2303250	.0982407	.0491204	-.3866479	-.0740021	-4.689	3	.018	0.628	0.372
Pair 11	AI - SL	-.1491000	.0861836	.0430918	-.2862373	-.0119627	-3.460	3	.041	0.885	0.115
Pair 12	AI - PS	-.1441500	.1668656	.0834328	-.4096704	.1213704	-1.728	3	.182	-0.871	0.129
Pair 13	T – SL	.0812250	.0461568	.0230784	.0077792	.1546708	3.520	3	.039	0.911	0.089
Pair 14	T – PS	.0861750	.2493536	.1246768	-.3106022	.4829522	.691	3	.539	-0.875	0.125
Pair 15	SL - PS	.0049500	.2514721	.1257360	-.3951982	.4050982	.039	3	.971	-0.987	0.013

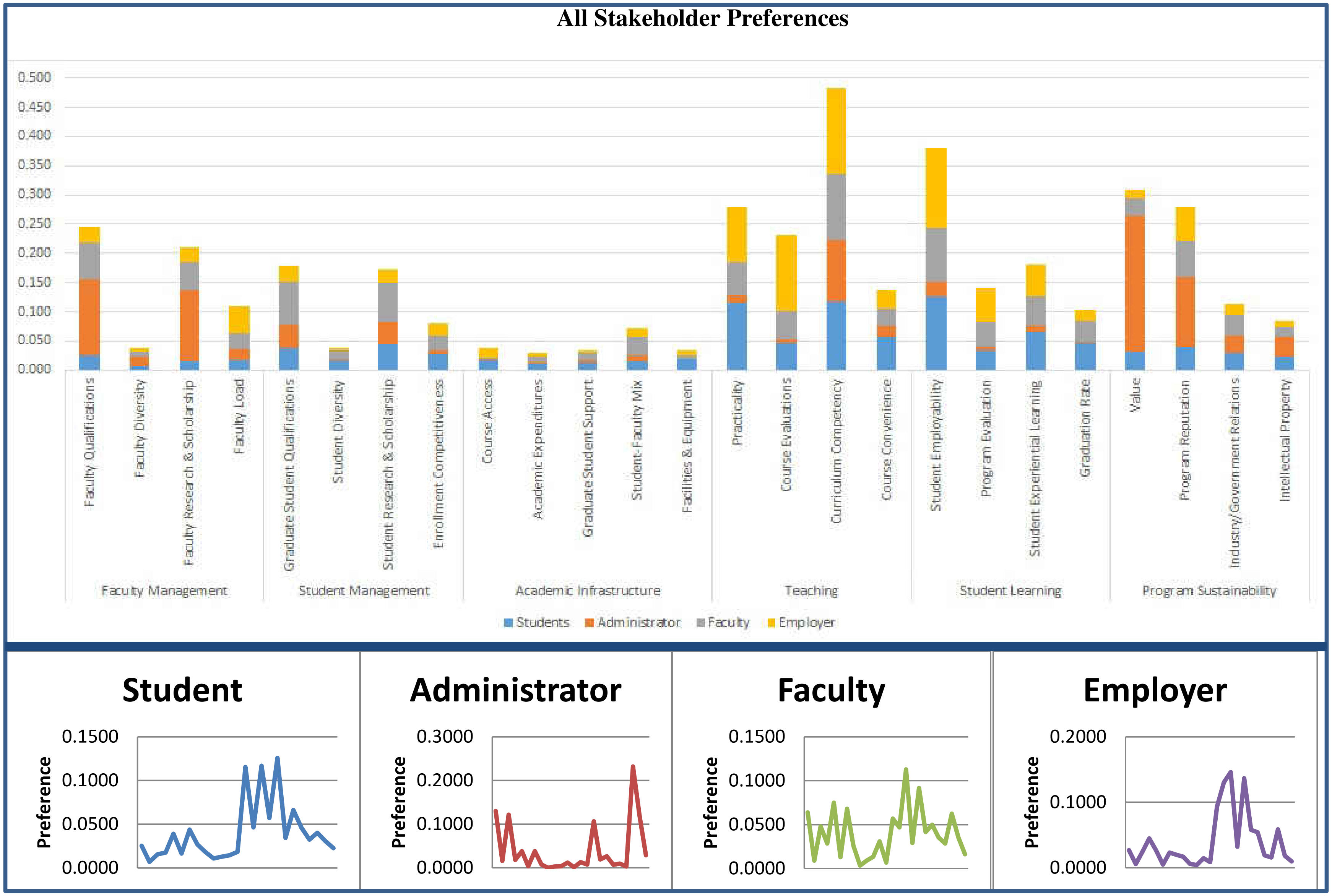


Figure 27: Preferences at the Attribute Level

These charts support the initial finding that there is a reasonable consensus across the groups that Teaching is a very important dimension. The administrator expressed more importance in some attributes within the Faculty Management and Program Sustainability dimensions than is apparent in other groups.

The overall spread of each group's preferences is shown in Table 17. The group with the greatest range, standard deviation, skewness and kurtosis is the Administrator.

Table 17: SAFE Descriptive Statistics (Attribute Level)

		Student	Administrator	Faculty	Employer	Composite
Descriptive Statistics	*N*	25	25	25	25	25
	Range	0.1187	0.2315	0.1094	0.1420	0.1134
	Minimum	0.0070	0.0004	0.0034	0.0041	0.0072
	Maximum	0.1257	0.2319	0.1129	0.1462	0.1207
	Mean	0.0400	0.0400	0.0400	0.0400	0.0400
	Std. Deviation	0.0335	0.0571	0.0279	0.0425	0.0298
	Variance	0.0010	0.0030	0.0010	0.0020	0.0009
	Skewness [std. error]	1.6560	2.0950	0.8640	1.5950	1.0241
		[0.464]	[0.464]	[0.464]	[0.464]	[0.464]
	Kurtosis [std. error]	1.9930	4.3750	0.5250	1.5080	0.7592
		[0.902]	[0.902]	[0.902]	[0.902]	[0.902]

To test the null hypothesis that the distributions of S, A, F, E are the same, the related samples, Friedman's two way ANOVA by ranks was used. The significance was .020. Therefore, the null hypothesis is rejected.

Since the data analysis implies that this may be due to the addition of the Administrator group, an additional null hypotheses were tested: H01- The distributions of Students, Faculty and Employer are the same (extracting the Administrator). When testing this alternate case, we do not reject H01 due to a significance of .326).

Next, the median difference between each pair of stakeholder groups was tested using the related samples, Wilcoxon Signed Rank Test. Specifically, the null hypothesis was that the median of difference between Stakeholder A and B is zero. All results were beyond .05, or sufficient to not reject H0. These results are featured in Table 18.

Table 18: P-values From Wilcoxon Signed Rank Test for SAFE

	Student	Administrator	Faculty	Employer
Student	1	.158	.989	.404
Administrator		1	.174	.427
Faculty			1	.554
Employer				1

The corresponding correlations (across stakeholder groups) are featured in Table 19. The results show that there is a positive and significant relationship between all stakeholder groups other than the administrator group.

Table 19: SAFE Correlations (Attribute Level)

	N=25	Student	Administrator	Faculty	Employer
Student	Pearson Correlation	1	.067	.758**	.833**
	Sig. (2-tailed)		.750	.000	.000
Administrator	Pearson Correlation	.067	1	.354	.073
	Sig. (2-tailed)	.750		.082	.730
Faculty	Pearson Correlation	.758**	.354	1	.743**
	Sig. (2-tailed)	.000	.082		.000
Employer	Pearson Correlation	.833**	.073	.743**	1
	Sig. (2-tailed)	.000	.730	.000	

Using preferences derived from the analysis, the performance indicators were initially limited from 25 to the ten most important. Table 20 lists these attributes given 2 group compositions, the composite SAFE group and a second group that does not consider administrators (SFE). In the first scenario, 69% of the preferences among all 25 is captured, versus only 53% when the administrators are removed.

Table 20: Top 10 Attributes

Rank	**SAFE (69%)**	**Removing Administrator (53%)**
1	Curriculum Competency (I)	Curriculum Competency (I)
2	Student Employability (O)	Student Employability (O)
3	Value (O)	Practicality (I)
4	Program Reputation (O)	Course Evaluations (O)
5	Practicality (I)	Student Experiential Learning (O)
6	Faculty Qualifications (I)	Program Reputation (O)
7	Course Evaluations (O)	Graduate Student Qualifications (I)
8	Faculty Research & Scholarship (O)	Student Research & Scholarship (O)
9	Student Experiential Learning (O)	Program Evaluation (O)
10	Graduate Student Qualifications (I)	Course Convenience (I)

Given the sample size and inconsistency concerns of the administrator group, there was an urge to delete this group from further inclusion in this process. Additional analysis was conducted to evaluate the ranking of the attributes among the different stakeholder groups to assist in this decision.

Figure 28 shows the ranking of the attributes for each stakeholder group, the composite group (SAFE) and all groups excluding the administrator group (SFE). The SAFE preferences ensures that at least 1 attribute is present from each dimension, with the exception of academic infrastructure. Curriculum Competency and Student Employability remain most important to both groups. One notation is warranted in that Students, Faculty and Employers place all attributes of Teaching in the Top 10. Three of four attributes of Student Learning are also present. In addition to the absence of attributes in the Academic Infrastructure dimension, the SFE group also does not view aspects of Faculty Management among the Top 10.

	Student	Administrator	Faculty	Employer	SAFE	SFE
Faculty Management						
Faculty Qualifications	15	2	5	10	6	11
Faculty Diversity	25	13	23	23	22	25
Faculty Research & Scholarship	21	3	9	12	8	14
Faculty Load	19	12	17	8	15	13
Student Management						
Graduate Student Qualifications	10	6	3	11	10	7
Student Diversity	20	20	21	24	21	21
Student Research & Scholarship	8	6	4	13	11	8
Enrollment Competitiveness	14	18	18	14	18	17
Academic Infrastructure						
Course Access	18	25	25	17	20	20
Academic Expenditures	24	22	22	22	25	24
Graduate Student Support	23	21	20	25	24	23
Student-Faculty Mix	22	15	14	19	19	18
Facilities & Equipment	17	24	24	21	23	22
Teaching						
Practicality	3	14	7	4	5	3
Course Evaluations	6	17	10	3	7	4
Curriculum Competency	2	5	1	1	1	1
Course Convenience	5	11	15	9	13	10
Student Learning						
Student Employability	1	10	2	2	2	2
Program Evaluation	11	19	11	6	12	9
Student Experiential Learning	4	16	8	7	9	5
Graduation Rate	7	23	13	15	16	12
Program Sustainability						
Value	12	1	16	18	3	16
Program Reputation	9	4	6	5	4	6
Industry/Government Relations	13	9	12	16	14	15
Intellectual Property	16	8	19	20	17	19

Figure 28: Stakeholder Group Ranking

Figure 29 shows stakeholder rankings for the Faculty Management Dimension. The greatest difference is between Students and Administrators. In general, administrators rank the attributes of this dimension higher than other groups with the exception of faculty load. The least important attribute to all groups is faculty diversity, although administrators rank this factor as number 13 compared to an average of about 24 for the other group compositions.

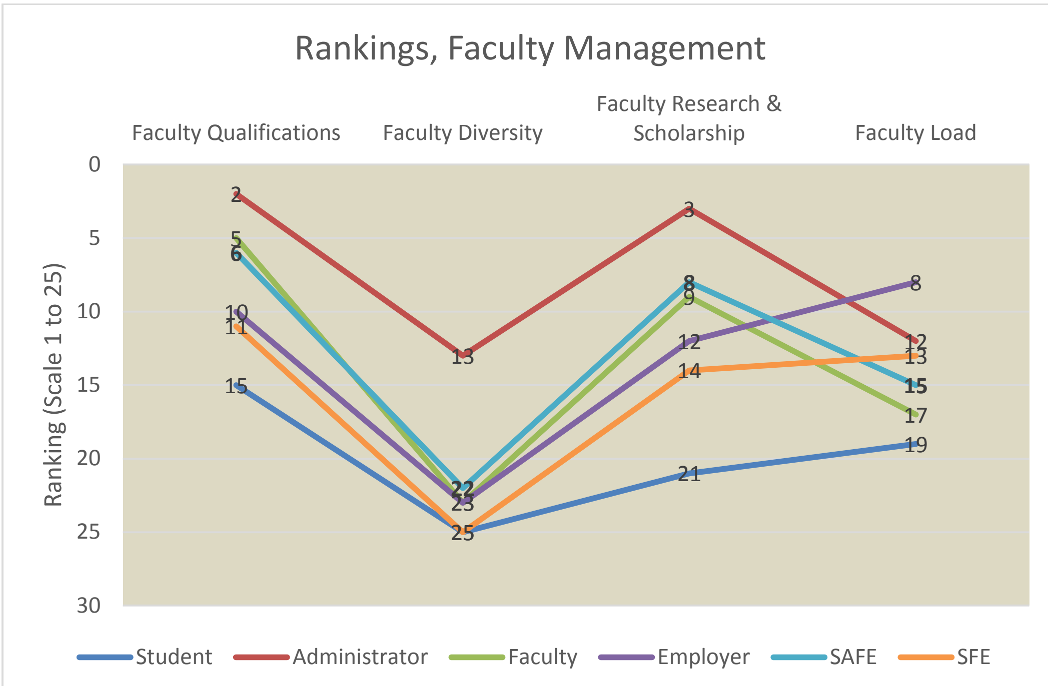


Figure 29: Group Rankings, Faculty Management

Figure 30 shows stakeholder rankings for the Student Management dimension. All groups follow a similar pattern with the lowest ranked attribute being student diversity. This attribute shows a small dispersion (numbers 20-24) similar to that of Enrollment Competitiveness, which reveals rankings from 14-18. More variation is present for the Graduate Student Qualifications and Student Research and Scholarship attributes.

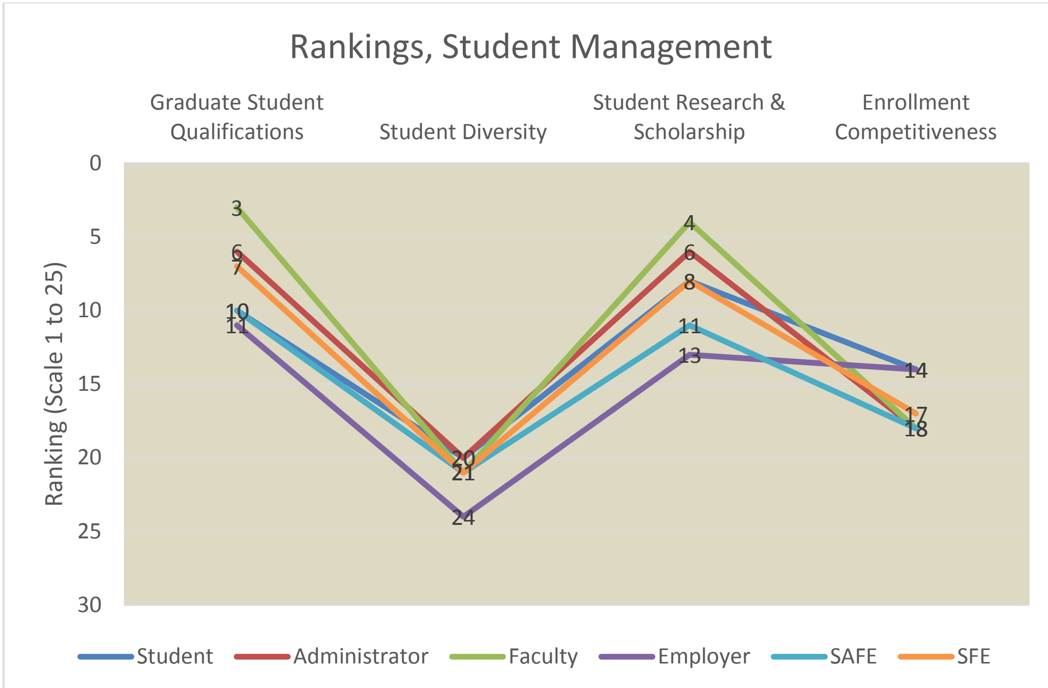


Figure 30: Group Rankings, Student Management

The next figure (Figure 31) shows the stakeholder group rankings for Academic Infrastructure. All attributes rank fairly low and all groups are somewhat similar.

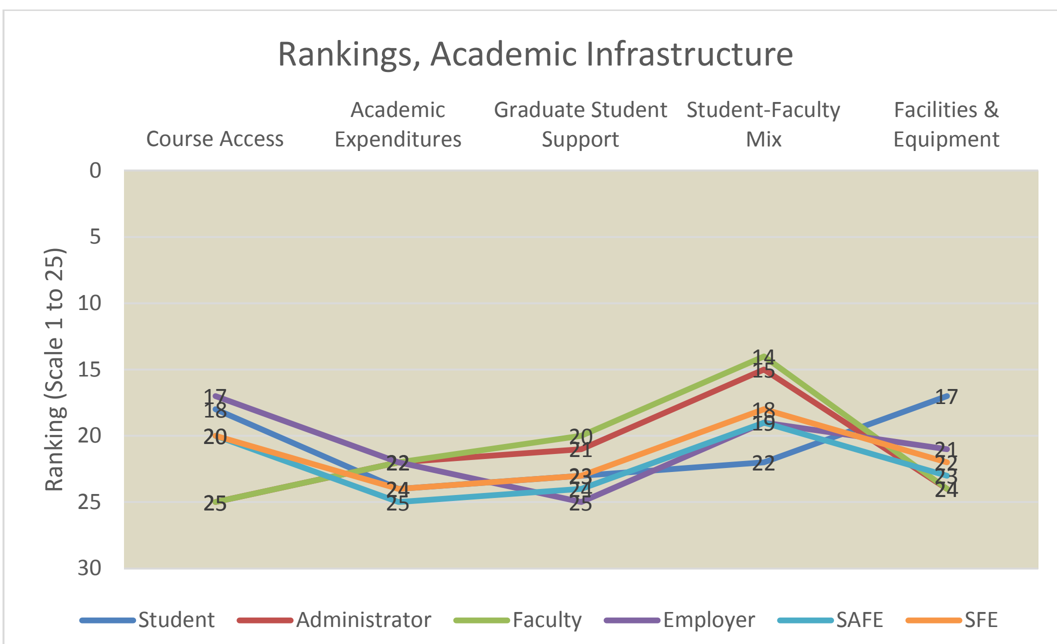


Figure 31: Group Rankings, Academic Infrastructure

Additionally, Figure 32 shows that there is a wide range of variation present within the Teaching Dimension. Practicality and Course Evaluations rank in the top 10 for all groups with the exception of Administrators, which expressed lower ranks of number 14 and number 17 respectively. However, Curriculum Competency exhibits a small dispersion as it ranks in the top 5 for all groups.

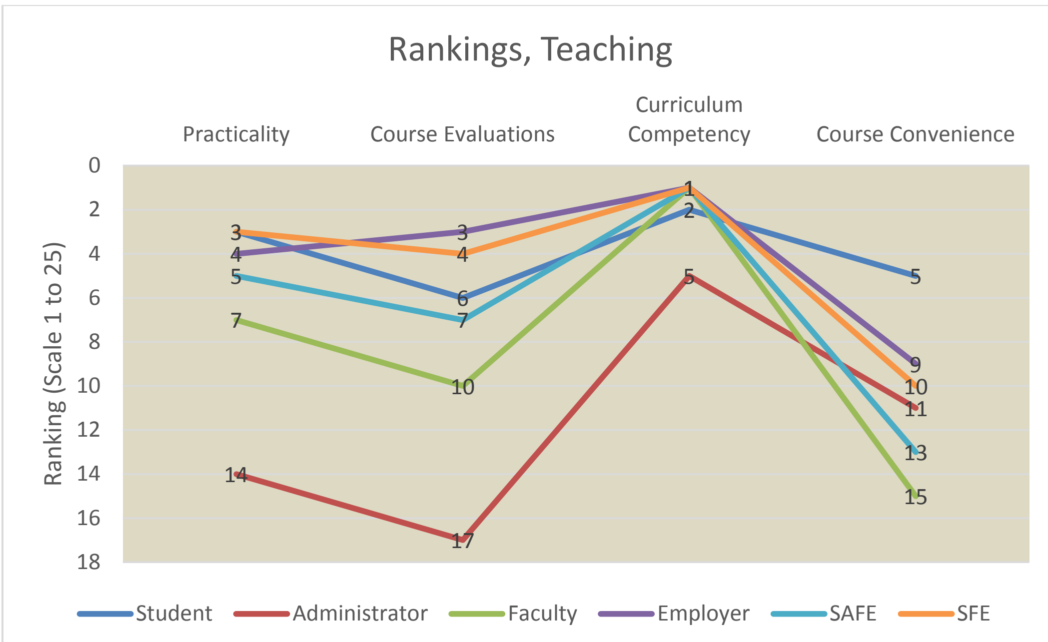


Figure 32: Group Rankings, Teaching

The next dimension, Student Learning, is captured in Figure 33. It shows that Administrators rate all the attributes lower than all other stakeholder groups. Student Employability is most important to all other stakeholder groups, ranging from number 1 to 2. The variation for Program Evaluation, Student Experiential and Graduation Rate and relatively small when excluding administrators, although graduation rate is vastly more important to students than all other groups.

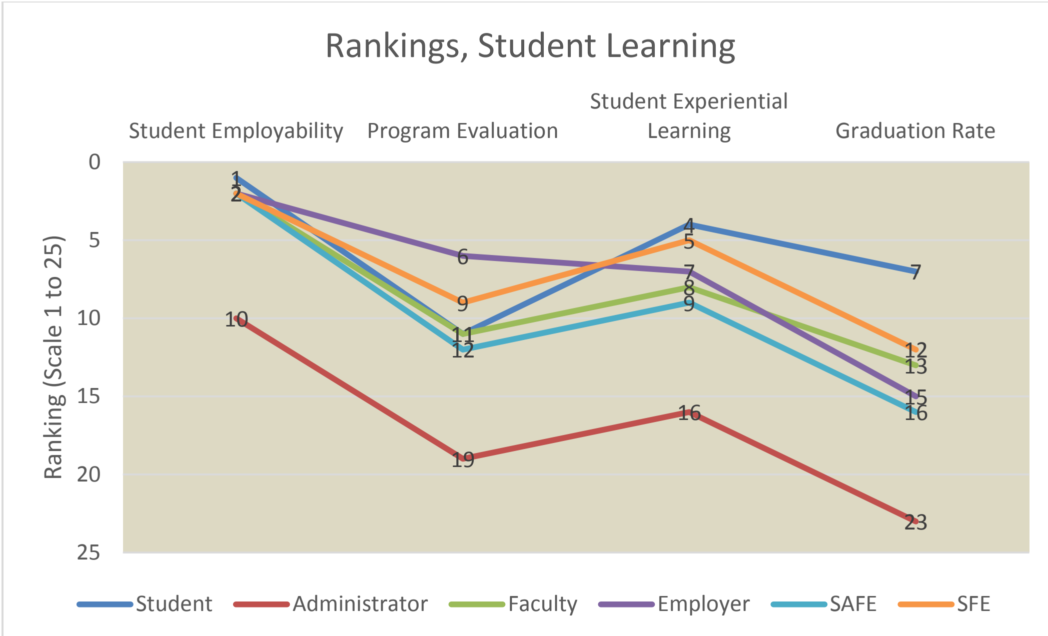


Figure 33: Group Rankings, Student Learning

In Figure 34 the stakeholder rankings for Program Sustainability are captured. Administrator rate all attributes in this dimension higher than or equal to other groups. Value demonstrates the greatest range. Administrators rank this attribute as most important among all factors (number 1), while Employers ranking it eighteenth. Program Reputation and Industry/Government Relations are more closely ranked among the groups but the variation increases in consideration of Intellectual Property.

A pattern seems to exist in this dimension. Program Reputation is more important than Industry/Government Relations, which is more important than Intellectual Property. One exception applies as Intellectual Property is slightly more important than Industry/Government Relations for Administrators (number 8 versus 9).

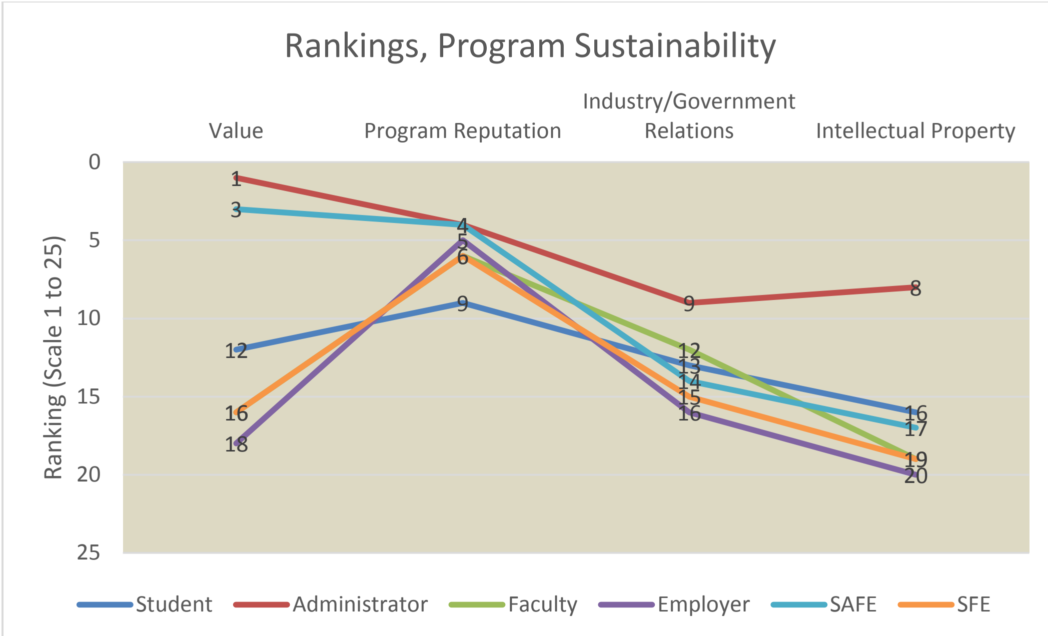


Figure 34: Group Rankings, Program Sustainability

Overall, most groups follow a similar pattern for each dimension of quality as implied by earlier analysis of results. Although the administrator groups seems to be an exception in many cases, there are several instances where their values align. This result may be due to sample size, the inconsistency in responses or to the true values and concerns of administrators. Yet, given the very similar distribution of the remaining groups and their heavy concentration on inputs, continued consideration of this group supports the premise of capturing competing needs.

Next, the number of key performance indicators to integrate into data envelopment analysis was dependent of the final combination of inputs and outputs. Since the decision was made to evaluate 4 departments over a period of 6 years, the limiting value is 24 DMUs. Recall that the product of the number of inputs and the number of outputs reveals the recommended maximum number of DMUs under consideration. Also recall the competing notion that three times the sum of inputs and outputs is the maximum number of DMUs that should be considered. In this dissertation, both views will be accepted.

Table 21 shows the number of inputs and outputs present in each scenario between the top 6-10 performance indicators. These values are based on the results shown in Figure 28 for the SAFE group. Being cognizant of data availability and the IO constraints of the DEA approach, the options were reduced to 6-8 IOs because these combinations meet the criteria for less than or equal to 24 DMUs. Although each are expected to result in sufficient discriminatory power, 8 IOs is at the limit of discriminatory power. By selecting to include only 7 indicators, both recommended constraints were withheld, and reasonable discriminatory power was expected.

Table 21: Discriminatory Power & Representation Estimates

N **%PREF**	**10** **(69%)**	**9** **(65%)**	**8** **(60%)**	**7** **(55%)**	**6** **(49%)**
INPUTS	4	3	3	3	3
OUTPUTS	6	6	5	4	3
I X O	24	21	15	12	9
3 X (I + O)	30	27	24	21	18

Figure 35 captures the essence of the quality model and highlights the top 7 attributes in green. It features the same content as the hierarchical form, although it organizes the attributes as either inputs or outputs. The arrows show that there is a two way relationship between the inputs and outputs of the model.

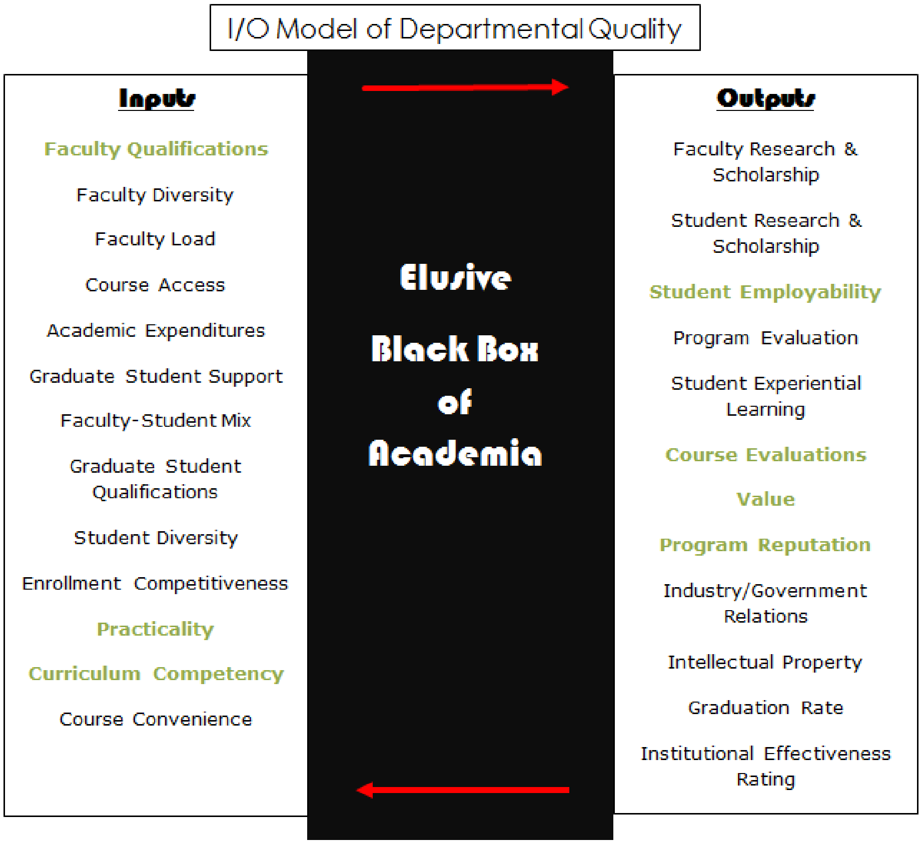


Figure 35: I/O Model of Departmental Quality

VII. Metrics Development

Available resources were explored throughout the University. Data requests were submitted to several offices to determine whether the target data was available and at what level of aggregation. Collecting historical data at the department level proved very difficult for many of the variables included in the model. In some cases it was necessary to assign alternative measures or proxies of the metric for the purpose of this analysis. However, best effort was taken to ensure the objectivity of the measures selected.

Table 22 captures all metrics that were requested from various data sources for the seven selected inputs and outputs. All sources contacted to provide data are listed, but the source of the data used is denoted explicitly. The definition of the attribute is shown and all metrics requested are identified as either the metric used or the alternative or proxy measures requested. The data was requested over 6 years, 2007-2012 with a minimum increment of 1 year. The definition of one year was accepted as a calendar year or a school term, dependent on how the data was tracked.

Table 22: Data Requested from Various Sources

Attribute (I/O) (Data Sources Sought/Data Source Used)	**Definition**	**All Data Requested at the Department Level per year unless otherwise stated** Metric Used / Alternative/Proxy Metric
Faculty Qualifications (I) (Office of Institutional Research)	Academic credentials of faculty	Total # of Part Time or Full Time tenure or tenure earning faculty of all types excluding lecturers and adjuncts/ (# PT/FT lecturers + # adjuncts)
Student Employability (I) (Alumni Association Survey/CECS Alumni Survey/ CECS Graduating Students Survey)	Students ability to secure "employment" post-graduation	Percentage of alumni employed or attending graduate school within # year of graduation (# selected arbitrarily based on data available)
		Percentage of Undergraduate/Graduate students with a job or graduate school offer at graduation
Practicality (I) (Online Curriculum Vitae/ CECS Conflict of Interest Reports)	Experiential context of curriculum and teaching	% of faculty (among all faculty, lecturer or instructor types) with FT industry experience of ≥ 1 year
		% of faculty reporting active external UCF consulting work
		Proxy: % of faculty (among all faculty, lecturer or instructor types) with a PE License
Course Evaluations (O) (CECS End of Course Survey)	Comprehensive course evaluation provided by enrolled students	Average end of course, course evaluation rating by students by program for department (All Undergraduate & Graduate Courses Combined)/Avg. course evaluation rating for the College

Attribute (I/O) (Data Sources Sought/Data Source Used)	Definition	All Data Requested at the Department Level per year unless otherwise stated Metric Used Alternative/Proxy Metric
		Average end of course, course evaluation rating by students by instructor (All Undergraduate/ Graduate Courses Combined)/Avg. course evaluation rating for the College
Curriculum Competency (O) (CECS Course Action Requests, Course Catalog)	Relevancy of the program content to the field	Number of years since last major curriculum revision (Note: "Major" denotes a formal process of identifying gaps in the curriculum and making adjustments- i.e. adding/deleting classes, restructuring classes, changing the scope of classes like the topics taught for example)
		Proportion of Course Action Requests to the number of courses offered in the course catalog
		Proxy: % of faculty attending a professional conference (among all faculty, lecturer or instructor types)
		Proxy: # of different professional conferences at least 1 faculty attended
Value (Student Accounts/ Financial Aid/ Graduate Studies/ Office of Institutional Research/CECS)	Overall program affordability to its students	Avg. student (stated) costs per credit hour per program including any fees to take the specific course.
		Avg. student loan debt at graduation (Undergraduate, Masters, or Doctoral, or collective) among all graduating students (with or without loans)
		Avg. student costs per credit hour per program after fellowships and assistantships
		National average of program (stated) cost per credit hour per program
		Proxy: Proportion of graduate students with a fellowship, assistantship or center appointment to number of graduate students calculated by headcount
Program Reputation	National reputation of program	US News & World Report Rank by graduate program (averaged for instances of multiple

Attribute (I/O) (Data Sources Sought/Data Source Used)	Definition	All Data Requested at the Department Level per year unless otherwise stated Metric Used Alternative/Proxy Metric
(Library- USNWR Annual Graduate Program Rankings Report, USNWR Website, CECS)		ranked programs in a department) / # schools ranked in respective USNWR category
		US News & World Report Rank by undergraduate program (averaged for instances of multiple ranked programs in a department) /# schools ranked in respective USNWR category
		Avg. US News & World Report Scores by graduate program per department *(Note: Not ranking)*

Therefore, the final metrics were:

(1) Curriculum Competency- *Proportion of course action requests from the year prior to the number of courses offered by department.* This measure represents a quadratic metric based on the assumption that too little change in the curriculum implied stagnation, while too much change implied instability in the curriculum. In an attempt to account for this assumption, 3 categories were developed- Stagnation or Instability (1) and Evolutionary Change- Low (2) or High (3). Stagnation was defined as less than 5% courses with changes in the curriculum, while instability was defined as greater than 30% change in the department's courses. The remaining ranges were the categories of evolutionary change, 2 ($5\% \leq$ ratio $< 15\%$) and 3 ($15\% \leq$ ratio $< 30\%$) respectively. This categorical measure indicates that stagnation or instability are undesirable. On the other hand, most Course Action Requests (CARs) are of a relatively cosmetic nature and a fairly high proportion of them (15 to 30%) increase the odds that some requests are new courses or substantial changes to existing courses, thus important to keep the curriculum up to date with science and technology.

Metric Limitation- The use of CARs to capture the relevancy of the program's content to the field may not be the best available measure. Further insight about the nature of each CAR would limit the measure to substantial, relevant changes in the curriculum such as course additions, course content changes and other non-administrative changes. Still, the assumption that changes in the curriculum imply that the department is continuously aligning with the current state of the field may be unfounded.

(2) Faculty Qualifications- *The percent of tenure/tenure-track and visiting faculty to all instructor types (including instructor, adjunct, and lecturer).* While this may be disputed as a fair measure of quality, the presence of a large proportion of full-time faculty in a department implies the availability of faculty for additional duties, academia experience, a commitment to the program, and general alignment of the faculty with the goals and mission of the institution. This measure is not to imply that tenure/tenure track or visiting faculty is more suited than other faculty types for teaching responsibilities.

Metric Limitation- The goal of this metric is to capture the academic credentials of faculty. Credentials refer to evidence that the faculty can perform teaching, research, service and scholarship in the field. Tenure and promotion are awarded at different stages of a faculty's career but represents demonstration of competent performance. Although use of tenure earning faculty in this metric may seem acceptable, some transparency may be lost in the role of such faculty.

(3) Practicality- *The percent of faculty reporting consulting experience on the annual conflict of interest report.* Several measures were considered for this indicator including the number of faculty with an active PE license. This alternative was not available over the time period of analysis and the annual change was assumed near negligible. However, current consulting experience shows that the instructor is active in the applied field in addition to his or her duties as an instructor, and that external actors value their expertise.

Metric Limitation- The goal of this metric was to capture the experiential context of the curriculum and teaching. While consulting experience is assumed to increase the practicality injected into course lessons, this measure is concerned with only consulting external to the University. It is also assumed to be positively linear, although too much external consulting could easily degrade the commitment of faculty to the University.

(4) Program Reputation- *Annual U.S. News & World Report score calculated based on graduate specialty rankings from one year prior.* Because this metric is collected at the program level and was not available for all programs within each department, the average for all ranked programs within a department was calculated and deemed acceptable. The USNWR scoring methodology for graduate engineering programs by field range between 0 and 5 although the CECS scores range from 2-4.

Metric Limitation- The goal of this measure is the capture the national reputation of the department's programs. It is dependent on USNWR reporting and only captures the reputation of the graduate engineering programs. Undergraduate specialty program are currently tracked by USNWR, although the results of the assessment are not available annually.

(5) Student Employability- *Percent of graduating students (Undergraduate/Graduate) reporting a job offer or graduate school at time of graduation survey.* The graduation survey is completed early in the semester of graduation therefore, the results may be slightly lower than the actual number of students employed at time of graduation. Yet, two years of data from the CECS graduation surveys were deemed acceptable for the purposes of this analysis. This data was representative of different time periods so was treated to ensure the data was more comparable.

Metric Limitation- The goal was to obtain data that captures employment or acceptance to graduate school rates post-graduation (at some arbitrary time). Reliable data was not available as the employment data was deemed not representative of the population by data sources due to very small sample sizes. Therefore, data was gathered from student graduation surveys which may be disseminated too early in the process to know with confidence whether or not a student will have a job or further their education.

(6) Value- *Percent of graduate students with an appointment as a fellow, graduate assistant, or center appointments.* This is a proxy measure of Value, assuming this form of support reduces the amount of out-of pocket cost the student accrues, thus the amount of student loans received. In an article in the Central Florida Future, the author referenced a ranking system where Value was assessed based on a number of factors including the amount of student loan debt students

had at graduation from the university (Hitzing, 2013). As student loan debt data becomes available at the department level, this data would be substituted into the model.

Metric Limitation- The goal of the metric is to capture the value of a department's programs to its students; how much is a student willing to pay for their education? Unfortunately, a failure to acquire student loan data resulted in using a variable that could be an input or output metric to capture this output variable. For example, the percent of students with an appointment, fellowship or assistantship can be viewed as a metric within the direct control of departments (input). Yet, this metric could also be the result of other inputs in the model. For example, faculty/students demonstrating research productivity could in turn, increase opportunities to support additional students (output). This ambiguity complicates the interpretation of DEA results and is dependent on the stakeholder view considered and the part of the higher education process being considered.

(7) Course Evaluations- *Average course evaluation rating of the department.* Every end of course survey in CECS asks students to measure the 'Overall Assessment of Instructor'. The results are captured using departmental and college averages. In this case, the departmental average measure was used to capture this variable. The selected metric is summarized on a scale from 1 to 5, although all CECS values seem close to 4.

Metric Limitation- The goal of this metric was to capture comprehensive course evaluations provided by students enrolled in the program's courses. The risk lies in whether the survey is completed in a fair and accurate manner and whether the student's perspective is skewed by their performance in the course.

Table 23 depicts the DMU data collected. All available data was used and any missing data was defined as the average of available data. The number of observations, k, varies slightly per indicator. The only variable based completely on historical data is Faculty Qualifications. This information was available for the past 6 years. Student Employability was only available for 2 years. By employing k=2, four data points were derived using the data's average to complete the sample. This was a special case variable, where 1 year of Student Employability data captured information about graduates in the fall and spring semesters (2011), while the 2012 data covered only spring. To combat this issue, the percent of students with a job offer or an accepted graduate school application was first calculated. This percent was then averaged to represent the missing values.

Similarly, k=4 for Value and k=3 for Course Evaluations and Practicality. Further details including some raw data is featured in Appendix R.

Table 23: Derived DMU Data

	Inputs			Outputs			
ID	Curriculum Competency	Faculty Qualifications	Practicality	Program Reputation	Value	Student Employability	Course Evaluations
CECE, 07	3	0.677	0.226	2.22	0.363	0.696	3.98
CECE, 08	3	0.514	0.200	2.24	0.366	0.696	3.98
CECE, 09	1	0.471	0.206	2.25	0.320	0.696	3.98
CECE, 10	1	0.613	0.194	2.25	0.279	0.696	3.94
CECE, 11	1	0.541	0.243	2.15	0.237	0.642	3.92
CECE, 12	1	0.513	0.154	2.30	0.322	0.750	4.09
EECS, 07	1	0.756	0.128	2.60	0.412	0.811	3.86
EECS, 08	1	0.727	0.130	2.70	0.395	0.811	3.86
EECS, 09	2	0.639	0.120	2.45	0.358	0.811	3.86
EECS, 10	3	0.667	0.115	2.47	0.331	0.811	3.68
EECS, 11	3	0.962	0.170	2.43	0.340	0.896	3.89
EECS, 12	1	0.743	0.162	2.47	0.291	0.727	4.00
IEMS, 07	1	0.875	0.125	2.27	0.103	0.838	3.79
IEMS, 08	1	0.826	0.130	2.38	0.104	0.838	3.79
IEMS, 09	1	0.696	0.130	2.30	0.066	0.838	3.79
IEMS, 10	1	0.667	0.125	2.30	0.084	0.838	3.79
IEMS, 11	2	0.727	0.136	2.10	0.064	0.843	3.72
IEMS, 12	3	0.750	0.150	2.80	0.071	0.833	3.86
MSMAE, 07	3	0.723	0.078	2.09	0.486	0.692	3.63
MSMAE, 08	2	0.702	0.078	2.11	0.515	0.692	3.62
MSMAE, 09	3	0.667	0.081	2.10	0.442	0.692	3.63
MSMAE, 10	2	0.500	0.100	2.10	0.451	0.692	3.63
MSMAE, 11	2	0.600	0.050	2.05	0.467	0.784	3.59
MSMAE, 12	3	0.585	0.094	2.20	0.123	0.600	3.68

Table 24 follows with a summation of the DMU data highlighting range, mean, variation and the distribution properties (symmetry and flatness) for all variables except Curriculum Competency, a categorical (ordinal) variable. Clearly, the KPIs are defined such that high values are desirable. Detailed descriptive statistics for the DMU data is located in Appendix S.

Table 24: Descriptive Statistics of Key Performance Indicators

	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
Curriculum Competency	1.000	3.000				
Faculty Qualifications	.471	.962	.673	.120	.358	.249
Program Reputation	2.050	2.800	2.305	.199	.934	.419
Practicality	.050	.240	.139	.049	.427	-.233
Value	.064	.515	.291	.149	-.363	-1.221
Student Employability	.600	.896	.759	.078	-.183	-1.066
Course Evaluations	3.590	4.090	3.815	.143	.014	-1.041

Figure 37 shows the number of instances a department is classified in each Curriculum Competency category- Stagnant, Low, Desirable and Unstable. IEMS exhibits the most stagnant curriculum with 4 of 6 years within this category. In contrast, EECS appear unstable in 3 of 6 years. MMAE represent low curriculum competency 3 of 6 years. Fortunately, each DMU appeared in the Desirable range a minimal of one year (CECE- 2, EECS- 2, IEMS- 1, MMAE- 3). Additional information may be gained by analyzing raw data in Appendix R.

Figures 38 and 39 summarize the quantitative information in boxplot form showing all percent-based KPIs initially (Figure 38) and then Program Reputation and Course Evaluations in the figure 39. Like the first set of variables, the last two measures also share a similar scale.

Table 25 captures the correlation between each of the key performance indicators. Note that some very interesting implications of variable relationships are represented in this table. There were very few significant correlations among the KPIs: Program Reputation and Student Employability; Faculty Qualifications and Student Employability; and Course Evaluation and Practicality are significantly correlated pairs at $\alpha = 0.01$. Practicality and Course Evaluations exhibited the highest level of correlation (.833) at a significance level of $\alpha = .01$. It seems that students appreciate faculty with good academic credentials who relate their practical experience to the material being taught. As expected, a good reputation and qualified faculty enhances student employability.

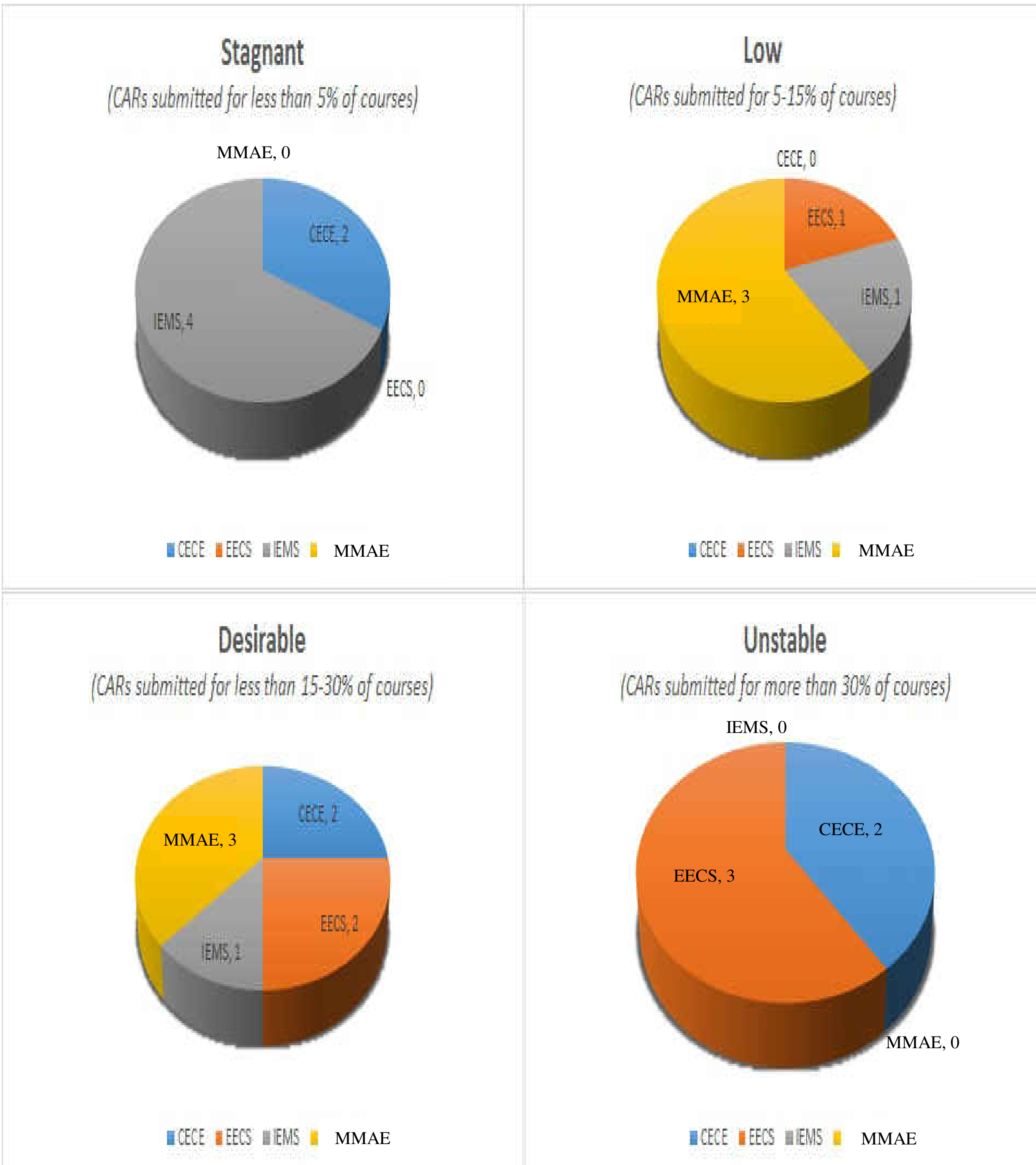


Figure 36: Number of DMUs in Curriculum Competency Categories

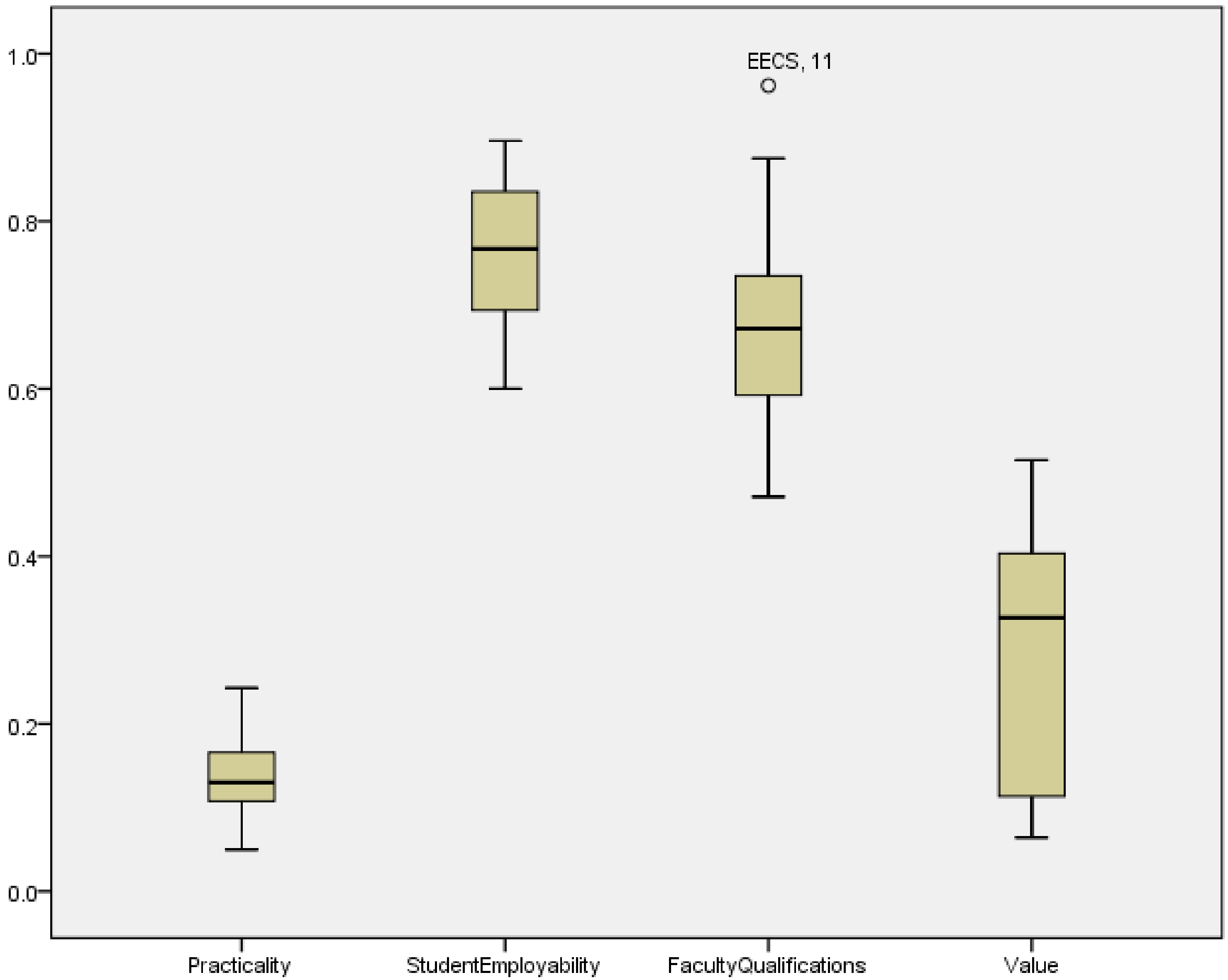


Figure 37: Box Plot of Proportion-based DMU Data

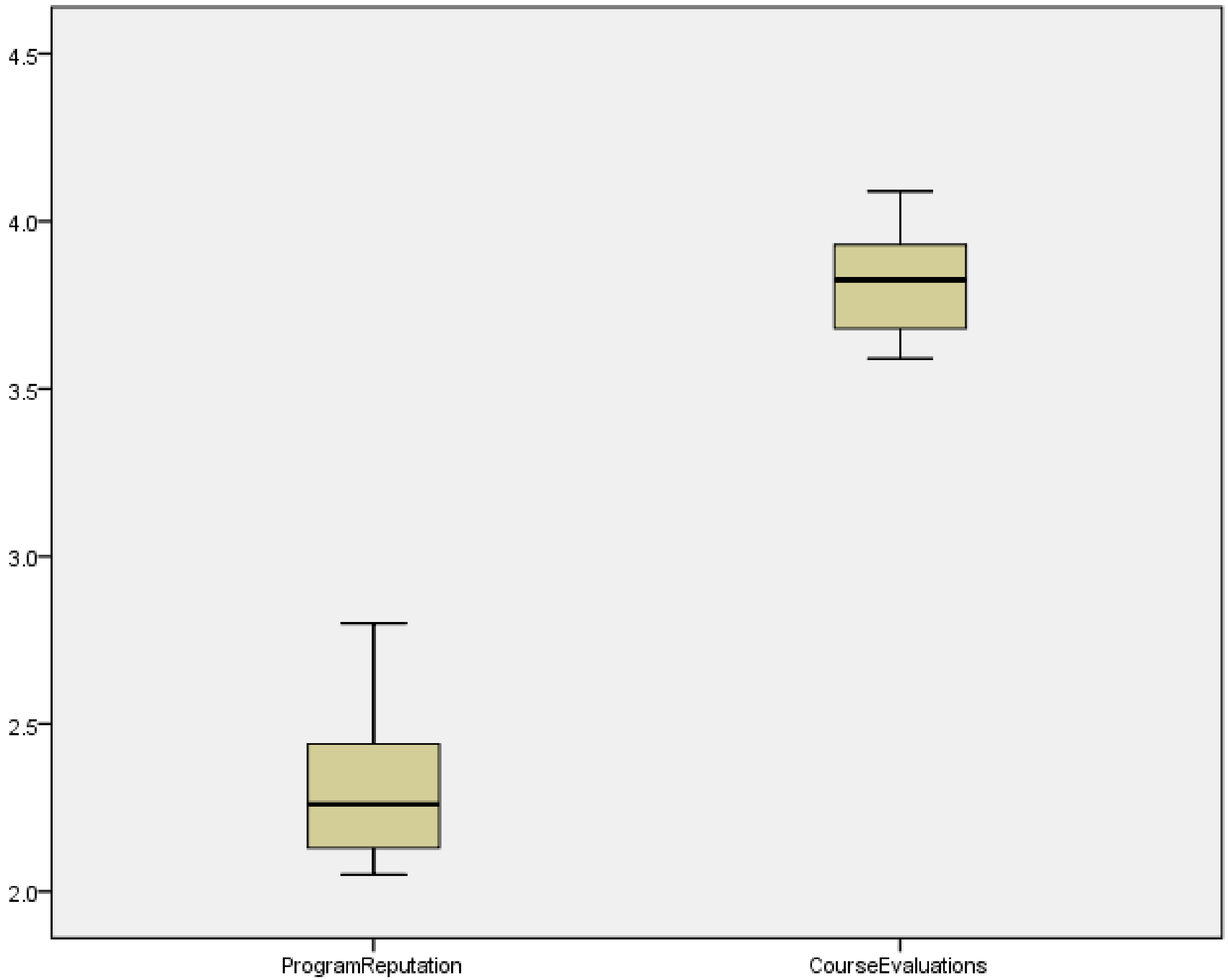


Figure 38: Box Plot for Program Reputation and Student Evaluation DMU Data

Table 25: KPI Correlations

Correlations

**. Correlation is significant at the 0.01 level (2-tailed).

		Curriculum Competency	Faculty Qualifications	Practicality	Program Reputation	Value	Student Employability	Course Evaluations
Curriculum Competency	Pearson Correlation	1	.054	-.194	-.122	.254	-.179	-.349
	Sig. (2-tailed)		.802	.363	.570	.231	.402	.094
	N	24	24	24	24	24	24	24
Faculty Qualifications	Pearson Correlation	.054	1	-.171	.386	-.237	.664**	-.123
	Sig. (2-tailed)	.802		.423	.062	.265	.000	.567
	N	24	24	24	24	24	24	24
Practicality	Pearson Correlation	-.194	-.171	1	.170	-.221	-.142	.833**
	Sig. (2-tailed)	.363	.423		.428	.299	.509	.000
	N	24	24	24	24	24	24	24
Program Reputation	Pearson Correlation	-.122	.386	.170	1	-.218	.515**	.401
	Sig. (2-tailed)	.570	.062	.428		.306	.010	.052
	N	24	24	24	24	24	24	24
Value	Pearson Correlation	.254	-.237	-.221	-.218	1	-.362	-.164
	Sig. (2-tailed)	.231	.265	.299	.306		.082	.442
	N	24	24	24	24	24	24	24
Student Employability	Pearson Correlation	-.179	.664**	-.142	.515**	-.362	1	.016
	Sig. (2-tailed)	.402	.000	.509	.010	.082		.942
	N	24	24	24	24	24	24	24
Course Evaluations	Pearson Correlation	-.349	-.123	.833**	.401	-.164	.016	1
	Sig. (2-tailed)	.094	.567	.000	.052	.442	.942	
	N	24	24	24	24	24	24	24

VIII. Data Envelopment Analysis Hierarchy Process (DEAHP)

Preceding aspects of the methodology enabled the identification of 3 key inputs and 4 key outputs of higher education from the SAFE perspective. Figure 39 features the DEAHP model as 3 inputs entering the education system, interacting with the system to produce 4 outputs. Using the limited scope of the College of Engineering & Computer Science at UCF and data from its 4 departments over 6 years, data envelopment analysis was performed. The summary reports for each DMU are included in Appendices T.

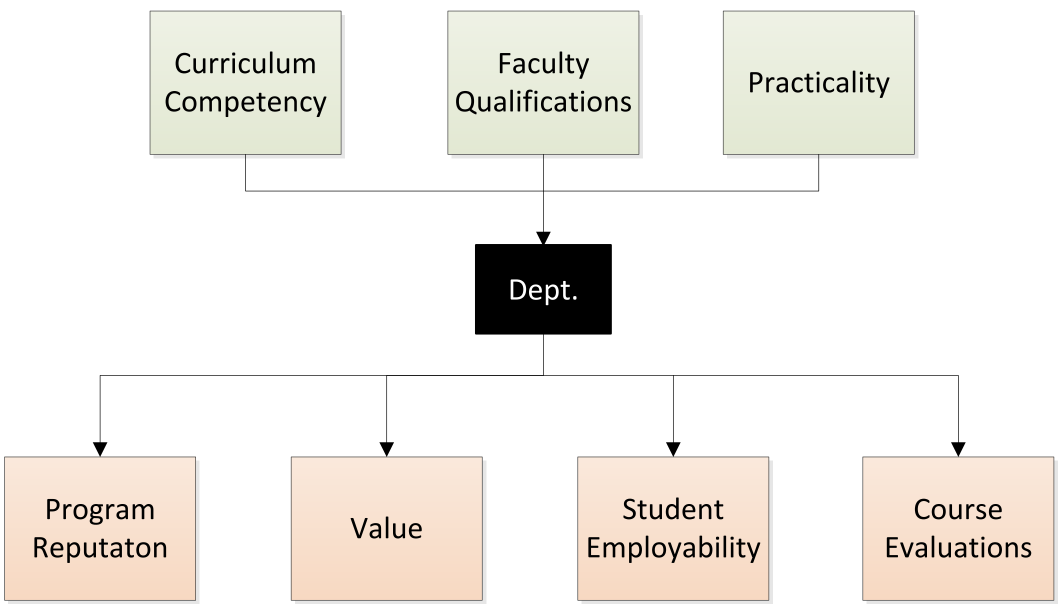


Figure 39: DEAHP Model

Table 26 shows the calculated efficiencies for each DMU. The colored formatting schema represents Efficient Departments (Green), Inefficient- Minimal Improvement (Yellow) and Inefficient- Major Improvement (Red). The ranges were arbitrarily selected, where Green represents an efficiency score of 100% and all slack variables equal zero, where applicable. Yellow represents efficiency scores from 90% to 100% if there is slack present and Red denotes any efficiency score below 90%.

Results are shown for the constant returns to scale (CCR) analysis as well as variable returns to scale (BCC). Under CCR, there were 12 efficient DMUs. The values ranged from about 68% efficient to 100% efficient. By adding flexibility to the model using the BCC approach, 16 units were identified as efficient but more interestingly all DMUs were evaluated as being close to one.

Table 26: DMU Efficiency by Department

	CCR	BCC
CECE, 07	73.60%	99.87%
CECE, 08	95.50%	100.00%
CECE, 09	100.00%	100.00%
CECE, 10	96.80%	96.80%
CECE, 11	96.00%	95.97%
CECE, 12	100.00%	100.00%
EECS, 07	100.00%	100.00%
EECS, 08	100.00%	100.00%
EECS, 09	95.70%	100.00%
EECS, 10	92.20%	99.96%
EECS, 11	67.80%	100.00%
EECS, 12	100.00%	100.00%
IEMS, 07	100.00%	100.00%
IEMS, 08	100.00%	100.00%
IEMS, 09	100.00%	100.00%
IEMS, 10	100.00%	100.00%
IEMS, 11	83.90%	99.19%
IEMS, 12	88.90%	100.00%
MMAE, 07	83.50%	99.37%
MMAE, 08	100.00%	100.00%
MMAE, 09	85.60%	98.08%
MMAE, 10	100.00%	100.00%
MMAE, 11	100.00%	100.00%
MMAE, 12	95.50%	98.82%
# Efficient	12	16

The sum of efficient DMUs using both approaches is captured in Figure 40. This chart delineates the number of DMUs at the department level and implies the discriminatory power present in each analysis. The difference for CECE, EECS, IEMS and MMAE were 0, 1, 2 and 1 respectively. The CCR approach is clearly more conservative in that it results in fewer efficient units. Figure 41 continues this analysis by capturing the number of times a department is classified in one of the three efficiency categories.

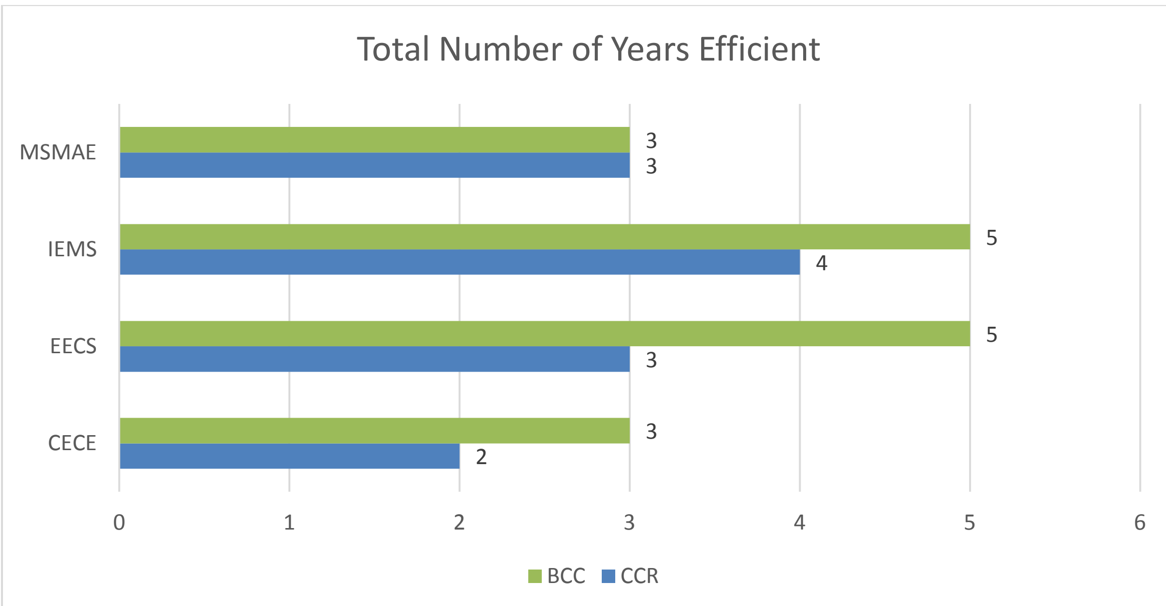


Figure 40: Cumulative Results

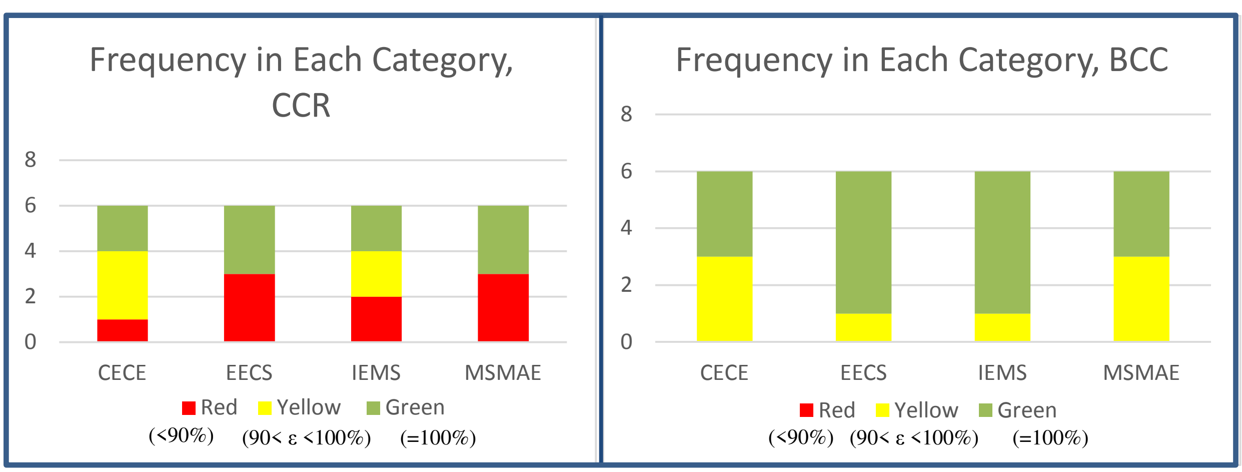


Figure 41: Department frequency in categories for CCR and BCC models

Figures 42 represent the efficiency of each department using both approaches over the 6 year period. In cases where there was a difference between the results generated using CCR and BCC, the higher efficiency was in favor of the BCC approach.

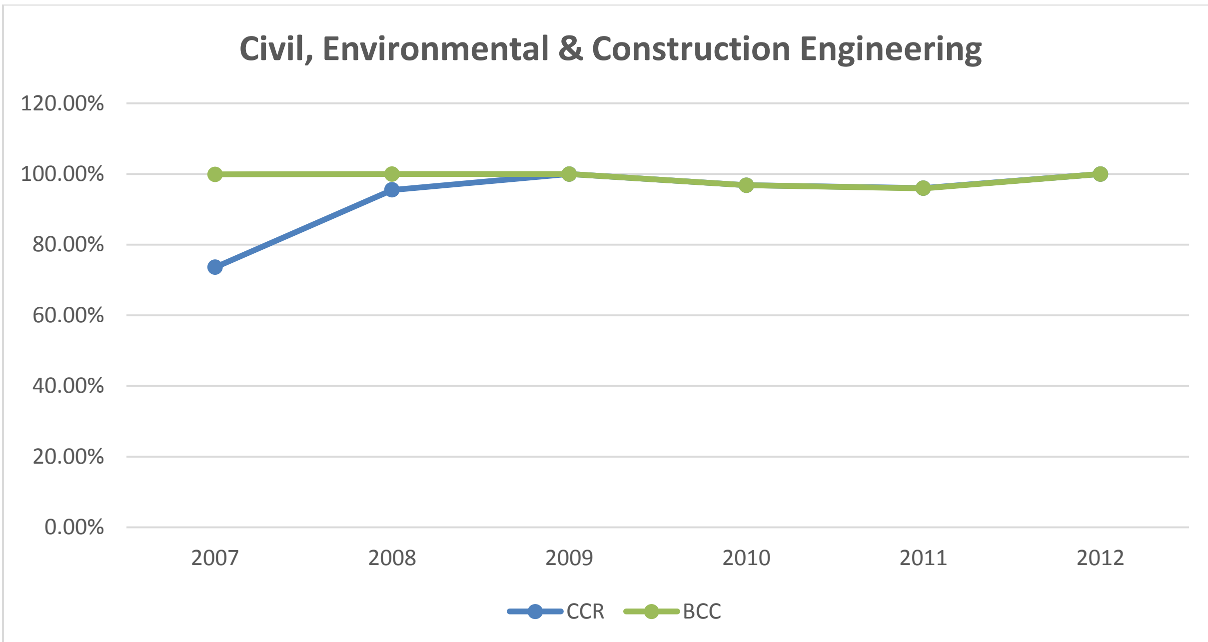


Figure 42: CECE CCR-BCC Results

A closer look at the CCR results in Figure 43 shows that CECE was operating at a lower efficiency during the 2007 and 2008 period. At Year 2009 and beyond, the results are at or near 1, but there are also opportunities for improvement in Years 2010 and 2011.

A slightly different observation can be made of EECS across the period. The department began as an efficient unit in 2007 but began a downward trend for the next 4 years. Something has resulted in a return to efficiency in the most current year (2012). Figures 44-45 offer additional observations.

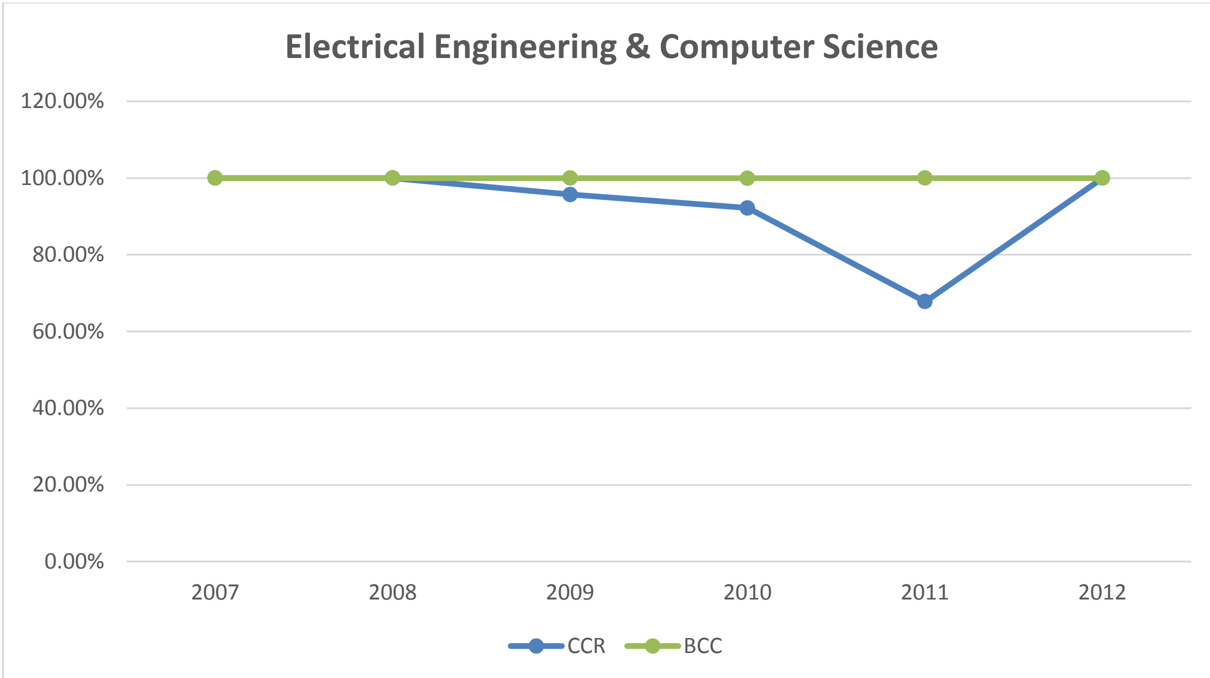


Figure 43: EECS CCR-BCC Results

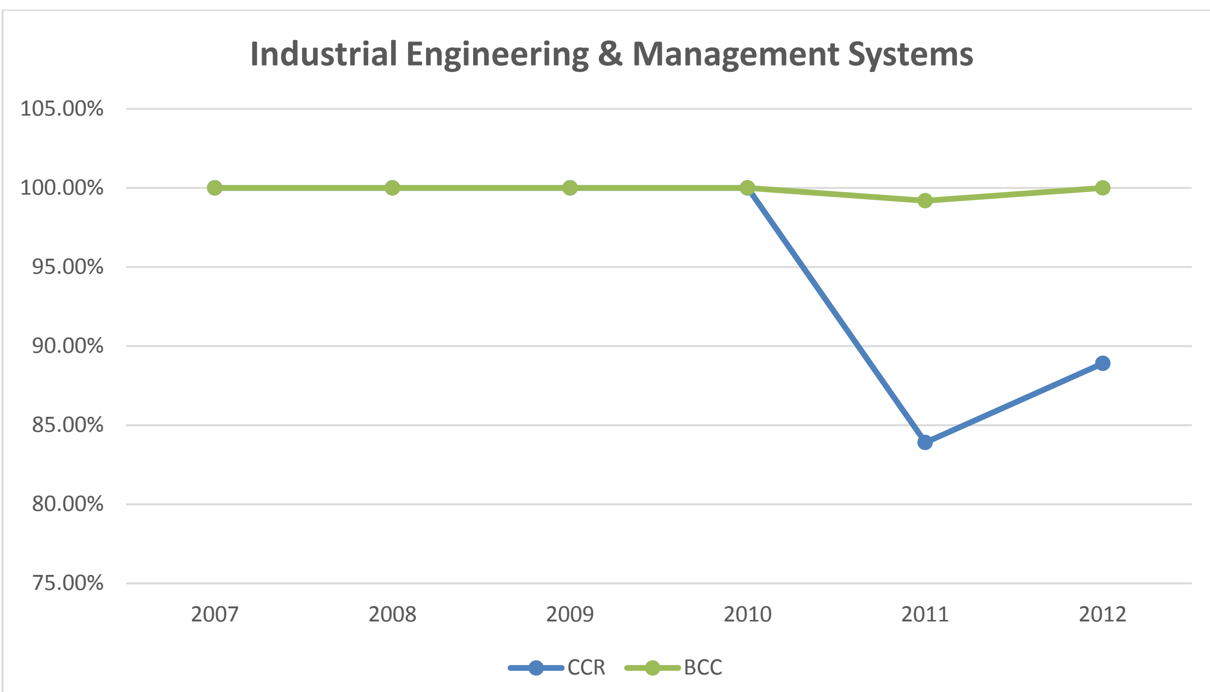


Figure 44: IEMS CCR-BCC Results

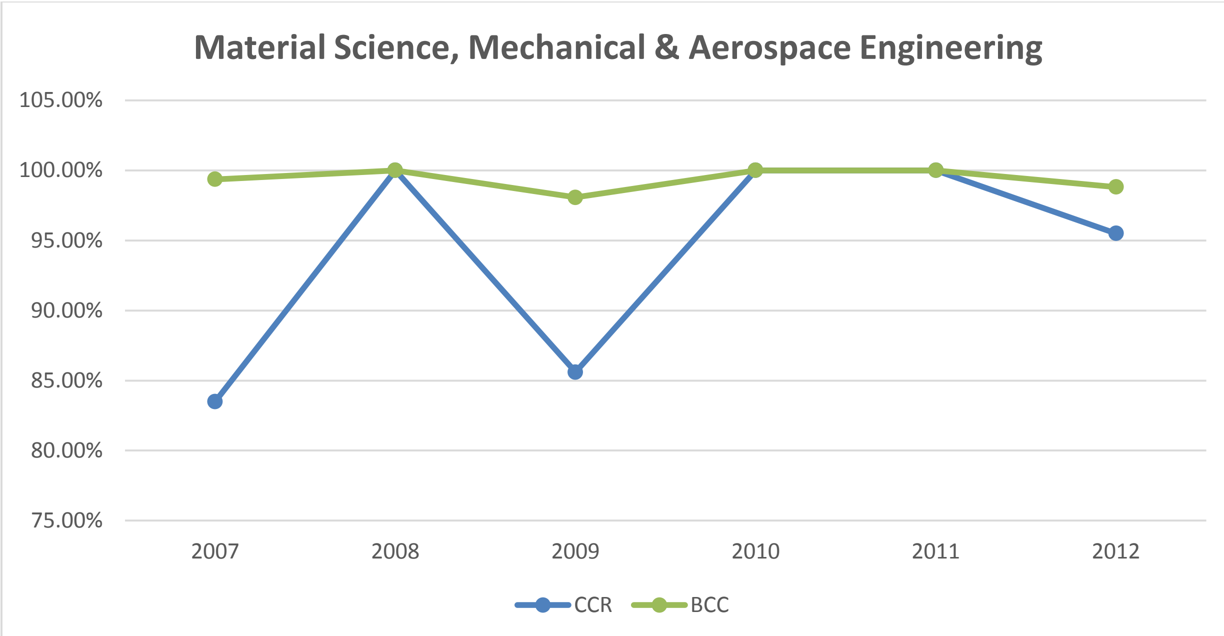


Figure 45: MMAE CCR-BCC Results

Figure 46 provides a different view of the same information (CCR results only). It shows that MMAE has the most unstable efficiency over the period. Industrial Engineering shows little to no change until Year 4, while CECE begins with low efficiency (Year 1) but exhibit at/near efficiency the remainder of the periods.

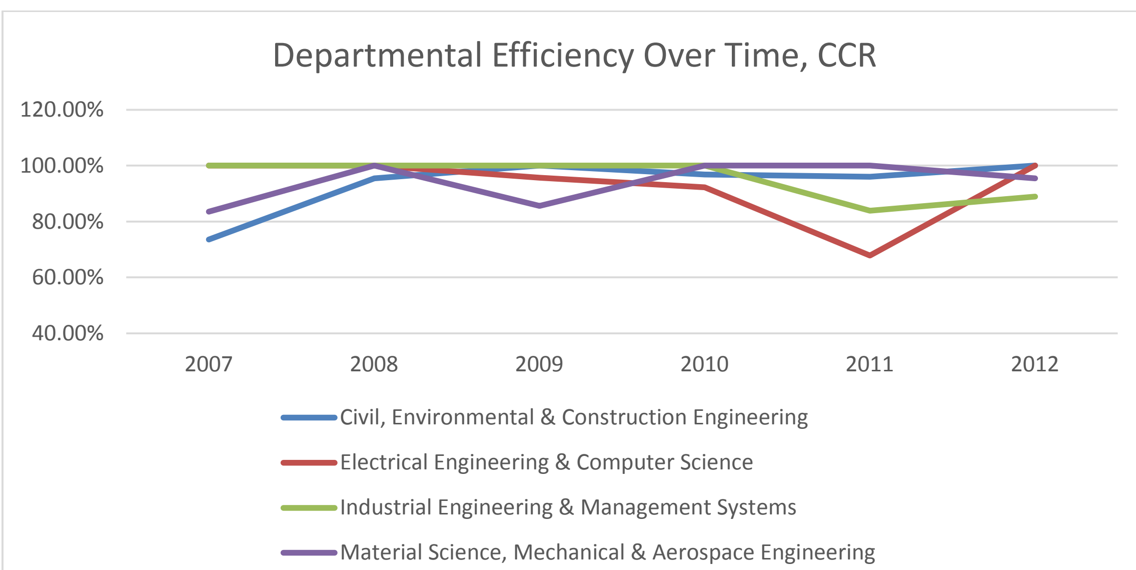


Figure 46: MMAE CCR-BCC Results

Figure 47 represents the results of the BCC analysis and shows a slightly different dynamic in that departments were at or near efficiency during all periods (falling between about 95% and 100%). This implies that more discriminatory power may be needed to increase the ability to identify improvements.

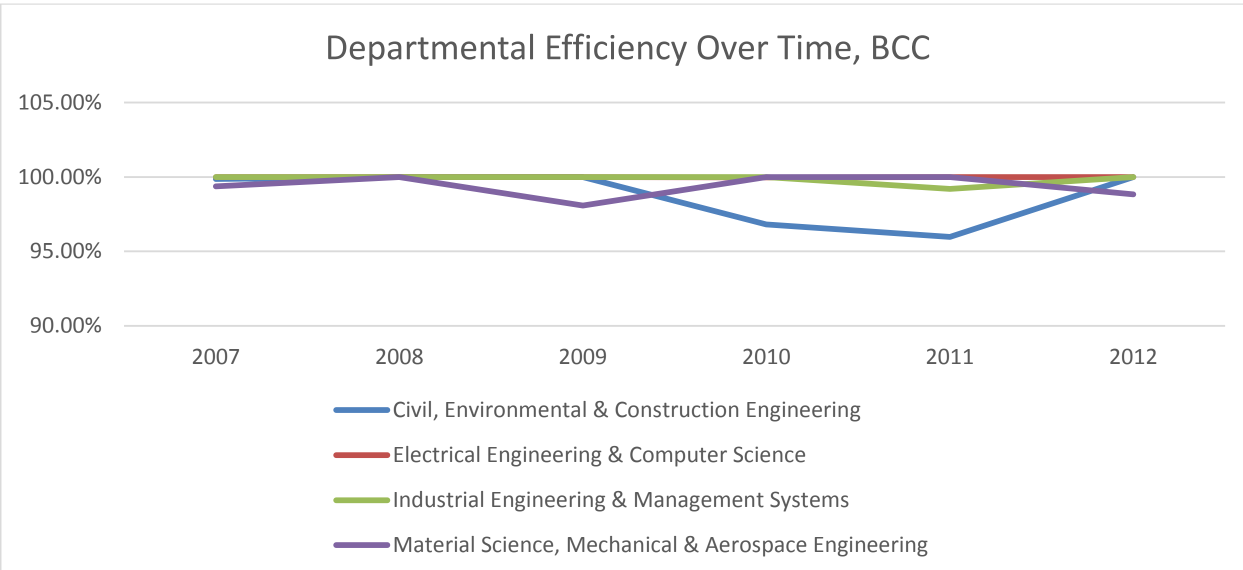


Figure 47: Annual Efficiency (2007-2012), BCC

Detailed results of the analysis is captured in Appendix S and show the improvement potential within each department per year. Figures 48-49 show the overall improvement potential across all DMUs, given the CCR model and BCC model (respectively). It is important to note that by calculating the output-oriented model, the objective of the analysis was to maximize output. So as it may seem inappropriate to conceive reducing the inputs of the model, the current goal is to use optimal resource levels to attain the highest level of quality output. The alternative would be to focus on reducing inputs to maintain the current level of output, which seems less appropriate.

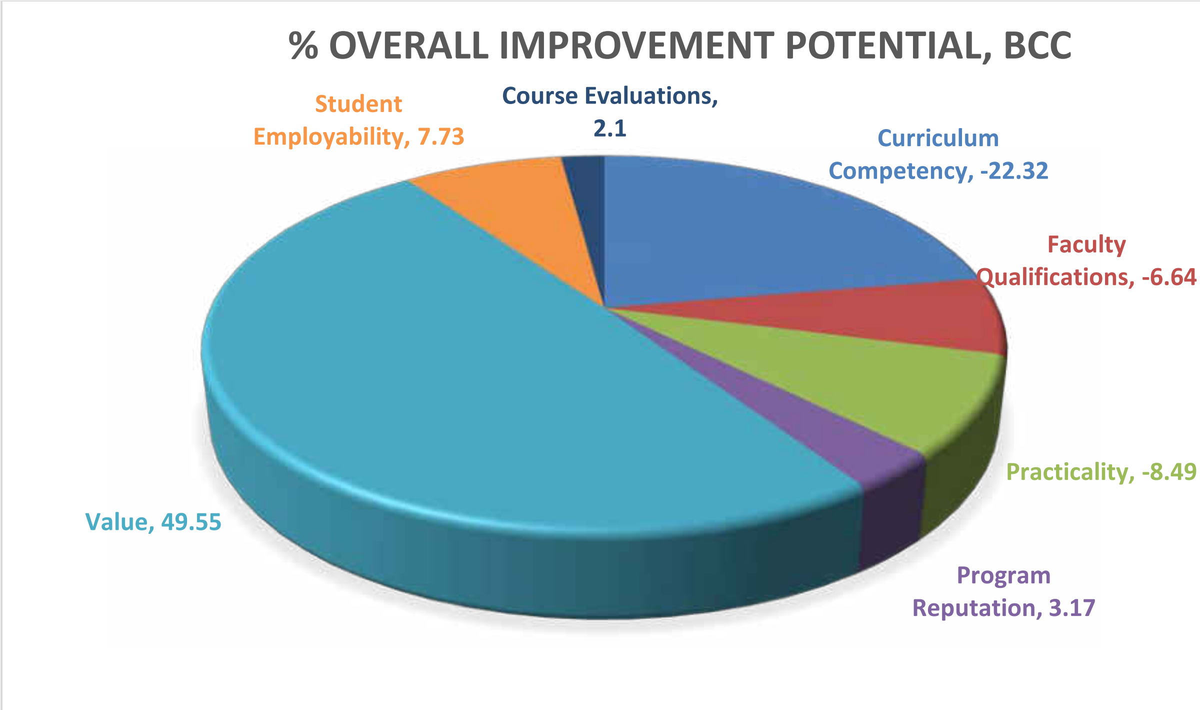


Figure 48: Improvement Summary (BCC)

Figure 48 shows that there are opportunities to reduce the inputs of the model considering all 24 DMUs. The numbers in the chart do not represent the percent of increase or decrease of each variable but rather the percent of total improvement opportunities inherent to each variable relative to other variable. Notice that input variables have a negative sign and the sum of the absolute value of all variables adds to 1. These results would tell an administrator that trying to produce opportunities to employ students in university supported roles presents the greatest opportunity to improve the perceived quality of departments. It also implied that considerable effort should be expended to reduce the number of course action requests. The resources applied to this effort are currently being wasted as the results imply that the same level of output could be maintained, if the number of CARs were reduced.

Similar inferences are in order for Faculty Qualifications and Practicality, the two remaining inputs. If administrators want to improve its operational efficiency they may choose to hire more adjuncts, instructors or lecturers, or incorporate policies that further restricts faculty consulting work external to the University.

The aforementioned analysis considers improvement at the College-level, as there is no discrimination among each departments. This would be most useful to the Dean and Associate Deans, but less likely to be used by department chairs. To increase the usefulness of the results to department chairs, the results would be limited to either (1) a single DMU, during a single year, or (2) all DMUs for a single department (improvement potential over time). The chart would reveal the same type of information and this insight could be used alone or to supplement other ongoing data collection and assessment efforts.

To enable a more detailed discussion of the results of this process, performance during the most recent year of evaluation (2012) is depicted in Figure 49.

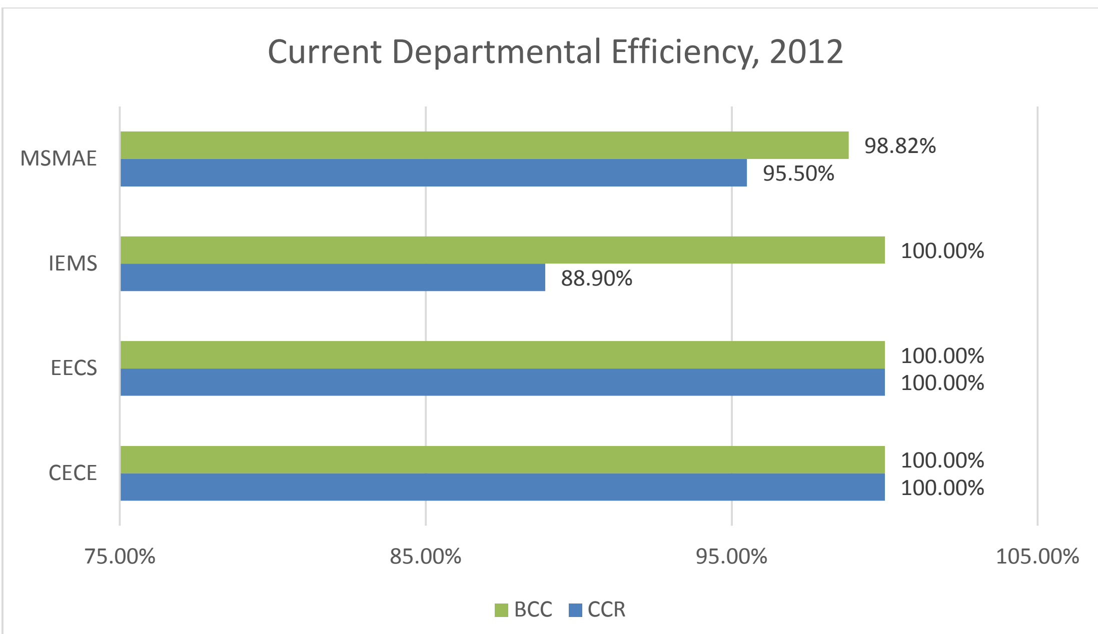


Figure 49: Efficiency for Year 6 (2012)

It is ideal to continue this analysis using the results of the BCC model. Assuming variable returns to scale relieves the constraint that inputs directly affect the level of outputs produced. The results for 1 efficient DMU, CECE, and one inefficient DMU, MMAE, using this approach is captured in Tables 27 and 28.

The actual column represents the DMU variable values introduced in Appendix R, while the target value represents what the value would need to be to be efficient. The potential improvements column represents the percent difference between the target and actual columns. The contribution column captures the degree to which each attribute contributes to the overall efficiency evaluation (by inputs and by outputs). In this column, a higher value among the inputs imply that the impact of applying resources to that factor will have positive effect on the overall efficiency of the DMU.

Table 27: Output for CECE12, BCC

Based on the results for CECE12, the department achieved satisfactory resource optimization. Potential improvements at each KPI is 0% but for planning purposes, decision makers may opt to apply resources to increase practicality and faculty qualifications over curriculum competency. The contribution levels show a greater potential impact in these areas.

If resources are applied to refine the scope for future resource allocation, decision makers would focus ways to increase their program reputation.

Table 28: Performance Summary for MMAE 12, BCC

The inefficient department, MMAE, shows slightly more deviation from the target values. Potential improvements are available in all areas except faculty qualifications and practicality. A 45% reduction in changes in the curriculum competency (number of CARs) should increase the output produced. The greatest impact would be in Value (247%) and Student Employability (27%). The contribution values of the inputs support this notion. As more resources become available to the Department, an investment in curriculum competency would be less than ideal because it is currently at a 0% contribution to the objective function. The output variable Value is farthest from its target but its percent contribution to the efficiency score is 0%. Therefore, more resources should be garnered to invest in initiatives to improve Student Employability and Program Reputation s.

A. Sensitivity Analysis

Additional analysis was conducted to examine the effect of two scenarios on the efficiency of departments (BCC models only) and are shown in Figure 50. The first alternative was to delete the least important measure using the AHP preferences, to determine the effect. By removing Course Evaluations, the model slightly increased in its ability to identify inefficient units. The second alternative model removed an input and an output, reducing the number of efficient units to 9 DMUs. In this case, the two least important measures per the AHP results were removed (Course Evaluations and Faculty Qualifications).

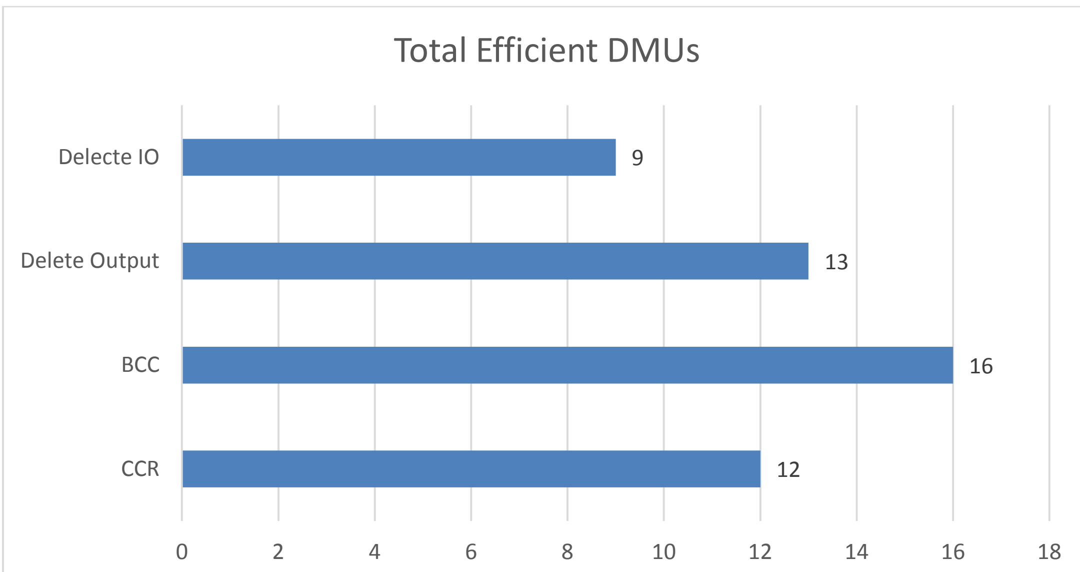


Figure 50: Total Efficient DMUs under Alternative Models

Table 29 shows the efficiency levels of each DMU in each alternative model. As in earlier tables, the green field represents an efficient unit (100%), the yellow field identifies a unit near efficiency (90-99.99%) and the red fields imply high inefficiency levels (Efficiency < 90%). The new color, blue, indicates that the unit achieved an efficiency evaluation of 100% yet still exhibit opportunities to improve. In applying the DEA methodology, these units were not included in the total number of efficient units.

Table 29: Efficiency Levels given Alternative Models

Slack Exist | 100% | 90-99.99% | <90%

	BCC	BCC- Minus Output	BCC- Minus IO
CECE, 07	99.87%	87.97%	86.65%
CECE, 08	100.00%	98.88%	87.23%
CECE, 09	100.00%	100.00%	85.49%
CECE, 10	96.80%	90.29%	85.23%
CECE, 11	95.97%	90.62%	79.63%
CECE, 12	100.00%	100.00%	91.82%
EECS, 07	100.00%	100.00%	100.00%
EECS, 08	100.00%	100.00%	100.00%
EECS, 09	100.00%	100.00%	98.39%
EECS, 10	99.96%	99.96%	99.11%
EECS, 11	100.00%	100.00%	100.00%
EECS, 12	100.00%	91.48%	91.48%
IEMS, 07	100.00%	100.00%	100.00%
IEMS, 08	100.00%	100.00%	100.00%
IEMS, 09	100.00%	100.00%	100.00%
IEMS, 10	100.00%	100.00%	100.00%
IEMS, 11	99.19%	99.19%	98.32%
IEMS, 12	100.00%	100.00%	100.00%
MMAE, 07	99.37%	97.36%	97.36%
MMAE, 08	100.00%	100.00%	100.00%
MMAE, 09	98.08%	94.31%	94.01%
MMAE, 10	100.00%	100.00%	93.89%
MMAE, 11	100.00%	100.00%	100.00%
MMAE, 12	98.82%	98.19%	91.25%
# 100%	16	14	10
#Efficient	**16**	**13**	**9**

A graphical representation of these results are shown in Figure 51. It is clear that the model with less inputs and outputs demonstrate greater discriminatory power and has lower efficiency levels.

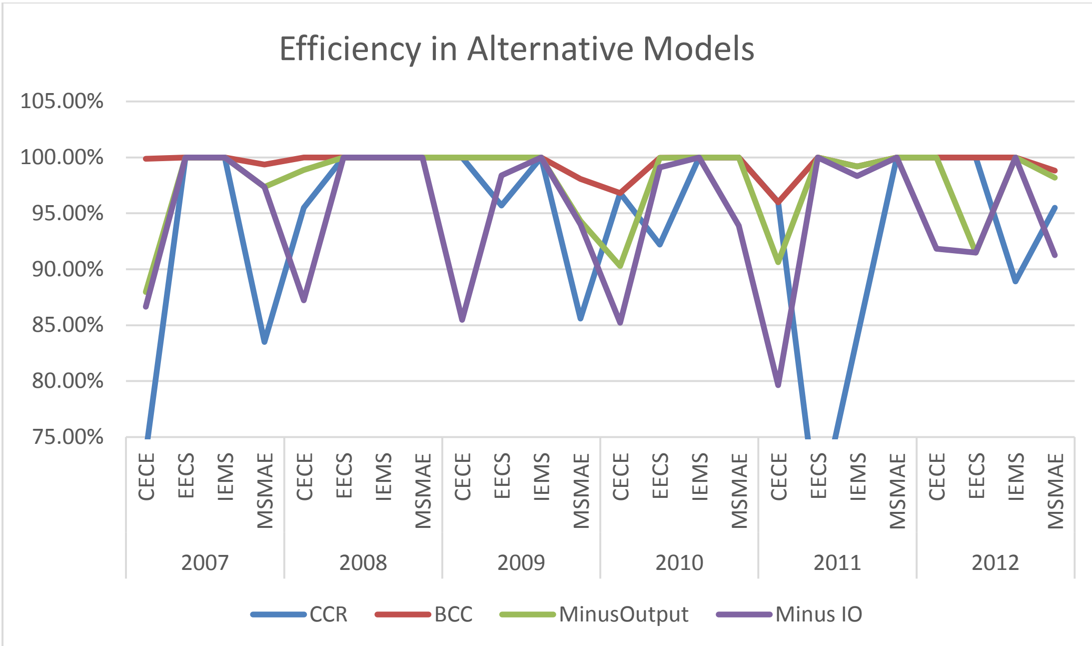


Figure 51: Graph of Efficiencies Given Alternative Models

Deleting an Output

The first variation of the model involved deleting Course Evaluations from the analysis. By decreasing the number of outputs from 4 to 3 (i.e. deleting the least important factor per the AHP results), the number of efficient DMUs decreased by two showing a small increase in discriminatory power. The evaluation of efficiency either remained constant or decreased. There was no case of an increase in efficiency when deleting the output variable.

Additionally, all efficient DMUs in the standard BCC model remained efficient, with the exception of EECS in 2012 and IEMS in 2009. The latter change reflect a department with 100% efficiency score, but improvement potential based on slack variable values. These results support the notion that an inefficient unit will not become an efficient unit with the deletion of an output.

Deleting an Input and an Output

The second analysis involved deleting the two least important KPIs per the AHP results. Those two factors, Course Evaluations and Faculty Qualifications, meant a deletion of 1 input and 1 output. This model shows increased discriminatory power, as only 9 DMUs were deemed efficient. The changing DMUs were all efficient units transforming to inefficient ones. The results support the notion that an inefficient unit will not become an efficient unit with the deletion of an input or output when using a BCC model with the same orientation.

IX. Discussion

The results derived through this process support the notion that a Delphi-DEAHP approach is a reasonable, feasible and data driven alternative to not only define and assess quality but also to gain insight into opportunities for improvement in the production of output and utilization of resources. Yet, this recommendation does come with a number of caveats.

Gaining participation in the data collection process is difficult. Participants internal to UCF combat competing priorities and tasks, while external participants suffer from conflicts of interests, verification of the legitimacy of solicitation, and possession of a sense of stake in the matter. Additionally, employers or industry partners may have difficulty completing the surveys due to a lack of understanding of what occurs within the education system. Yet, this is also the case internally. Students are typically exposed to a limited view of the system, as are the faculty. Since administrators may be conscious of the concerns of many stakeholders, their understanding may exhibit more breadth but is likely tainted by the more traditional business concerns they must address. This is evidenced in the stakeholder preference results, as the administrator was more concerned with faculty management and program sustainability over the remaining dimensions of quality.

The quality model was developed with input from a small group of about 15 people. These individuals represented each stakeholder group, compliant with the requirements of the model development process. Although the number of participants seem relatively small for drawings conclusions, it is appropriate for the Delphi method where the goal was to gather varying views and compile them irrespective of which group the comment originated with. Several researchers mention that small sample sizes are acceptable in this form of data collection in that qualitative and more open forms of input are often desirable (Pill, 1971; Okoli and Pawlowski, 2004; Hsu & Sandford, 2007). Similar works like that offered by Landeta (2006) supports this inclination with a sample size of 14. The feedback received from a small group of willing participants in this iteration was very thorough, and enabled ease in the synthesis of diverse comments.

In a similar instance, the AHP sample size may be questioned. Although generalizations could not be made for any of the stakeholder groups other than the student group, the voluntary nature of the survey, its length, cognitive load requirement and the lack of incentive deems the samples acceptable. At least the participants considered in the preference calculations were only those demonstrating consistency; consistency was present in the majority of individuals. However, a variety of random indices exist to calculate this ratio; employment of an alternative index may reveal a slightly different consistency ratio, hence slightly different results (Alonso & Lamata, 2006).

An additional consideration of the AHP portion was the decision to complete only a partial hierarchy. Armacost, Hoesseini and Pet-Edwards (1999) describe the AHP process in two phases- the Criteria Phase and the Alternative Phase. Although the authors ultimately accomplished both phases, the goal of determining the importance of the quality attributes and dimensions eliminated the need to proceed to the Alternative Phase. The article also addresses the issue of unequal numbers of attributes as this may require additional attention to ensure additional preference is not assigned due to differences in the number of inputs under consideration. Unfortunately, the final quality model reflects 4 attributes for all dimensions except the Academic Infrastructure dimension. Similar unbalanced AHP models were found in works like that posed by Koksal and Egitman (1998). Since the model reflects actual input from stakeholders, the reduction of this dimension to 4 factors seem to prematurely discount the 5th attribute, which may end as the most important. Therefore, the unbalanced hierarchy was deemed acceptable in this iteration.

Group aggregation normally follows two schemas. The more common approach involves the computation of the geometric mean of the pairwise comparisons and then computing the pairwise comparison. Armacost, Hoesseini, Pet-Edwards (1999) mention a process of using the eigenvector method to compute priorities and then calculating the arithmetic mean to derive the group preference. Both approaches were tested but given the similar results that prevailed, this dissertation evolved with the results from the latter method.

Then, the literature did not reveal a single DEA model that evaluated all departments within a single College at a single institution over time. This may be due to many factor including the need to evaluate a sufficient number of DMUs. The determination of the recommended number of DMUs within this scope was somewhat subjective although the literature states that the number of DMUs should be larger than the product of number of inputs and outputs and/or at least 3 times larger than the sum of the number of inputs and outputs (Avkiran, 2001; Sinuany-Stern et al., 1994).

IO selection was constrained because data availability limited the number of years under analysis, data aggregation limited the value of the analysis results, changes in College structure jeopardized the homogeneity of the data and a decision still remained on how close to the calculated DMU constraints one should operate. Data availability limited the total possible number of DMUs to 24. Data aggregation levels was limited to the program and department levels due to the insight that the use of aggregate data can produce misleading results (Johnes, 2006). Homogeneity constraints eliminated the 2012-2013 term data from analysis (The College changed from 4 departments to 5). The equation results constrained the ideal DMU range to 18 - 24. To avoid pushing the discriminatory power limitations too far, the mid-point reflecting 7 IOs was selected.

Recall, comparisons have shown that different indicators produce different evaluations of DMUs (Johnes & Taylor, 1990). The high correlation between inputs and outputs were suspected to enable the reduction of the number of IOs (Sinuany-Stern, 1994). Yet in this iteration there was no instance where a variable could be eliminated due to this relationship. The only significant correlation coefficients were at .833 (Course Evaluations-Practicality), .515 (Student Employability-Program Reputation) and .664 (Faculty Qualifications-Student Employability). However, a positive correlation exist between some attributes which may deserve additional attention in future iterations.

The metric used to capture the KPIs posed additional concerns such as that present for Curriculum Competency and Value. The derived measure for the former was non-linear and the process of conforming the data to linear program constraints (using categories), may have caused some loss in the data's meaning. The results ultimately capture whether to increase or decrease the number of course action requests but to what extent can only be assumed.

Additionally, it was unfortunate that a direct metric could not be captured for Value. The selected measure actually captures Graduate Student Support, which is one of the other measures in the quality model. The SAFE group measured Graduate Student Support as less than 1% of total preference in comparison to the 7% importance of Value. This measure shows a very wide spread with a less than ideal variation compared to the remaining metrics. Yet, in the Central Florida Future article by Hitzing (2013), a measure described in the Value ranking system captured average student debt at graduation. Given an inability to secure the appropriate data from available sources, at the aggregation levels desired, the data was accepted as a proxy of the measure and deemed suitable for the purpose of this analysis.

The results show several noteworthy observations, one being that Faculty Qualifications offer two outliers in the data (25.5 and 7). When this data was treated to represent the % Tenure/Tenure Earning over the total number of faculty across all types, 25.5 (or .96) remained an outlier although its difference from other values was less extreme. Further investigation may be desired to determine why such drastic values exist in this data.

Besides, the need to utilize data smoothing techniques to derive missing values in the data may have increased the efficiency scores of departments. As more information becomes available, actual data for all periods under review could be considered.

DMU data was analyzed based on constant returns to scale and variable returns to scale to enable a comparison among the two. The differences found deemed the data less suitable for the CRS model and therefore, the BCC model became the basis for further analysis. This approach was offered by Avkiran (2001) and proved successful.

Additional models tested the deletion of an output, the deletion of an input and an output and the transformation of an output to an input. The rule that says that variable addition and deletion cannot cause an already inefficient DMU to become efficient proved valid (Sinuany-Stern, 1994). In the instance where the attribute was swapped, the results varied slightly. The major difference was that 3 inefficient units became efficient and 2 efficient units became inefficient. No previous research was found that queried the effects of swapping an attribute. The results also imply that using 6 IOs may be more useful. More units were deemed inefficient, more opportunities for improvement were captured and less data would be required.

A decision was made to limit the DEA sensitivity analysis to evaluating efficiency changes given alternative models. This method not only provides insight into the unit's performance based on multiple configurations as suggested by Avkiran (2001), but it also provides preliminary basis for sensitivity and significance. Although statistical tests are available for further review (i.e. Pastor, Ruiz and Sirvent Test and Bootstrapping) it is outside the scope of the first iteration of this dissertation. Support for this decision lies in the common practice to test the significance of factors in the model by calculating alternative models (Johnes, 2006), as this too will provide an idea of model sensitivity.

A. Special Considerations

Data used in this dissertation considers the time between 2007 and 2012, so the results are influenced by the state of the economy during this time. Late 2008 is recognized as the beginning of a global recession due to steady economic decline beginning years prior. Many consequences of this circumstance are income disparities among the middle and lower class, significant unemployment increases and decreased government appropriations to universities. The effect of the recession was particularly severe in Florida and the state’s support for its universities. Each of these consequences has the potential to impact the perceived quality of academic departments.

Appendix U show the number of full-time equivalent (FTE) students, educational appropriations and total educational revenue for public institutions per FTE between 1987 and 2012, delimiting the United States and Florida. The United States shows a steep incline in student enrollment since 2001. It is somewhat steady between 1992-2001, increases by about 1 million FTE students between 2001 and 2008 but doubles to 2 million FTE student enrollments between 2008 and 2011. The period between 2011 and 2012 appear somewhat steady. Clearly, tuition increases are being used to supplement the decline in educational appropriations, which was at its lowest level since 1987 in 2012.

Moreover, the Florida data reveals very similar findings. There has been a steep increase in student enrollments since 2001. Tuition income is much lower than the national average beginning in 2004 but this is not reflected in increased government appropriations. The amount of appropriations received by Florida public institutions has been at a steady decline since 2007.

The issue is that many unemployed or economically stagnant individuals go to college to not only increase their marketability for employment but in some cases, to enable student loan support. If the student is unemployed and unsupported, the student may be more likely to accept higher loan packages. This support serves as income in the short term, but potentially a burden in the long term. If the number of experiential opportunities or jobs available to students does not increase proportionate with the number of students enrolled or graduating, more students will be less competitive, unemployed or underemployed at the time of graduation. If increased student out-of pocket expenses are required, a student is more likely to accumulate more debt in pursuit of that degree. If the schools are not provided sufficient financial support to maintain its overall infrastructure, the physical and operational strain may compromise the perceived quality of departments.

Thus, universities are challenged to do more with less and therefore the efficiency results cannot be accepted without this caveat. Notice, the factors discussed here are somehow reflected in the 25 attributes of the $LIFTS^2$ model. Department inputs and output values over the period under review are impacted by factors beyond those treated in this model. The efficiencies score should be viewed as reflecting how well departments perform with what they have comparable to departments under similar conditions rather than absolute implications of efficiency.

X. Conclusion

Quality definition and assessment is a topic of concern in higher education and beyond. Understanding what is important and utilizing best effort to define useful measures to evaluate the effectiveness of decision making units at maximizing quality is a noble step towards the task of performance measurement in academia. The results in this chapter illuminates the potential application of the decision support methodology to drive this assessment.

The results show what is important to the four major stakeholder groups and highlights the differences and similarities they share. It uses that understanding to limit the number of factors considered in the model to assess quality and quality efficiency. After capturing data and in some cases, revising the metric to reflect available data, data envelopment analysis was used to identify efficient and inefficient units, the degree of potential improvements in each factor, and their contribution to the efficiency measured. While the process and results implicate several probable improvements to the model including the need for stronger metrics and data, it also provides support as a practical approach that can be relevant in an array of applications.

CHAPTER FIVE: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This dissertation demonstrates the use of decision science tools to investigate a real world problem. Stakeholder input guided a generic quality definition, representative of the combined, yet competing interests of key groups. The analytic hierarchy process enabled the capture of diverse perspectives in a dynamic and changing environment. Data envelopment analysis employed an input-output approach that eliminated the debate of the internal processes of academia ("the black box"), and focused the analysis on the high-level transformation of inputs into outputs. At University-wide level, the approach can be used to evaluate quality at College and Institute levels.

This dissertation recognized quality as a loosely defined, flexible and quantifiable concept. The result was a stakeholder-relative model of quality reflective of competing interests and needs. It is in direct opposition to subjective and qualitative approaches to quality assessment common in the literature. The approach can be easily adapted to alternative applications.

I. Administrator Use of Model & Results

University administrators are charged with finding ways to do more with less. As resources continue to tighten, administrators are challenged to allocate adequate resources to maintain current output, but also to increase output. By accepting that the shift in University dynamics to less government support intensifies the needs to satisfy its most crucial stakeholders, administrators should see the merit in applying the models herein.

Although this dissertation focuses on one specific College and is hence an assessment and decision making aid for associate deans and the Dean of the College, it is transferrable to higher levels in University Administration. For instance, the President may use the model to evaluate College or Department level efficiency across the entire University. Specifically, ongoing continuous quality improvement efforts by the University can benefit from the ease of implementation of this model so that the assessment is more repetitive and the recommendations derived from the results are used to support the improvement of the department.

Ultimately, the models help to create a sense of shared investment in the operations and processes of the University. The things that are important to multiple stakeholders are accounted for and used as the basis of the analysis. Identification of efficient units would provide transparency into the utilization of resources provided and its impact on the generation of outputs. It negates the assumption inherent to common approaches that more resources generates more outputs and highlights instead that, there are ways to produce more with less inputs.

II. Lessons Learned

Data collection is one of the most time consuming, unpredictable aspects of conducting research of this nature. The very complex and dynamic nature of the University environment further dilutes the ability to communicate with the "right people" at the "right time".

In further consideration of the target populations in this study, the second survey may have been too lengthy. The survey not only called for refinement of the model derived in Survey 1, but also the ranking of prevailing performance measures and requested participants to brainstorm additional ones. The cognitive effort required to give meaningful feedback on all of these areas may have been better suited as 2-3 additional rounds of surveys. Yet, this would have introduced additional risks related to participation longevity over a greater number of surveys.

Essentially, survey participation was poor. Irrespective of the electronic or hardcopy solicitation efforts directly from the researcher, the average response rate was about 17%, given Average of 9% (S), 14% (A), 23% (F), and 23% (E). In future iterations, it would be worthwhile to query whether mass solicitation from an authoritative entity would be more effective.

III. Recommendations

Participation in this dissertation was strictly voluntary. As an exercise of this nature may have significant repercussions in the way departments are evaluated and new resources are allocated, clear support from the University's administration should be garnered early in the process. This support should be obvious in the request for participation and is expected to result in increased participation rates. An alternative strategy is to select specific stakeholder samples parallel to existing filters in the College's email system. This would place the participation request within official channels, coming from an official source and is therefore expected to increase participation rates.

Nevertheless, as a proof of concept and demonstration of a process, the dissertation illuminates several opportunities for improvement:

(1) Allow participants more time to complete the AHP survey to increase the response rate. In this dissertation, the surveys were disseminated in the latter portion of the semester, while many prospective participants were busy with final exams, grading, etc. In many cases, the short time allowance was also a red flag and caused many individuals to forgo participation. In future iterations, a minimum of four weeks should be allotted for survey participation starting around the second month of the fall or spring semester.

(2) The selection of a common medium for the AHP survey dissemination should be used. Adobe Forms Central is a new server utilizing cloud technology to host form submission online. Several participants returned both the electronic submission on Forms Central and sent a copy via email. In this duplication, the respondents expressed a lack of confidence in the information transfer. While the server seemed 100% reliable in these cases, it may be more useful to use a dissemination tool that is more commonly used in academia for future iterations of this dissertation.

(3) The dissemination of AHP surveys to faculty and administrators in a group setting may be more effective. In consideration of faculty and administrator load, using a setting pre-arranged for other purposes (i.e. staff meeting or department meeting), faculty and administrators may be more likely to participate in the survey.

(4) Redesign the AHP survey. Several comments were made regarding the natural flow of cognitive processes in making comparisons. By designing the survey using the bottoms up approach, participants will form a better understanding of the discrimination of dimensions at the next level. Although definitions of dimensions and attributes were provided in the dissemination package, this simple rearrangement may aid the participant's ability to make clear comparisons. This also provides the potential to reduce response inconsistency.

(5) Improve DMU Metric. There has been a lot of discussion throughout this dissertation about the limitations of the metrics employed. The question that remains is what data do I need to increase the credibility of the results. Table 30 below captures the 7 key attributes and a more

ideal measure or each attribute. It also lists potential data sources to acquire desired data. The final column houses any recommendations increase the likelihood that the data is available.

Table 30: Data Recommendations

Attribute	Ideal Metric	Data Source	Recommendation
Curriculum Competency (Input)	Proportion of Curricular Changes across 2 categories (Revise Course Content, Add Courses) to the number of courses offered by department.	Institutional Effectiveness Report/Course Catalog	The Office of Operational Excellence and Assessment Support should provide CECS the 2 curricular changes data points at the department level each year. Since each department's program coordinator is responsible for the input to the report, the data may be provided directly from each department.
Faculty Qualifications (Input)	The proportion of student credit hours (SCH) taught by full time faculty to the total SCH taught by department.	Office of Institutional Research	This measure limits the scope of faculty qualifications to teaching which is still not the intent. A better measure should be sought.
Practicality (Input)	The percent of full time faculty reporting consulting experience or work on University research contracts and grants	Faculty Activity Report	Add a collector to the annual faculty activity report that captures whether faculty participated in consulting or research contracts and grants in the current year.
Program Reputation (Output)	The average USNWR score based on graduate and undergraduate specialty rankings from one year following.	USNWR/ CECS	Contact USNWR to express interest in annual undergraduate specialty rankings to ensure it exists.
Student Employability (Output)	Percent of alumni reporting a job or graduate school attendance within 1 year of graduation.	Office of Alumni Affairs/CECS	Both Alumni Affairs and CECS has ongoing efforts to track alumni accomplishments. At least one entity should add a collector to its instrument.

Attribute	Ideal Metric	Data Source	Recommendation
Value (Output)	The total student debt accumulated by graduating students, treated by level of degree earned.	CECS	Add a collector on the existing graduating student survey.
Course Evaluation (Output)	Average course evaluation rating of the department.	CECS	Continue with current data.

IV. Contribution to Industrial Engineering

Industrial Engineering is a broad field of evolutionary and integrative approaches to develop, implement, evaluate and improve systems of people, products, money, operations, processes and services thereby stimulating efficiency, effectiveness, quality and innovation. Its diverse toolkit can be applied to nearly any domain, as evidenced throughout the literature.

This dissertation embraces the notion of industrial engineering's broad applicability by addressing the assessment of stakeholder-relative, efficiency at achieving quality by *developing* a methodology driven by the literature to outline the process (the model); *implementing* the model in higher education, specifically the College of Engineering & Computer Science at UCF; systematically *evaluating* academic departments to identify optimal allocations of inputs and production of outputs; and identifying opportunities to *improve* the process and data metrics through reflection and lessons learned.

By integrating quantitative and qualitative techniques, the views of competing stakeholders drive the systemic evaluation of each department's ability to meet the expectation of the stakeholders. The tools themselves are well known, simple, tools that, alone, are applied by many. This process of applying the Delphi method to drive the analytic hierarchy process which drives the data envelopment analysis to issues in higher education is unique. Inclusively, the descriptive, prescriptive and normative nature of the results and reasonably objective inputs to the model deems this dissertation a notable contribution to industrial engineering.

V. Broad Contribution

There are many situations where it is imperative to evaluate the importance of criteria for decision-making purposes, whether it involves one set of judgments, those of a group or those of several groups. There are also many scenarios where it is useful to assess a unit's performance without truly understanding the interactions among the processes therein. These tasks are often reduced to solutions based on ad hoc and highly subjective techniques, rather than a data-driven and analytic approach.

The methodology introduced in this report offers the opportunity to utilize stakeholder feedback to clearly delineate explicit judgment of relative importance of diverse perspectives. By marrying tools like the Delphi method, the analytic hierarchy process and data envelopment analysis, complex tasks were tackled. Not only did this approach query busy individuals in a non-invasive manner to gain open feedback as to their beliefs and values, it also quantified relativity measures of the commonly subjective topic of quality and evaluated several entities based on their ability to transform key inputs into maximum outputs.

The proposed methodology results in a tool that can be used by administrators, managers or planners to assess which units are providing acceptable quality while being consistently efficient in using whatever resources they are assigned and therefore should get first priority when new resources become available. In an era of tight budgets this may be an invaluable tool.

This specific case considered the quality of academic departments but can be transferred to the training and education domains of academia and industry, with minimal considerations.

The methodology additionally lends itself to environments where needs and requirements should be taken into account in order to assess how well an entity is meeting those requirements given available resources. For example, the hospitality industry uses a star rating to identify the quality of a hotel. Given the very different needs of travelers, this rating may or may not be reflective of the traveler's concept of quality. By customizing the degree of importance of factors in the hotel's quality matrix, each traveler can more clearly select a hotel that meets their needs and hospitality managers can ensure appropriate use of its resources to attract/satisfy the desired traveler group(s).

All in all, the methodology introduced in this report satisfies four motivations- (1) What are the key dimensions/attributes of academic programs that identify quality performance?; (2) What measures can be used to capture the essence of each attribute?; (3) What is the relative importance of the quality model's components to the SAFE stakeholder groups?; and (4) How can we systemically measure the relative efficiency of achieving this view of quality?

Similarly, the removal of the academic departmental scope reveals a methodology to answer the same, but more generic questions- (1) What are the key factors of an entity that identifies quality performance?; (2) What measure(s) can be used to capture the essence of each factor?; (3) What is the relative importance of the quality model's components to a stakeholder (or stakeholder groups)?; and (4) How can we systemically assess the relative efficiency of achieving this view of quality? The answers to such questions may meet the needs of hospitals, department stores, government, contractors and many more.

The more salient point is that this methodology further supports the notion that complex systems can be assessed in a data driven manner, while maintaining a sense of transparency throughout the overall process. Future research should build upon the models derived throughout, or use this methodology as a basis for different applications.

VI. Future Research

There are several opportunities to extend this research including:

(1) Expand Fidelity. This dissertation approaches the analysis at the department level. By performing the analysis at the *program level*, the number of DMUs are greatly increased, thereby increasing the discriminatory power of the model and enabling the introduction of additional inputs and/or outputs. Recall: 3 x (number of inputs + number of outputs) is less than the number of DMUs and number of inputs x number of outputs is less than the number of DMUs.

(2) Decrease Fidelity. There exist several instances where it may be of value to conduct the analysis at the *College level*. Much of the DEA literature in academia is conducted at the College level due to the availability of data reported to public sources at this level of aggregation. This abundance of data would allow for ease of analysis but the utility of the results would likely exist at the Provost level.

(3) Increase Breadth. By extending the analysis beyond a single University, analysis is possible across multiple colleges or as prominent throughout the DEA literature, multiple universities. While this level of analysis challenges many of the system dynamics and homogeneity concerns raised throughout this dissertation, there are instances where this level of analysis would be appropriate.

(4) Use ANP. The Analytic Network Process is used to capture the interrelatedness of components in a non-linear structure. By eliminating the constraint of a hierarchical definition of quality, a more complex (and possibly representative) assessment of quality is available.

(5) Integrate Other Methodologies. Integrate other methodologies such as Quality Function Deployment, SWOT Analysis and House of Quality.

(6) Derive Scoring Schema. Use DMU data to compute a quality scoring schema based on the AHP preferences.

(7) Add/Delete Stakeholders. Perform tests of statistical difference in preference among stakeholder groups to ensure the capture of the most meaningful stakeholders. For instance, based on the results of this study, it would be valuable to run the analysis based on the SFE groups and a second analysis on the A (hopefully with more participants in this group). It may also be effective to reduce the SFE to a group that is more accessible to reduce the data load.

(8) Develop Stakeholder Standards. The ability to determine a standard set of key areas of improvement based on the stakeholders of interest could be very useful. Using aggregate preferences for every possible combination of the 4 groups (19 combinations total) such a tool can be developed.

(9) Stakeholder Ranking. Vary the importance of stakeholder groups within the aggregate calculations to reflect the decision maker's perception of each group's importance to the decision at hand. This could be done by doing a AHP exercise at the Dean and Associate Deans level.

(10) Multiple Measures of a Single Attribute. The argument may be made that no single metric would be able to capture the information necessary to determine whether a department is of quality. This could be represented in a more robust manner, featuring multiple measures per unit as needed. However, either additional DMUs would be needed to add additional metrics or the analysis could be run per dimension. Recall that DEA limits the number of Inputs and Outputs that can be used depending on the number of DMUs because the ability to discriminate among units are compromised. This issue may be combat by viewing DMUs as programs over time.

(11) Multiple DEA Approach. Given the constraint that at least 1 input and 1 output has been identified for each dimension in the data envelopment analysis, it would be very useful to run DEA on each dimension. This would require data to capture all dimensions and a constraint that each cluster must have at least 1 input and 1 output. The number of DEA models would also be significantly greater.

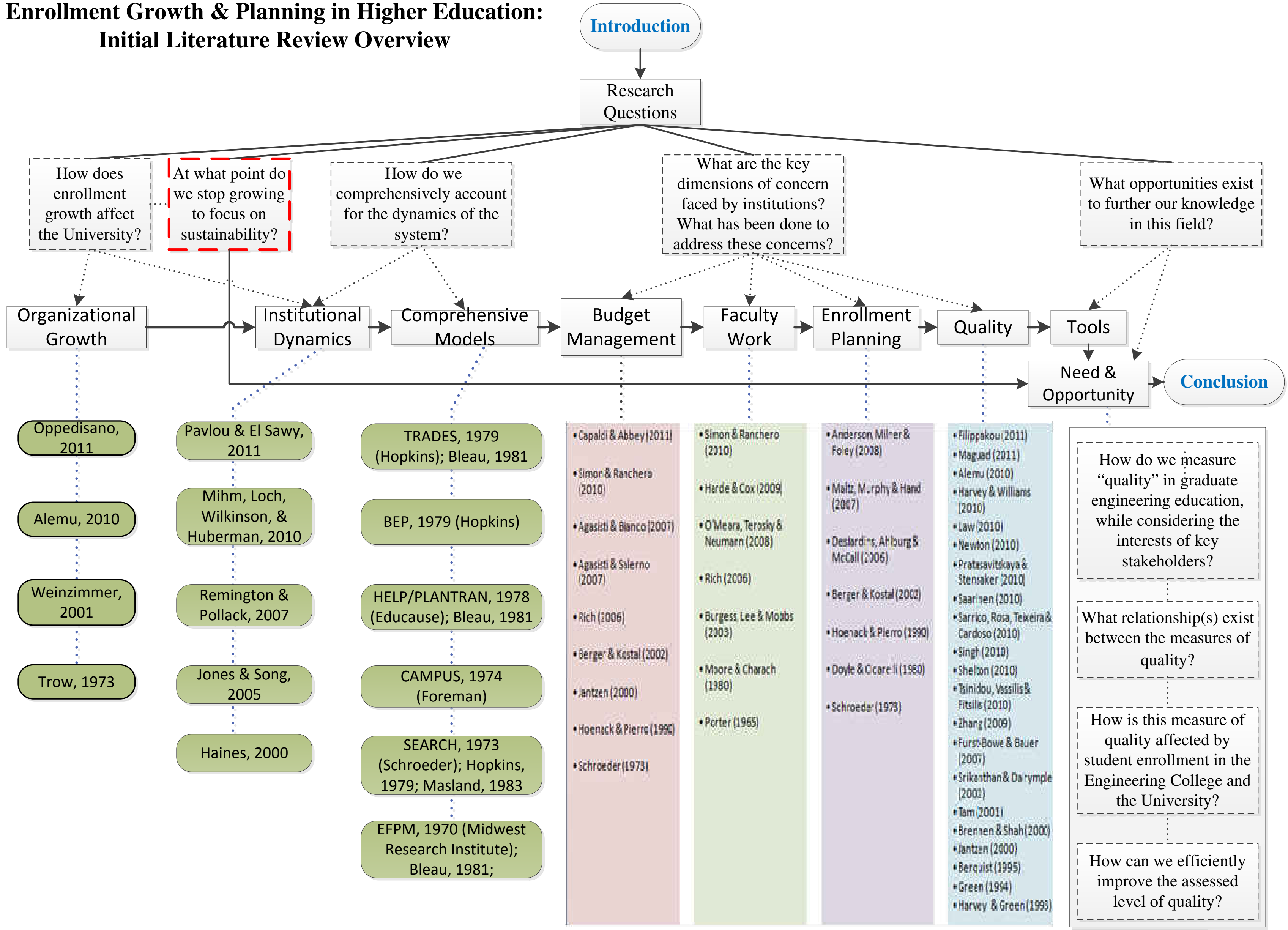
(12) Try input-oriented VRS model. Political forces may require an alternative to this approach. The objective would be to minimize inputs while maintaining the current level of quality. If administrators are satisfied with the current output and are more concerned with the reduction of resources, this may be a valid exercise. The results of this analysis could be compared with the results of the output-oriented model.

(13) Calculate quality costs. In an era of constrained resources the added value of understanding quality costs provides an opportunity to extend this research. Quality costs would capture any cost incurred as a result of not achieving total quality- investments to a void nonconformance, assessment of quality and an actual failure to meet the requirements.

(14) Create an Interactive Interface. The addition of a graphical user interface would make this model more user-friendly and automate the more tedious tasks. This GUI would allow the decision maker to be less concerned with the computational intensity of the model(s).

APPENDIX A: INITIAL LITERATURE REVIEW

Enrollment Growth & Planning in Higher Education: Initial Literature Review Overview



APPENDIX B: QUALITY CHARACTERISTIC REVIEW

Exploration of Quality Factors

Student (S), Faculty (F), Employers (E), Government (G), Community (C), Administrators (A)

	Stakeholders						Tool/Method	Inputs/Outputs/Factors/Characteristics
	S	F	E	G	C	A		
Ibrahim (2001)	N/A						Fuzzy Logic	Admission Requirements, Technical Requirements, Learner Support Services, Fees, Financial Aid, Enrollment, Faculty Support, Faculty Member Qualifications, Interactions, Delivery Structures, Curriculum, Learner's Assessment, Accreditation, Completion Rate, Employability of Graduates
Farid, Mirfakhredini, & Nejati (2008)		X					Professor Surveys/ Balanced Scorecard/ Fuzzy Logic	*(In order observed satisfaction)* Student Satisfaction, Academic Staff Satisfaction Grade, Ratio of Masters+ PhD Students to Academic Staff, Student Satisfaction Grade, Student's tendency to enter school, Level of performance-based culture availability, Ratio of Student to academic staff in undergraduate programs, University's position in national and international rankings, Avg. # of papers by academic staff published in ISI journal per year, average cycle of renewing educational facilities and equipment, Time cycle of computer and IT equipment at school, Avg. # papers published by academic staff in referred journals per year, # of complaints per month, avg. use of library services, ratio of office automation in processes, avg. # of papers by academic staff published by academic staff per year, Ratio of international students to total students, # of online programs offered by the school, Ratio of using computer in processing and keeping documents, value of contracts with industry per year, avg. lifecycle of facilities and equipment, annual revenue from tuition, total funds raised, avg. cost of educational staff, avg. cost of administrative staff, student's satisfaction level from school's internal processes; value of external raised services and aids, student's satisfaction level from school's administrative staff performance
Singh, Grover & Kumar (2008)	X	X	X				Quality Function Deployment/ Pairwise Comparison	Education Policy, Leadership, Monitoring, Self-Assessment, Strategic Planning, Top Management Commitment, Fund, Expenditure per student, Fee structure, cost of course, income source, Computers, infrastructure & buildings, library space & management, auditorium, health facilities, *(unreadable)*, class rooms & offices, sports complex, transportation, organization culture, quality assurance & audit, communication & information, course delivery, course & study material, IT & Multimedia, quality in teaching & learning, student & teacher assessment, student satisfaction, Industry/Institute Interaction, R &D Culture, Journal available, market orientation and focus, alumni, and quality of service
ABET Accreditation (2012-2013)	N/A						Required Measurable Outcomes	Evaluation Criteria grouped based on the following areas: Students, Program Educational Objectives, Student Outcomes, Continuous Improvement, Curriculum, Faculty, Facilities, Institutional Support

Kokal & Egitman (1998)	X	X	X				AHP/Quality Function Deployment	Stakeholder Requirements (General Knowledge, Skills and Approach; Professional Responsibility & Roles; Professional Knowledge) as related to education design requirements (curriculum design (required courses, electives, prerequisites, total credits, student industry experience), facilities & equipment (computers & network, labs, other electronic equipment, classrooms, library, cafeteria & canteens, dormitories, parking lots), faculty members (time, morale, credentials), teaching & counseling (class sizes, computer literacy, teamwork, teaching styles, exams, seminars & conferences, course schedules, counseling, multidisciplinary approach to practical problems), research (publications, industrial projects, scientific research), administration (budget, department philosophy, administrators), student life (student organizations, social & extracurricular activities) and other programs (post-graduate studies, pre-university programs, international programs, interdisciplinary programs)
Owlia & Aspinwall (1998)	X	X	X				Quality Function Deployment	Sufficiency of academic equipment, ease of access to the equipment, degree to which the equipment is modern-looking, ease of access to information sources, sufficiency of academic staff, theoretical knowledge of academic staff, extent to which academic staff are up to date in the subject, expertise of academic staff in teaching/communication, extent to which academic staff understand students' academic needs, degree of academic staff's willingness to help, availability of academic staff for guidance and advice, extent to which academic staff give personal attention, degree to which the gram contains primary knowledge/skills, degree to which the program contains ancillary knowledge/skills, extent to which students learn communication skills, extent to which students learn team working, relevance of curriculum to the future jobs of students, applicability of knowledge to other fields
Sahney & Karunes (2004)	X						SERVQUAL/ Quality Function Deployment	3 dimension: *Management system*- a well-accepted vision and mission statement, clearly defined and specific goals, effective and efficient leadership, clear and specific policies and procedures, strategic and operational planning, clear organizational structure and design, delegation of authority/power distribution, machinery for evaluation and control, budget priorities; Technical system- well defined curriculum design, suitability and relevance of curriculum content, curriculum planning, design, periodic review, instructional competence, expertise and adequacy, instructional arrangement, adaptive resource allocation (as in contingencies), adequate and competent administrative staff/support staff; Social system-trustworthiness among all, well-defined channels of communication, and customer focus/needs-based

Kennedy (1998)	X		X	X	X		Simulation/ Interviews	7 areas of quality- staff performance and productivity, budget, funding, student performance, quality of Research, quality of administration support, and equipment; Influence diagram of 67 key performance indicators- curriculum structure, information reached, staff views, course structure, assessment methods, resources available, commitment to teaching, quality of teaching, review of courseware and plans staff performance, employment opportunities, student perception, student performance, specialist staff, staff training, budget, staff motivation, communication overhead, remuneration, training period, allocated staff budget, staff involvement in planning, no of staff appraised, professional activities, management policy on staff recruitment, no of staff, terms of employment, fulltime, part time, planning policy, student contact time, lecture hours student motivation, staff support time, class size, student numbers, staff per student, number of graduates, quality of facilities, funding, grant and fees, previous grant and fees, target grant actual grant and fees, successful projects, quality of research, previous publication, planned publication, actual publication, internal funding, external funding, budget level, staff costs, teaching payroll, admin payroll, teaching number, admin number, research, research project, research dept, research students, research staff, non-staffing cost, class material, staff travel, FTT payroll, student no., FTT number
Tsinidou, Vassilis & Fitsilis (2010)	X						Fuzzy Logic/ Analytical Hierarchy Process / Analytical Network Process	Academic Staff (Academic qualifications, Professional experience, Communication skills, Friendliness/approachability, Links with enterprises, Research activity); Administration services (Rapid Service, Friendliness, Availability of Information material, Clear guidelines and advice, Office automation Systems for customer service (IT support), Use of internet for announcements, Sufficient working hours; Library services (Availability of textbooks and journals, Easy borrowing process, Friendliness, Working hours, E-library); Curriculum structure (Interesting module content/books, Educational material of high quality, Efficient structure of modules, Availability of information on the module structure, Variety of elective modules/modules on specialization areas, Laboratories (connection with market demands),Weekly timetable); Location (Accessibility, Frequency of transport service, Cost of transportation); Infrastructure (Quality infrastructure (classrooms and laboratories), Catering services, Free accommodation, Sport facilities, Medical facilities, Quality infrastructure (administration); Availability of services to host social and cultural events (theatrical plays, cinema); Carrier prospects (Perspectives for professional career, Opportunities for postgraduate programs, Opportunities to continue studies abroad, Availability of exchange programs with other institutes, Institution's links with business)

Hwarng & Teo (2000)	X	X					Quality Function Deployment/ Surveys/ Focus Groups	Article discusses several QFD applications with very specific purposes- i.e. course design & delivery, course registration, and research grant application.

APPENDIX C: HIGHER EDUCATION MODEL AUDIT

Model or Author	Descriptive					Normative			Prescriptive					
	Utility Functions	Time Series & Causal Forecasts	Fuzzy Theory	Networks	Other	Linear, Multi-Criteria Programming	Simulation	Networks	Decision Trees	Analytical Hierarchy Process	Data Envelope Analysis	Desciptive	Normative	Prescriptive
New Quality-Based Sources with Models														
Farid, Mirfakhredini, Nejati			1									Yes	No	No
Singh, Grover, Kumar					1							Yes	No	No
Ibrahim			1									Yes	No	No
Owlia, Aspinwall					1							Yes	No	No
Aydin, Kahraman, Kaya			1							1		Yes	No	Yes
Koksal, Egitman					1					1		Yes	No	Yes
Kennedy							1					No	Yes	No
Hwarng, Teo					1							Yes	No	No
Sahney & Karunes					1							Yes	No	No
Models in Higher Education Introduced in Candidacy Report/Presentation														
TRADES/EFPM	1					1						No	Yes	No
CAMPUS							1					No	Yes	No
RRPM		1					1					Yes	Yes	No
SEARCH							1					No	Yes	No
HELP/PLANTRAN							1					No	Yes	No
Agasisti, Bianco						1						No	Yes	No
Agasisti, Salerno											1	No	No	Yes
Berger, Kostal						1						No	Yes	No
Cohn, Rhine, Santos					1							Yes	No	No
DesJardins, Ahlburg,McCall	1											Yes	No	No
Doyle, Cicarelli		1										Yes	No	No
Geoffrion, Dyer, Feinberg						1						No	Yes	No
Harde and Cox					1							Yes	No	No
Hoenack, Pierro						1						No	Yes	No
Jantzen	1	1										Yes	No	No
Maltz, Murphy, Hand		1						1	1			Yes	Yes	Yes
Moore, Charach		1										Yes	No	No
Oppedisano		1										Yes	No	No
Porter		1										Yes	No	No
Shelton					1							Yes	No	No
Tsinidou, Vassilis & Fitsilis				1						1		Yes	No	Yes
Zhang					1							Yes	No	No

APPENDIX D: IRB APPROVALS

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Federica S. Robinson**

Date: **July 10, 2012**

Dear Researcher:

On 7/10/2012, the IRB approved the following activity as human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Project Title:	Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.
Investigator:	Federica S. Robinson
IRB Number:	SBE-12-08558
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 07/10/2012 08:48:31 AM EDT

IRB Coordinator

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Federica S. Robinson**

Date: **October 16, 2012**

Dear Researcher:

On 10/16/2012, the IRB approved the following minor modification to human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Modification Type:	The content of survey 2 has been modified. There are no additional changes to the study.
Project Title:	Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.
Investigator:	Federica S. Robinson
IRB Number:	SBE-12-08558
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 10/16/2012 04:20:43 PM EDT

Joanne Muratori

IRB Coordinator

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Federica S. Robinson**

Date: **February 12, 2013**

Dear Researcher:

On 2/12/2013, the IRB approved the following modification to human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Modification Type:	Addition of new Consent Forms, Protocol revisions, Methodology Revisions,
Project Title:	Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.
Investigator:	Federica S. Robinson
IRB Number:	SBE-12-08558
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. <u>When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.</u>

In the conduct of this research, you are responsible to follow the requirements of the <u>Investigator Manual.</u>

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 02/12/2013 09:31:30 AM EST

IRB Coordinator

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Federica S. Robinson**

Date: **February 28, 2013**

Dear Researcher:

On 2/28/2013, the IRB approved the following modification to human participant research that is exempt from regulation:

Type of Review:	Exempt Determination
Modification Type:	Modification to survey 4
Project Title:	Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.
Investigator:	Federica S. Robinson
IRB Number:	SBE-12-08558
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 02/28/2013 12:13:51 PM EST

IRB Coordinator

APPENDIX E: EMAIL INVITATIONS FOR PARTICIPATION

Round 1 Initial Email Invitation

Hello <Name>.

I am Federica Robinson-Bryant, a doctoral student in the University of Central Florida's Industrial Engineering and Management Systems Department. I am contacting you to solicit your feedback as to what characteristics or attributes constitute quality in academic programs. The purpose of this exercise is to develop a quality hierarchy based on the multiple and competing needs of key stakeholders in higher education, namely students, faculty, administrators and industry partners.

This research consists of three short rounds, conducting over the next few months. At any time, you do not wish to continue participation, simply discontinue submittal of the questionnaire. *Your participation is completely voluntary.*

Each round builds from the previous round and serves as a summary and editing process. All responses will be combined into one collaborative model, therefore anonymity among participants will be upheld.

Please review the attached consent document for more details about the project and continue to the following website if you choose to participate: <Insert Link>

For participation tracking purposes only, your personal identifier is <Insert #> and should be used consistently throughout this study.

If you have any questions about this study, please contact me at Federica_Robinson@knights.ucf.edu or refer to my faculty adviser and dissertation chair Dr. Jose Sepulveda of the IEMS Department at Jose.Sepulveda@ucf.edu.

Note: Round 1 will be open for participation <Enter Dates> only.

Thank you very much.

Federica Robinson-Bryant
Federica_Robinson@knights.ucf.edu

Round 1 Follow-up Email

Hello again.

The reason for this email is to remind you of the following invitation to participate in research to identify key factors denoting quality in academic programs (see the email thread below).

Please consider participating in Round 1 of this study by <Insert Date> at <Insert Time>. It is comprised of about 3 questions, requiring a short commitment in time.

Thank you very much.
Federica Robinson-Bryant

<Thread to Email #1>

Round 2 Initial Email Invitation

Hello <Name>.

I am Federica Robinson-Bryant, a doctoral student in the University of Central Florida's Industrial Engineering and Management Systems Department. I am contacting you to solicit your feedback as to the degree of relevance of several characteristics or attributes used to capture the quality of academic programs.

This research consists of one questionnaire requiring about 30-60 minutes of your time. If at any point you do not wish to continue participation, simply discontinue submittal of the questionnaire. *Your participation is completely voluntary.* The results will be analyzed anonymously, but your personal identifier (<Insert #>) will be used for participation tracking purposes.

Please review the attached consent document for more details about the project and continue to the following website if you choose to participate: <Insert Link>

If you have any questions about this study, please contact me at Federica_Robinson@knights.ucf.edu or refer to my faculty adviser and dissertation chair Dr. Jose Sepulveda of the IEMS Department at Jose.Sepulveda@ucf.edu.

Note: This questionnaire will be open for participation <Enter Dates> only.

Thank you very much.

Federica Robinson-Bryant
Federica_Robinson@knights.ucf.edu

Round 2 Follow-Up Email

Good morning.

This is a reminder email to inform you that the study to capture the importance of the characteristics of quality in academic programs will be closing soon. I would really appreciate your participation to expand the breadth of representation in your particular stakeholder group.

I am attaching a copy of the consent document for your review. Keep in mind that this survey may take 30 minutes to complete.

Please submit the attached document by <Enter Date> if you decide to participate by (1) pressing submit at the end of the form, (2) printing completed form and submitting to Dr. Sepulveda's IEMS mailbox, (3) emailing to Federica_Robinson@knights.ucf.edu or (4) arranging for pick-up.

Thank you very much for your support.

Federica Robinson-Bryant

Federica_Robinson@knights.ucf.edu

<Thread to Email #1>

Round 3 Initial Email Invitation

Hello CECS Administrators and Dissertation Committee Members.

I am working on a project to attempt to measure program efficiency at providing and maintaining quality as defined by multiple and competing stakeholder groups. I am currently in a phase of developing a concise model of quality to serve as the foundation of the overall decision support system.

As I finish of the final round of the stakeholder-heavy, Delphi-like study near <Insert Date>, I would like to hold a meeting with CECS administrators and several of my committee members at UCF Main Campus to finalize the model defining program quality.

If you would like to participate in this meeting, please respond with your availability between <Enter Dates>. I anticipate the time required to be around 1 hour and I will provide the draft model based on the four stakeholder groups collectively, prior to the meeting for your review.

Thank you very much.
Federica Robinson-Bryant
IEMS Department
Dissertation Chair: Dr. Jose Sepulveda

Round 3 Follow-Up Email

(Sent as a threaded message with the initial message)

Hello CECS Administrators and Dissertation Committee Members.

I originally sent a request in October regarding a meeting request to finalize a quality model required in my dissertation's methodology. I was unable to secure enough interest from CECS administrators. This email is a second attempt to gather a small group of representatives for the CECS administrator stakeholder group to finalize the quality model and continue with its integration into the remaining parts of my methodology.

I am attaching the current draft of the model for your review. If interested in assisting, please submit your availability <Enter Dates>, assuming the model review will take 1 hour or feel free to submit your feedback electronically.

Thank you very much beforehand for your willingness to participate.

Federica Robinson-Bryant
<Phone #>

Round 4 Initial Email Invitation

Good Day!

I am Federica Robinson-Bryant, a doctoral student in the University of Central Florida's Industrial Engineering and Management Systems Department. I am contacting you to solicit your feedback as to what characteristics or attributes constitute quality in academic programs. The purpose of this exercise is to develop a quality hierarchy based on the multiple and competing needs of key stakeholders in higher education, namely students, faculty, administrators and employers/industry partners.

This research consists of several pairwise comparisons. At any time, you do not wish to continue participation, simply discontinue submittal of the questionnaire. *Your participation is completely voluntary.* Your identity will never be disclosed therefore anonymity among participants will be upheld.

Please review the attached consent document for more details about the project and complete the Adobe file (.pdf) if you choose to participate. Submissions are accepted via email, hard copy or directly from the form.

If you have any questions about this study, please contact me at Federica_Robinson@knights.ucf.edu or refer to my faculty adviser and dissertation chair Dr. Jose Sepulveda of the IEMS Department at Jose.Sepulveda@ucf.edu.

Note: This survey will be open for participation until <Insert Date & Time> only.

Thank you very much.

Federica Robinson-Bryant
Federica_Robinson@knights.ucf.edu

Round 4 Follow-Up Email
(Sent as a threaded message with the initial message)

Good Day!

This is a reminder email to inform you that the study to capture the importance of the characteristics of quality in academic programs will be closing soon. I would really appreciate your participation to expand the breadth of representation in your particular stakeholder group.

I am attaching a copy of the consent document for your review. Keep in mind that this survey may take 30 minutes to complete.

Please submit the attached form by <Insert Date> if you decide to participate. Submissions are accepted via email, hard copy or directly from the form.

Thank you very much for your support.
Federica Robinson-Bryant
Federica_Robinson@knights.ucf.edu

APPENDIX F: SURVEY ONE

Definition of Quality: Round 1

Explanation of Research/Consent Form

Title of Project: Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.

Principal Investigator: Federica Robinson-Bryant

Faculty Supervisor: Dr. Jose Sepulveda

You are being invited to take part in a research study. Whether you take part is up to you.

•The purpose of this research is to solicit input from multiple stakeholder groups, as to what indicators (or attributes) describe the quality of academic programs.

•Faculty, students, administrators and industry partners will be expected to complete three (3) rounds of short questionnaires on the SurveyMonkey.com server. Each round builds from the previous and will be available for completion for approximately 2 weeks.

•Only completed questionnaires will be included in the study results. Therefore, any participant electing to withdraw from the study at any time should discontinue any remaining rounds.

•Each round must be completed in on sitting so please allow approximately 30-60 minutes for completion. If there is a need to return to a round, no answers will be saved and the round will remain open for the remainder of the period assign to that round.

*****You must be 18 years of age or older to take part in this research study.**

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints Federica Robinson-Bryant, Doctoral Student, Industrial Engineering Program, College of Engineering and Computer Science, Federica_Robinson@knights.ucf.edu or Dr. Jose Sepulveda, Faculty Advisor, Department of Industrial Engineering and Management Systems at (407) 823- 5307 or by email at Jose.Sepulveda@ucf.edu.

Definition of Quality: Round 1

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

Do you voluntarily agree to participate in Round 1 of this study at this time?

- Yes
- No

Please enter the respondent number found on your invitation email for participation tracking purposes.

RN# ____________________

Questionnaire

Thank you for choosing to participate in this study designed to acquire your perspective related to the quality of academic programs. "Quality" is being used to implicate your idea of "best", "effective", "efficient", or similar programs based on your stakeholder needs and requirements.

Directions: There are 3 questions in this round. Answer the following questions from the perspective of the stakeholder group to which you best belong- students, faculty, administrator or employer/industry partner.

Select the group to which you best belong:

- Student
- Faculty
- Administrator
- Employer/Industry Partner

Definition of Quality: Round 1

Based on your stakeholder needs and requirements, define a quality academic program or department in higher education.

Note: One or two sentences are ideal.

What attributes or aspects of an academic program or department is indicative of a quality program (for example, post-program employment rates or national reputation)? List as many descriptors as possible.

Thank you very much for your time. You will receive an email with access to the second round soon.

APPENDIX G: SURVEY TWO

Definition of Quality: Round 2

Explanation of Research/Consent Form

Title of Project: Developing a quality definition hierarchy based on multiple stakeholder needs and requirements.

Principal Investigator: Federica Robinson-Bryant

Faculty Supervisor: Dr. Jose Sepulveda

You are being invited to take part in a research study. Whether you take part is up to you.

•The purpose of this research is to solicit input from multiple stakeholder groups, as to what indicators (or attributes) describe the quality of academic programs.

•Faculty, students, administrators and industry partners will be invited to complete three (3) rounds of short questionnaires on the SurveyMonkey.com server. Each round builds from the previous and will be available for completion for approximately 2 weeks.

•Only completed questionnaires will be included in the study results. Therefore, any participant electing to withdraw from the study at any time should discontinue any remaining rounds.

•Each round must be completed in on sitting so please allow approximately 30 minutes for completion. If there is a need to return to a round, no answers will be saved and the round will remain open for the remainder of the period assign to that round.

*****You must be 18 years of age or older to take part in this research study.**

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints Federica Robinson-Bryant, Doctoral Student, Industrial Engineering Program, College of Engineering and Computer Science, Federica_Robinson@knights.ucf.edu or Dr. Jose Sepulveda, Faculty Advisor, Department of Industrial Engineering and Management Systems at (407) 823- 5307 or by email at Jose.Sepulveda@ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

Do you voluntarily agree to participate in Round 2 of this study at this time?

- Yes
- No

Please enter the respondent number found on your invitation email for participation tracking purposes.

RN#

Thank you for choosing to participate in this study designed to acquire your perspective related to the quality of academic programs. "Quality" is being used to implicate your idea of "best", "effective", or "efficient" programs based on your stakeholder needs and requirements.

Directions: There are 3 questions. Answer the following questions from the perspective of the stakeholder group to which you best belong- students, faculty, administrator or employer/industry partner.

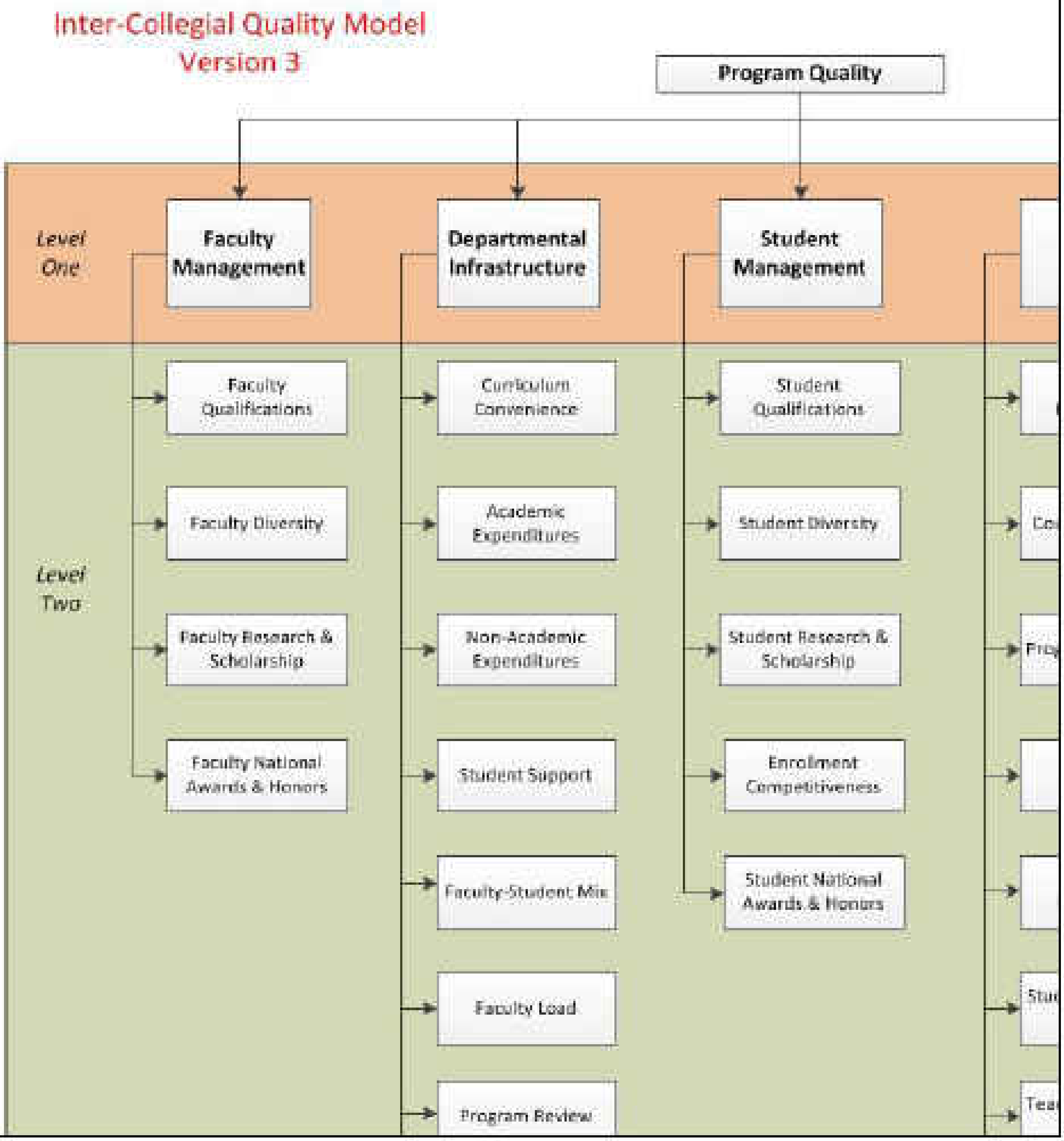
Select the group to which you best belong:

- Student
- Faculty
- Administrator
- Employer/Industry Partner

Definition of Quality: Round 2

Given the responses from Round 1, an initial model examining program quality within a single college has been constructed. Take a moment to absorb the contents of this model and proceed to the questions that follow.

Draft Program Quality Model



Definition of Quality: Round 2

Enter any comments or changes to the quality dimensions (Level One) below.

Note: Keep comments high-level at this time because the remainder of this survey is dedicated to evaluating the suitability of each attribute of Level Two.

Faculty Management

Departmental Infrastructure

Student Management

Student Learning

Program Sustainability

Other

Definition of Quality: Round 2

Faculty Management

This dimension of program quality, Faculty Management, currently has 4 attributes-

(1) Faculty qualifications: suitability of faculty (credentials, experience or similar)
(2) Faculty diversity: demographic mix of faculty
(3) Faculty research & scholarship: presence and impact of faculty in academic research
(4) Faculty's national awards and honors: faculty receiving national recognition

Take a moment to make comments, suggestions or changes to this dimension that would better identify attributes that capture the quality of faculty management.

*****Given the attribute FACULTY QUALIFICATIONS, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Ratio of full-time faculty to part-time faculty

*****Given the attribute FACULTY DIVERSITY, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Custom Derived Diversity Factor (taking into account ethnicity and sex)

Definition of Quality: Round 2

***Given the attribute **FACULTY RESEARCH & SCHOLARSHIP**, rank the following indicators assuming only one indicator will be selected to capture the attribute. Note: FTE is full-time equivalent.

[▾]	Metadata on number of citations of faculty's research
[▾]	Number of publications (journals, books, chapters, conference papers/presentations) per FTE
[▾]	Number of publications in an A-tier source per FTE

Include any suggestions outside the current list in the space below:

***Given the attribute **FACULTY NATIONAL AWARDS & HONORS**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Number of national awards and honors received per FTE

Definition of Quality: Round 2

Departmental Infrastructure

This dimension of program quality, Faculty Management, currently has 8 attributes-

(1) Curriculum Convenience: level of "flexibility" in program curriculum
(2) Academic Expenditures: budget resources allocated to academic expenditures
(3) Non-Academic Expenditures: budget resources allocated to academic expenditures
(4) Student Support: financial support provided to students during matriculation
(5) Faculty-Student Mix: distribution of faculty among its students
(6) Faculty Load: balance of faculty responsibilities
(7) Program Review: internal evaluation of program
(8) Service to the Community: mmount of service provided to the community

Take a moment to make comments, suggestions or changes to this dimension that would better identify attributes that capture the quality of departmental infratructure.

*****Given the attribute CURRICULUM CONVENIENCE, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

Percent of required courses offered via alternative delivery

Percent of curriculum that are electives (restricted/non-restricted)

Include any suggestions outside the current list in the space below:

*****Given the attribute ACADEMIC EXPENDITURES, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Proportion of program budget dedicated to academic expenditures

Definition of Quality: Round 2

***Given the attribute **NON-ACADEMIC EXPENDITURES**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Proportion of program budget dedicated to non-academic expenditures

***Given the attribute **STUDENT SUPPORT**, rank the following indicators assuming only one indicator will be selected to capture the attribute.

- Percent of students grad students receiving UCF supported fellowships/assistantships
- Percent of students grad students receiving internal/external fellowships/assistantships
- Amount of graduate student support

***Given the attribute **FACULTY-STUDENT MIX**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Ratio of FTE faculty to students (ugrad + grad)

***Given the attribute **FACULTY LOAD**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Average number of courses taught per FTE

Definition of Quality: Round 2

***Given the attribute **PROGRAM REVIEW**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Overall program evaluation rating given in departmental reviews

***Given the attribute **SERVICE TO THE COMMUNITY**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Number of service hours to the community per FTE

Definition of Quality: Round 2

Student Management

This dimension of program quality, Student Management, currently has 5 attributes-

(1) Student qualifications: preparedness of student (credentials, experience or similar)
(2) Student diversity: demographic mix of student
(3) Student research & scholarship: presence and impact of student in academic research
(4) Enrollment Competitiveness: Level of competition for admission
(5) Student national awards and honors: students receiving national recognition

Take a moment to make comments, suggestions or changes to this dimension that would better identify attributes that capture the quality of student management.

*****Given the attribute STUDENT QUALIFICATIONS, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

Entering GPA

Percent of students in Top 10% of High School Class

Include any suggestions outside the current list in the space below:

*****Given the attribute STUDENT DIVERSITY, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Custom Derived Diversity Factor (accounting for ethnicity and sex)

Definition of Quality: Round 2

***Given the attribute **STUDENT RESEARCH & SCHOLARSHIP**, rank the following indicators assuming only one indicator will be selected to capture the attribute.

- Metadata on number of citations of student research
- Number of publications (journals, books, chapters, conference papers or presentations)

Include any suggestions outside the current list in the space below:

***Given the attribute **ENROLLMENT COMPETITIVENESS**, rank the following indicators assuming only one indicator will be selected to capture the attribute.

- Ratio of students accepted to student applications
- Average GRE score of accepted Graduate student
- Average entering GPA of Undergraduate students
- Average entering GPA of accepted Graduate student

Include any suggestions outside the current list in the space below:

***Given the attribute **STUDENT NATIONAL AWARDS & HONORS**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Number of national awards & honors received

Definition of Quality: Round 2

Student Learning

This dimension of program quality, Student Learning, currently has 8 attributes-

(1) Student Employability: students' ability to secure employment post-graduation
(2) Course Evaluations: comprehensive course evaluation provided by enrolled students
(3) Program Evaluations: comprehensive evaluation of a program by its graduates (at all levels)
(4) Curriculum Competency: relevancy of the curriculum content to the field
(5) Student Performance: student academic performance in the program
(6) Student Experiential Learning: student participation in recognized practical experiences while matriculating through program.
(7) Teaching Relevancy/Quality: relevancy or quality of teaching delivered
(8) Student Competency: students' exemplification of mastery of topics related to discipline

Take a moment to make comments, suggestions or changes to this dimension that would better identify attributes that capture the quality of student learning.

*****Given the attribute STUDENT EMPLOYABILITY, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

Percentage employed within 1 year of graduation

Percentage employed in field within 1 year of graduation

Include any suggestions outside the current list in the space below:

*****Given the attribute COURSE EVALUATIONS, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Course evaluation rating

Definition of Quality: Round 2

***Given the attribute PROGRAM EVALUATION, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Program Evaluation Rating

***Given the attribute CURRICULUM CONVENIENCE, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

- Percentage of student passing national exam
- Curriculum-related student course evaluation rating

Include any suggestions outside the current list in the space below:

***Given the attribute STUDENT PERFORMANCE, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

- Undergrad student course grade (any student enrolled in program's course)
- Confirmed undergrad student's non-general education GPA

Include any suggestions outside the current list in the space below:

***Given the attribute STUDENT EXPERIENTIAL LEARNING, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

- Percent of undergraduate students graduating with experiential learning experience (not counting capstone exercise)
- Average amount of experiential experience at undergraduate exit

Definition of Quality: Round 2

Include any suggestions outside the current list in the space below:

*****Given the attribute TEACHING RELEVANCY/QUALITY, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

- Average number of courses taught by per FTE
- Teaching-related student course evaluation rating

Include any suggestions outside the current list in the space below:

*****Given the attribute STUDENT COMPETENCY, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: Percentage of students passing national exam in field

Definition of Quality: Round 2

Program Sustainability

This dimension of program quality, Program Sustainability, currently has 5 attributes-

(1) Affordability: long-term affordability of the program to its students
(2) Program Reputation: national reputation of program
(3) Industry/Government Relations: program presence in government and industry
(4) Intellectual Property: any patents, licensures, or other intellectual property held by the program
(5) Student Retention: program's ability to retain its students through graduation from the program

Take a moment to make comments, suggestions or changes to this dimension that would better identify attributes that capture the quality of program sustainability.

*****Given the attribute AFFORDABILITY, rank the following indicators assuming only one indicator will be selected to capture the attribute.**

[ ]	Graduate student debt at graduation
[ ]	All student debt at graduation
[ ]	Undergraduate Student debt at graduation
[ ]	Ratio of student salary after graduation to student debt at graduation

Include any suggestions outside the current list in the space below:

*****Given the attribute PROGRAM REPUTATION, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.**

Indicator: U.S. News & World Report Score

Definition of Quality: Round 2

***Given the attribute **INDUSTRY/GOVERNMENT RELATIONS**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Total research dollars from industry and government

***Given the attribute **INTELLECTUAL PROPERTY**, the following indicator was identified. Assuming only one indicator will be selected to capture the attribute, include any suggestions outside the current list in the space provided.

Indicator: Dollar value of intellectual property

***Given the attribute **STUDENT RETENTION**, rank the following indicators assuming only one indicator will be selected to capture the attribute.

	Percent of undergraduates receiving a degree in 5 years
	Percent of students internally transitioning from Undergraduate to Graduate Program

Include any suggestions outside the current list in the space below:

Definition of Quality: Round 2

Enter any additional comments, suggestions or links to references for further review below:

Thank you very much for your time. You will receive an email with access to the last round soon.

APPENDIX H: USER GROUP, FACILITATION SLIDES

Quality Model Review

Federica Robinson-Bryant

Voluntary Consent

Title of Project: *Developing a quality definition hierarchy based on multiple stakeholder needs and requirements*

Principal Investigator: *Federica Robinson-Bryant*

Faculty Supervisor: *Dr. Jose Sepulveda*

You are being invited to take part in a research study. Whether you take part is up to you.

- *The purpose of this research is to solicit feedback from multiple stakeholder groups, as to the appropriateness of several indicators (or attributes) in describing the quality of academic programs.*
- *You must be a UCF administrator to participate in this study.*
- *We ask that administrators participate in one (1) in-person session for approximately 1 hour.*
- *You are free to discontinue participation at any time by stating you no longer wish to participate. Therefore, any participant electing to withdraw from the study at any time should discontinue attendance.*

***You must be 18 years of age or older to take part in this research study.

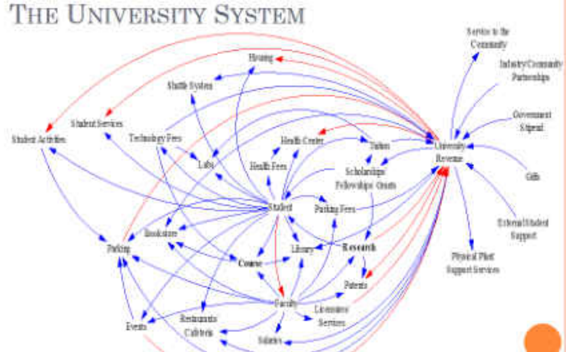
Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints Federica Robinson-Bryant, Doctoral Student, *Industrial Engineering Program, College of Engineering and Computer Science, Federica_Robinson@knights.ucf.edu or Dr. Jose Sepulveda, Faculty Advisor, Department of Industrial Engineering and Management Systems at (407) 823-3367 or by email at Jose.Sepulveda@ucf.edu.*

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

Agenda

- Research Questions
- Prospective Quality Architecture
- Progress to Date
  - Survey 1: n, Target Population, Objectives
  - Survey 2: n, Target Population, Objectives
  - Expert Group- Model Review: n, Target Population, Objectives
- Current Model
- Current I/Os
- Questions/Feedback

The University System



Research Questions

- What are the key dimensions/attributes of academic programs that constitute quality performance?
- How important are these dimensions/attributes to key stakeholders in their perception of a quality program?
  - How do you account for the dynamics of the system in the measurement of this view of "quality" while simultaneously considering the interests of key stakeholders?
- What measure(s) can be used to capture the essence of each attribute?
- How can quality inputs be leveraged to "optimize" program quality?

Research Questions

- What are the key dimensions/attributes of academic programs that constitute quality performance? ←
- How important are these dimensions/attributes to key stakeholders in their perception of a quality program?
- What measure(s) can be used to capture the essence of each attribute? ←
- How can quality inputs be leveraged to optimize program quality?

Assumptions

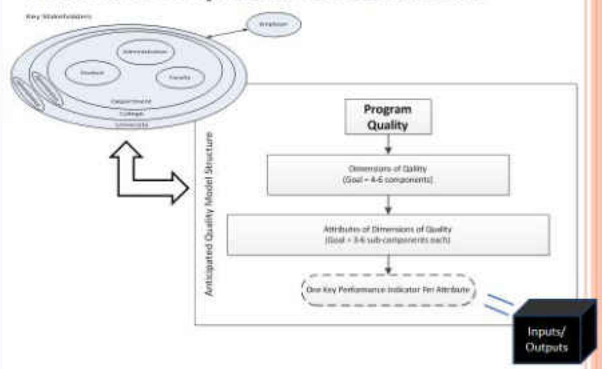
- Much data aggregated at the department level
- Cross functional use of faculty across programs

Solution: Program Quality = Departmental Quality

- Student enrollment in CECS is open, pending *only* acceptance into the University

Solution: Inputs exclude UGRAD factors outside of administrator control

Prospective Quality Architecture



Progress-to-Date

1 **Survey 1, Goal: n ≥ 4**
Target Population: SAFE

Objectives:
- Gather unique definitions of program quality
- Identify key areas of programs that implicate quality
- Highlight potential key performance indicators to capture those areas

2 **Survey 2, Goal: n ≥ 8**
Target Population: SAFE

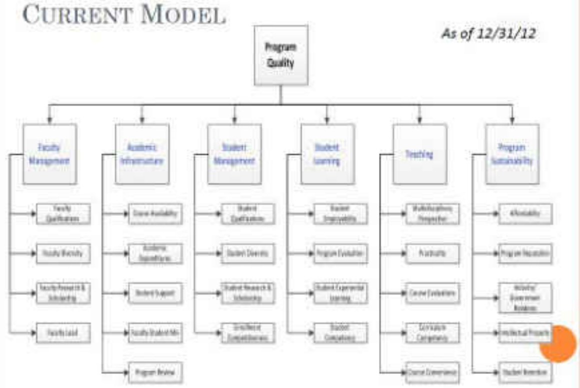
Objectives:
- Critique quality model
- Rank performance measures
- Incorporate stakeholder feedback to "clean" model architectures and identify KPIs

3 **Focus Group, Goal: n ≥ 5**
Target Population: Administrators

Objectives:
- Query appropriateness of model architecture and selected KPIs
- Identify data existence/availability/location
- Brainstorm alternative KPIs based on admin decision making needs

Current Model

As of 12/31/12



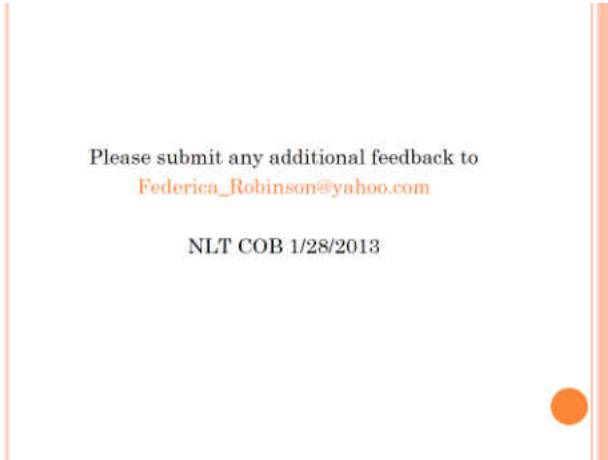
Current Inputs/Outputs

As of 12/31/12

Attribute	I/O	Definition	Key Performance Indicator
1.0 Faculty Management			
1.1 Faculty Qualification	I	Suitability of faculty- credentials, experience	% with a terminal degree in the discipline
1.2 Faculty Diversity	I	Demographic mix of faculty	Custom Derived Diversity Factor
1.3 Faculty Research & Scholarship	O	Impact of faculty in academic research	(Metadata) Avg. # of citations of faculty's work
1.4 Faculty Load	I	Balance of faculty responsibilities	Faculty impact matrix (see s2 results)
2.0 Academic Infrastructure			
2.1 Course Availability	I	Regularity of course offerings	% of courses offered multiple semesters
2.2 Academic Expenditures	I	Budget resources allocated to academic expenditures	$ of academic expenditures/program budget *(Program budget is pure program budget or program budget + research funding?)*
2.3 Student Support	I	Level of financial support provided to students during matriculation	Average amount of graduate student support/ graduate student
2.4 Faculty-Student Mix	I	Distribution of faculty among its students	Ratio of FTE teaching faculty to students (# of students enrolled in a program's course)
2.5 Program Review	O	Internal evaluation of program	Overall program evaluation (enhance, maintain, reduce, or eliminate outcomes)

Attribute	I/O	Definition	Key Performance Indicator
3.0 Student Management			
3.1 Student Qualifications	I	Preparedness of students- credentials, experience	Avg. graduate student entering GPA
3.2 Student Diversity	I	Demographic mix of students	Custom Derived Diversity Factor
3.3 Student Research & Scholarship	O	Presence of students in academic research	% of students with publications (journals, books, chapters, conference papers, conference presentations)
3.4 Enrollment Competitiveness	I	Admissions competition	# of graduate applications/# of graduate students accepted
4.0 Student Learning			
4.1 Student Employability	O	Students ability to secure "employment" post-graduation	Percentage employed in field within # year of graduation or attending graduate school
4.2 Program Evaluation	O	Comprehensive evaluation of a program by its graduates (at all levels)	Cumulative program evaluation rating
4.3 Student Experiential Learning	O	Student participation in recognized practical experiences while matriculating through program.	% of UGRAD graduating with experiential learning experience (not counting capstone exercise)
4.4 Student Competency	O	Exemplification of mastery of topics related to discipline	% of student passing national exam

Attribute	I/O	Definition	Key Performance Indicator
5.0 Teaching			
5.1 Multidisciplinary Perspective	I	Cross Discipline/Multidisciplinary context of curriculum and teaching	% of faculty teaching in multiple disciplines (departments)
5.2 Practicality	I	Depth of teaching potential	% of faculty with industry experience
5.3 Course Evaluations	O	Comprehensive course evaluation provided by enrolled students	Course evaluation rating
5.4 Curriculum Competency	I	Relevancy of the curriculum content to the field	# of years since last curriculum revision
5.5 Course Convenience	I	Level of "flexibility" in program curriculum	% of required courses offered via alternative delivery
6.0 Program Sustainability			
6.1 Affordability	O	Overall program affordability to its students	Ratio of average student salary after graduation to total cost of degree
6.2 Program Reputation	O	National reputation of program	US News & World Report Score
6.3 Industry/Government Relations	I/O	Program presence in industry/Government	Research $ from industry/government
6.4 Intellectual Property	O	Any patents, licensures or other intellectual property held by the program	# of patents per faculty
6.5 Student Retention	O	Program's ability to retain its students up to graduation from the program	% of students completing UGRAD program in 5/6 years



APPENDIX I: ABET CRITERIA

Criteria	Description
1	**STUDENTS**
1a	Evaluate student performance
1b	Monitor student progress
1c	Advise students regarding curricular and career matters
1d	Policies for acceptance of new and transfer students in place and enforced
1e	Policies for awarding transfer credits and work in lieu of courses taken at the institution
1f	Have and enforce procedure to ensure and document that students who graduate meet all graduation requirements
2	**PROGRAM EDUCATIONAL OBJECTIVES**
2a	Published and consistent with mission, the needs of the constituencies, and these criteria
2b	Documented and effective process, involving program constituencies, for the periodic review and revision of PEO's
3	**STUDENT OUTCOMES**
	Program has documented student outcomes that prepare graduates to attain the program educational objectives:
3a	-ability to apply knowledge of math, engineering, and science
3b	-ability to design and conduct experiments, as well as to analyze and interpret data
3c	-ability to design system, component or process to meet needs within realistic constraints
3d	-ability to function on multi-disciplinary teams
3e	-ability to identify, formulate, and solve engineering problems
3f	-understanding of professional and ethical responsibility
3g	-ability to communicate effectively
3h	-broad education
3i	-recognition of need by an ability to engage in life-long learning
3j	-knowledge of contemporary issues
3k	-ability to use techniques, skills, and tools in engineering practice
3l	-additional outcomes articulated by the program
4	**CONTINUOUS IMPROVEMENT**
4a	Regular use of appropriate, documented processes for assessing and evaluating the extent to which the program educational objectives are being attained
4b	Regular use of appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained
4c	Results of evaluations systematically utilized as input for the continuous improvement of the program
4d	Other information, if available, used to assist in improvement
5	**CURRICULUM**

5a	Devotes adequate attention and time to each component, consistent with the outcomes/objectives of the program/institution
5b	One year of college-level mathematics and basic (biological, chemical, and physical) sciences
5c	One and one-half years of engineering topics (See criterion statement)
5d	General education component consistent with program and institutional objectives
5e	Culminates in a major design experience based on knowledge and skills acquired in earlier course work and incorporates appropriate engineering standards and realistic constraints
6	**FACULTY**
6a	Sufficient number and competencies to cover all curricular areas
6b	Adequate levels of student-faculty interaction
6c	Adequate levels of student advising and counseling
6d	Adequate levels of university service activities
6e	Adequate levels of professional development
6f	Adequate levels of interaction with practitioners and employers
6g	Appropriate qualifications
6h	Sufficient authority for program guidance, evaluation, assessment, and improvement
6i	Overall competence
7	**FACILITIES**
	Adequate to support attainment of student outcomes and provide an atmosphere conducive to learning:
7a	Classrooms
7b	Offices
7c	Laboratories
7d	Associated equipment
7e	Modern tools, equipment , computing resources and laboratories are available, accessible, and systematically maintained and upgraded
7f	Students provided appropriate guidance regarding the use of the tools, equipment, computing resources, and laboratories
7g	Adequate library services, computing infrastructure, and information infrastructure
8	**INSTITUTIONAL SUPPORT**
8a	Institutional support and leadership sufficient to assure quality and continuity of the program
8b	Institutional services, financial support, and staff adequate to meet program needs
8c	Sufficient to attract and retain a well-qualified faculty and provide for their professional development
8d	Sufficient to acquire, maintain, and operate infrastructure, facilities, and equipment
8e	Sufficient to provide an environment to attain student outcomes

APPENDIX J: SURVEY THREE, AHP SURVEY

Departmental Quality Questionnaire Instructions

**Refer to the reference page for a description of each term introduced in this survey.*

Directions: Use the following scale to assign an importance rating to each pair.

1-	Equally Important	4-	Between Moderately and Strongly More Important	7-	Very Strongly More Important
2-	Between Equally and Moderately More Important	5-	Strongly More Important	8-	Between Very Strongly and Extremely More Important
3-	Moderately More Important	6-	Between Strongly and Very Strongly More Important	9-	Extremely More Important

For example, consider the following scenario:

Each row represents a comparison among 2 factors. Based on the 9-point scale above, denote the relative importance of the dominant factor nearest that factor.

______	Faculty Management	Academic Infrastructure	7
1	Faculty Management	Student Management	______
5	Faculty Management	Student Learning	______

Interpretation

Row 1- Academic Infrastructure is *Very Strongly More Important* than Faculty Management to Departmental Quality.

Row 2- Faculty Management is *Equally Important* as Student Management to Departmental Quality. Note: The 1 could be placed on either side since they are equal.

Row 3- Faculty Management is *Strongly More Important* than Student Learning to Departmental Quality.

Submission: All comparisons must be complete in order for the survey to count. Be sure to make all markings on the form. Please email completed surveys and/or any questions to Federica_Robinson@knights.ucf.edu or submit to Dr. Jose Sepulveda's physical mailbox in the UCF IEMS Department. All surveys are due by 3/27/13 at 5pm.

Reference Document | Consent Form

Departmental Quality Questionnaire

1. Please select 1 stakeholder group that best represents your role with respect to the University of Central Florida's College of Engineering & Computer Science:

☐ Student ☐ Faculty

☐ Administrator ☐ Employer/Industry/Government Partner

2. With respect to *Departmental Quality*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

	Faculty Management	Academic Infrastructure	
	Faculty Management	Student Management	
	Faculty Management	Student Learning	
	Faculty Management	Teaching	
	Faculty Management	Program Sustainability	
	Academic Infrastructure	Student Management	
	Academic Infrastructure	Student Learning	
	Academic Infrastructure	Teaching	
	Academic Infrastructure	Program Sustainability	
	Student Management	Student Learning	
	Student Management	Teaching	
	Student Management	Program Sustainability	
	Student Learning	Teaching	
	Student Learning	Program Sustainability	
	Teaching	Program Sustainability	

9-Pt Rating Scale

1- Equally Important
2- Between Equally and Moderately More Important
3- Moderately More Important
4- Between Moderately and Strongly More Important
5- Strongly More Important
6- Between Strongly and Very Strongly More Important
7- Very Strongly More Important
8- Between Very Strongly and Extremely More Important
9- Extremely More Important

Reference Document

PAGE 1

3. With respect to *Faculty Management*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

____	Academic Credentials of Faculty	Faculty Diversity	____
____	Academic Credentials of Faculty	Faculty Research & Scholarship	____
____	Academic Credentials of Faculty	Faculty Load	____
____	Faculty Diversity	Faculty Research & Scholarship	____
____	Faculty Diversity	Faculty Load	____
____	Faculty Research & Scholarship	Faculty Load	____

4. With respect to *Student Management*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

____	Graduate Student Qualifications	Student Diversity	____
____	Graduate Student Qualifications	Student Research & Scholarship	____
____	Graduate Student Qualifications	Enrollment Competitiveness	____
____	Student Diversity	Student Research & Scholarship	____
____	Student Diversity	Enrollment Competitiveness	____
____	Student Research & Scholarship	Enrollment Competitiveness	____

9-Pt Rating Scale

1- Equally Important
2- Between Equally and Moderately More Important
3- Moderately More Important
4- Between Moderately and Strongly More Important
5- Strongly More Important
6- Between Strongly and Very Strongly More Important
7- Very Strongly More Important
8- Between Very Strongly and Extremely More Important
9- Extremely More Important

Reference Document

5. With respect to *Academic Infrastructure*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

______	Course Access	Academic Expenditures	______
______	Course Access	Graduate Student Support	______
______	Course Access	Student-Faculty Ratio	______
______	Course Access	Facilities & Equipment	______
______	Academic Expenditures	Graduate Student Support	______
______	Academic Expenditures	Student-Faculty Ratio	______
______	Academic Expenditures	Facilities & Equipment	______
______	Graduate Student Support	Student-Faculty Ratio	______
______	Graduate Student Support	Facilities & Equipment	______
______	Student-Faculty Ratio	Facilities & Equipment	______

9-Pt Rating Scale

1- Equally Important
2- Between Equally and Moderately More Important
3- Moderately More Important
4- Between Moderately and Strongly More Important
5- Strongly More Important
6- Between Strongly and Very Strongly More Important
7- Very Strongly More Important
8- Between Very Strongly and Extremely More Important
9- Extremely More Important

6. With respect to *Teaching*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

______	Practicality	Course Evaluations	______
______	Practicality	Curriculum Competency	______
______	Practicality	Course Convenience	______
______	Course Evaluations	Curriculum Competency	______
______	Course Evaluations	Course Convenience	______
______	Curriculum Competency	Course Convenience	______

Reference Document

7. With respect to *Student Learning*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

______	Student Employability	Program Evaluation	______
______	Student Employability	Student Experiential Learning	______
______	Student Employability	Graduation Rates	______
______	Program Evaluation	Student Experiential Learning	______
______	Program Evaluation	Graduation Rates	______
______	Student Experiential Learning	Graduation Rates	______

8. With respect to *Program Sustainability*, rate the importance of the following pairs. Mark the rating nearest the dominant factor:

______	Value	Program Reputation	______
______	Value	Industry/Government Relations	______
______	Value	Intellectual Property	______
______	Program Reputation	Industry/Government Relations	______
______	Program Reputation	Intellectual Property	______
______	Industry/Government Relations	Intellectual Property	______

9-Pt Rating Scale

1- Equally Important
2- Between Equally and Moderately More Important
3- Moderately More Important
4- Between Moderately and Strongly More Important
5- Strongly More Important
6- Between Strongly and Very Strongly More Important
7- Very Strongly More Important
8- Between Very Strongly and Extremely More Important
9- Extremely More Important

Reference Document

Submit

PAGE 4

APPENDIX K: DISSERTATION RESOURCES

The resources required for this dissertation are categorized as being related to software, manpower, cost, and temporal bounds.

1. Software
    a. Microsoft Word was used to develop all base documents used throughout the dissertation.

    b. Adobe Acrobat XI Pro was used to transform a Microsoft Word document to a savable AHP survey with automatic submission capability via Adobe Forms Central.

    c. Matlab, a complex computation and analytics program, was employed to automate some of the more extensive or intensive computational needs. A Matlab program was developed to accomplish AHP analysis and simplify several tedious data analysis tasks.

    d. Microsoft Excel, a spreadsheet-based program, was used to collect, organize and maintain data throughout the phases of the dissertation. It was utilized to run initial analysis on methodology choices and assess their potential suitability to provide the output desired to answer the dissertation's questions.

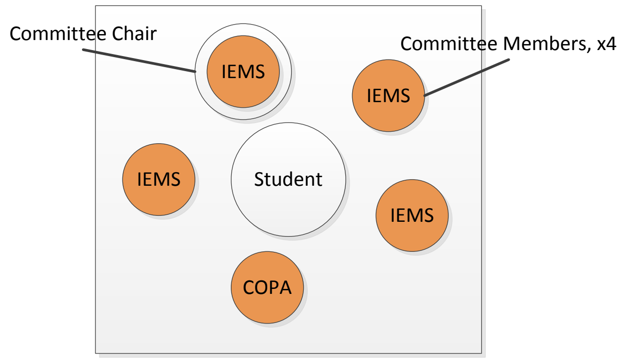
    e. Microsoft PowerPoint, a presentation tool, was used as the research facilitation mechanism in the expert group meeting to evaluate the draft quality model. It also served as the selected medium for the final dissertation presentation.

    f. SPSS, a statistics software solution, was utilized to analyze and verify the data throughout the lifecycle of the dissertation. Descriptive statistics, design of experiments tests, DEAHP model sensitivity analysis and other minor tasks were accomplished using this tool.

    g. Survey Monkey's online survey tool was utilized to conduct initial stakeholder surveys and provided full access to the data, per individual feedback and aggregate feedback. This data was manipulated online as needed and downloaded to a personal computer for further analysis.

2. Manpower

The manpower associated with this dissertation was one doctoral student under the advisement of four faculty and/or administrator level committee members and one committee chair. Under these conditions, an estimated 2080 man hours were expended by the student to complete this dissertation.



3. Budget

Cost associated with this dissertation was minimized due to negligible funding. As depicted in the table below, these costs were constrained to hardware and software-related expenses.

Hardware	Software
Dell Laptop ($500): Selective Purpose Device	Adobe Acrobat XI Pro & Forms Central ($50): Online Matlab ($100): Academic Version Micrsoft 365 ($100): Annual Subscription SPSS ($100) SurveyMonkey.com ($25 x 5 = $125) Frontier Analyst ($315)
	Total = $1290

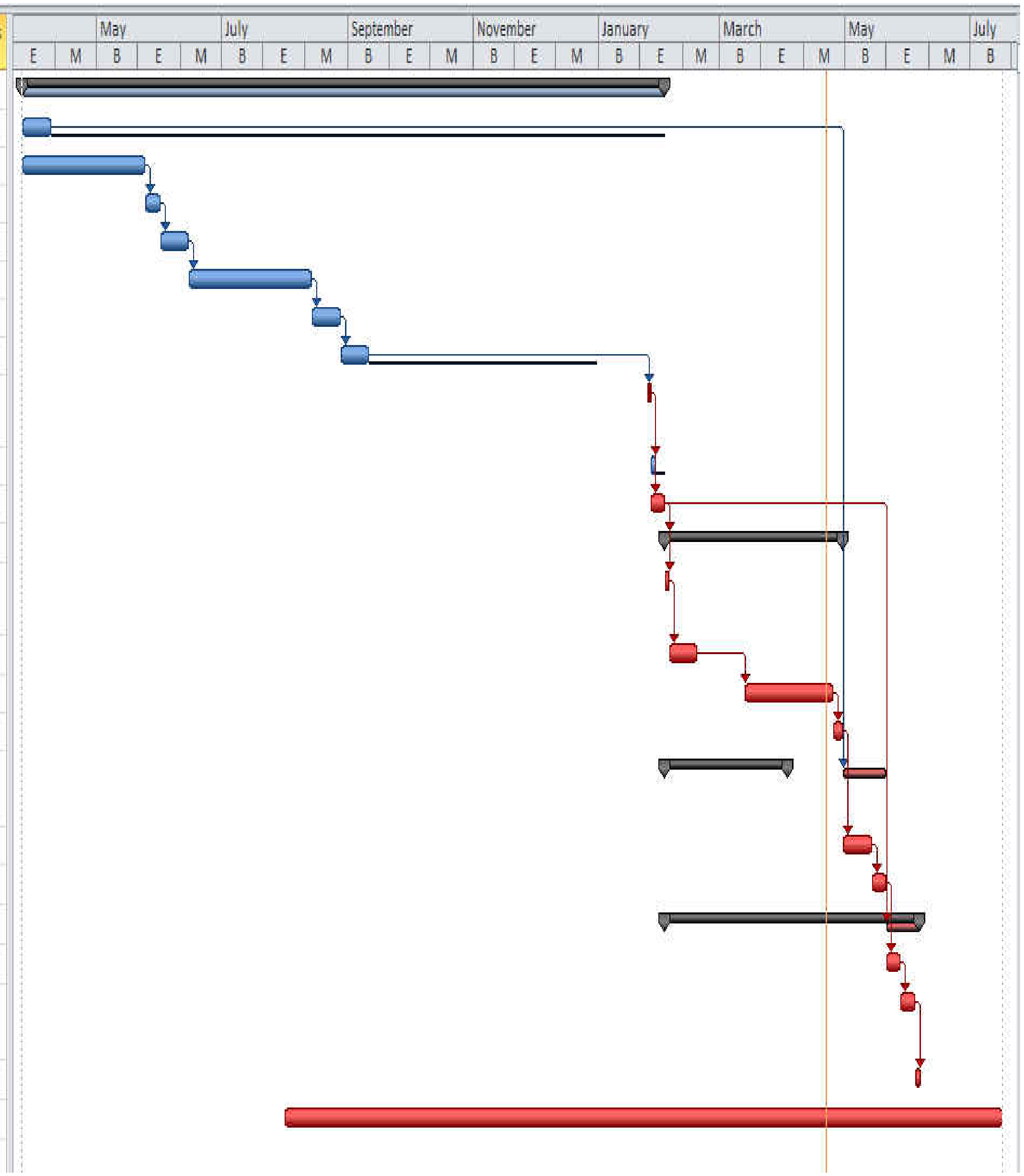
4. Schedule

The dissertation formally began following the completion of the proposal examination on 3/27/2012. The tasks were completed in both synchronous and asynchronous formats to improve the overall length of completion, ending with a completed dissertation by 7/16/2013 and a first iteration, formatted draft of the dissertation by 5/31/13.

This schedule ensured that all process-oriented requirements of the University were met for graduation in Summer 2013. Major university deadlines were acknowledged as the (1) Submission of near-complete dissertation for formatting review to UCF Graduate Studies- *5/31*; (2) Request of a dissertation defense date from advisor- *5/31*; (3) Dissertation defense deadline- *7/9*; and the (4) Final dissertation draft deadline to UCF Graduate Studies- *7/19.* These steps are outlined below, with some variation in the expected end date to allow for slack in the schedule. A more complete schedule follows.

	Est. Start	Est. End	Predecessor
1- Dissertation Proposal	1/1/2012	3/27/2012	
2- Conduct Dissertation	3/28/2012	5/31/2013	1
3- Dissertation Draft	3/28/2012	5/31/2013	1
4- Format Review Submission	4/1/2013	5/15/2013	
5- Dissertation Defense		7/1/2013	4
6- Final Format Review Submission		7/19/2013	5

Task Name	Duration	Start	Finish	Predecessors
Define Departmental Quality	**313 days**	**Mon 3/26/12**	**Fri 2/1/13**	
IRB Application	14 days	Mon 3/26/12	Sun 4/8/12	
Survey 1	60 days	Mon 3/26/12	Thu 5/24/12	
Quality Model.V1	7 days	Fri 5/25/12	Thu 5/31/12	3
IRB Addendum	14 days	Fri 6/1/12	Thu 6/14/12	4
Survey 2	60 days	Fri 6/15/12	Mon 8/13/12	5
Quality Model.V2	14 days	Tue 8/14/12	Mon 8/27/12	6
IRB Addendum	14 days	Tue 8/28/12	Mon 9/10/12	7
Conduct Expert Group Feedback Meeting	1 day?	Fri 1/25/13	Fri 1/25/13	8
Model Verification & Validation	3 days	Sat 1/26/13	Mon 1/28/13	9
Final Quality Model	7 days	Sat 1/26/13	Fri 2/1/13	9
Analytical Hierarchy Process	**87 days**	**Sat 2/2/13**	**Mon 4/29/13**	**11**
Convert Quality Model.V3 to AHP	2 days	Sat 2/2/13	Sun 2/3/13	11
IRB Addendum	14 days	Mon 2/4/13	Sun 2/17/13	13
AHP Survey	43 days	Wed 3/13/13	Wed 4/24/13	14
AHP Analysis	5 days	Thu 4/25/13	Mon 4/29/13	15
Identify Measures to Capture Quality	**60 days**	**Sat 2/2/13**	**Tue 4/2/13**	**2**
Collect & Organize Data	14 days	Tue 4/30/13	Mon 5/13/13	16
Des Stats & Correlation Analysis	7 days	Tue 5/14/13	Mon 5/20/13	18
Data Envelopment Analysis	**124 days**	**Sat 2/2/13**	**Wed 6/5/13**	**11**
DEAHP model(s)	7 days	Tue 5/21/13	Mon 5/27/13	19
Results Analysis, Testing, Verification	7 days	Tue 5/28/13	Mon 6/3/13	21
Validation	3 days	Tue 6/4/13	Thu 6/6/13	22
Dissertation Documentation	350 days	Wed 8/1/12	Tue 7/16/13	



APPENDIX L: RISK MANAGEMENT PLAN

The table below summarizes this project's approach. It correlates the research questions with the chosen methods to address each of them. The level of risks associated with data, time and costs requirements to achieve each component was estimated using a low, medium and high scale. The data collection tasks presented the highest risks, in that survey participation rates are generally low when no incentive is being offered. In addition, the Institutional Review Board (IRB) process can become extensive, and was not completely within the control of the researcher.

Low (green) Medium (yellow) High (red)

		Risks		
Research Questions	**Need & Approach**	**Data**	**Time**	**Cost**
What are the key dimensions/attributes of academic programs that identify quality performance?	Baseline Model → *Literature Analysis*	Low	Medium	Low
	Model Derivation → SAFE Surveys; *Expert Group; Validation*	High	High	Medium
What measure(s) can be used to capture the essence of each attribute?	Input-Output Limitation → *AHP Survey; Descriptive Statistics; Correlation Analysis; Significance Tests*	Medium	Low	Low
What is the relative importance of quality model components to SAFE stakeholder groups?	Stakeholder Preference Data Collection → *Survey Dissemination & Analysis*	High	High	Medium
	Derive AHP weights to determine importance of inputs and outputs → *Analytic Hierarchy Process*	Low	Low	Low
How can we systemically measure quality while considering the needs of stakeholder groups?	Dept. Data Collection → *Data collected via public sources and provided by contacts*	High	High	Low
	Measure relative effectiveness of DMUs → *DEAHP*	Medium	Low	Medium
	Model Verification & Validation → *Sensitivity Analysis*	Low	Low	Low

Risk Mitigation Strategy

The high risks in this dissertation were related to data collection and several strategies were adapted to mitigate the risks of occurrence and its impact:

(1) Model Derivation- SAFE Surveys, Expert Group

Data: The surveys were disseminated to a limited sample of participants so as to increase the likelihood of future participation (i.e. in the AHP survey).

Time: Survey invitations listed a 2- week availability for each round of the survey, although the window allocated in the schedule was much longer. This approach was utilized to motivate respondents to take action in a timely manner and to aid in the process of non-participant follow-up.

Cost: The free membership of Survey Monkey.com was used to develop each survey. Only when actual dissemination was to take place was the membership upgraded to a paid membership.

(2) Stakeholder Preference Data Collection- AHP Surveys

Data: Several formats were created and disseminated among stakeholder groups, a paper form delivered in person and an electronic form delivered via email.

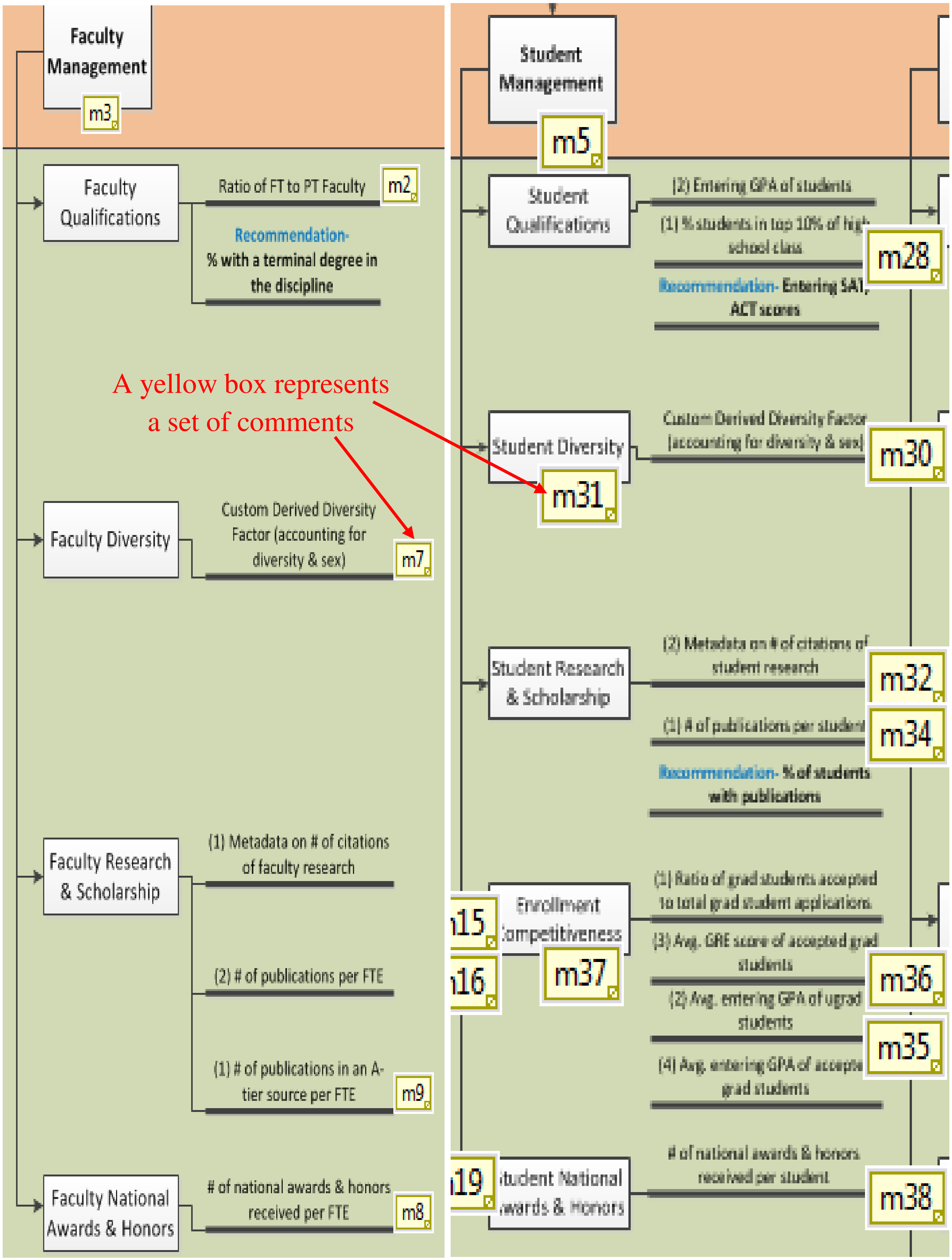
Time: The instrument was delivered following a temporal strategy similar to that employed in the Delphi method data collection process. One difference is that paper surveys were delivered to each faculty/administrator's office space about mid-way through the process, and surveys were also delivered to student classrooms.

Cost: The free membership of Adobe Forms Central was used to develop each survey. Only when actual dissemination was to take place was the membership upgraded to a paid membership. Additionally, paper surveys were printed on an as needed basis, for immediate distribution.

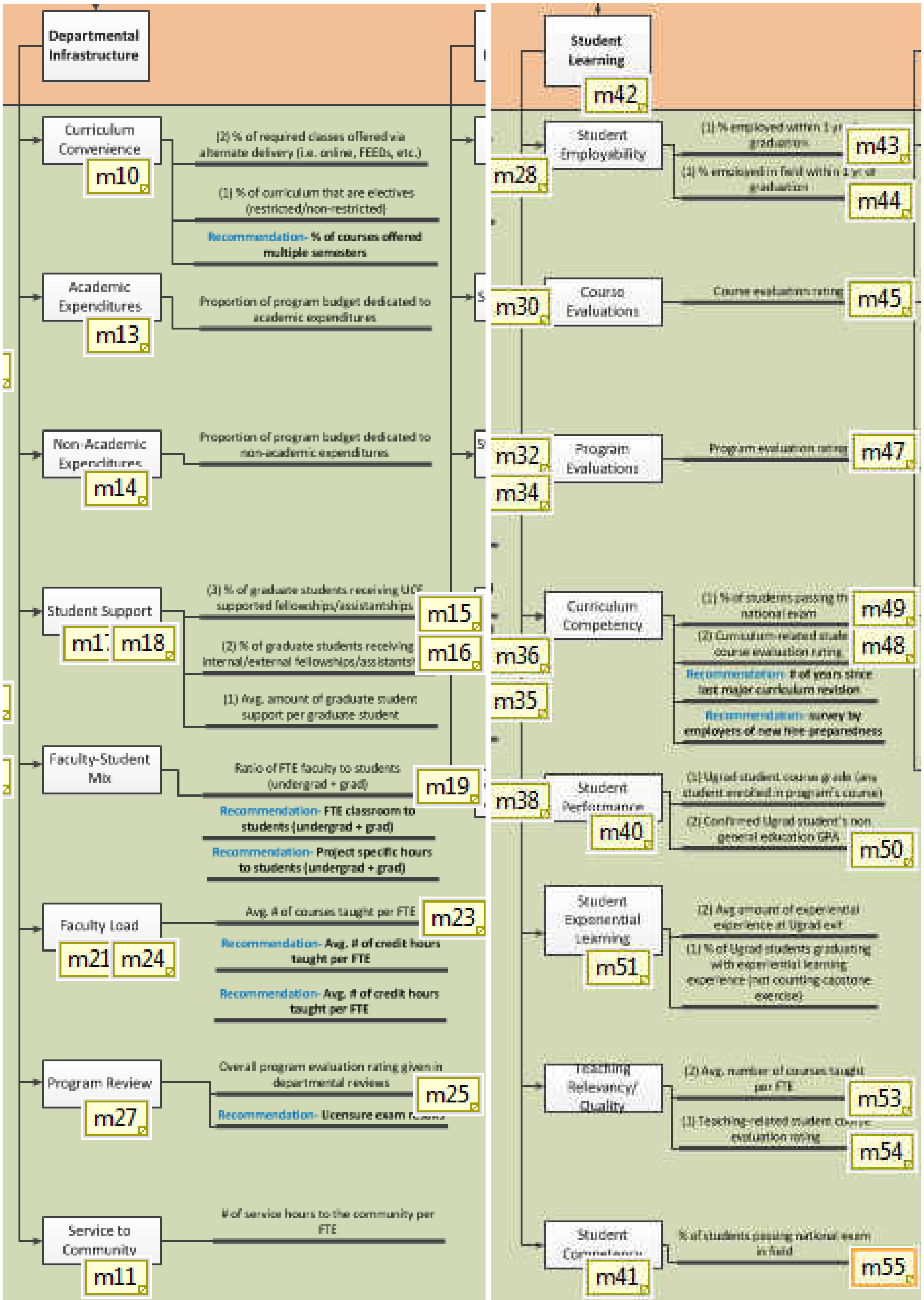
(3) Department Data Collection- KPI DMU Data

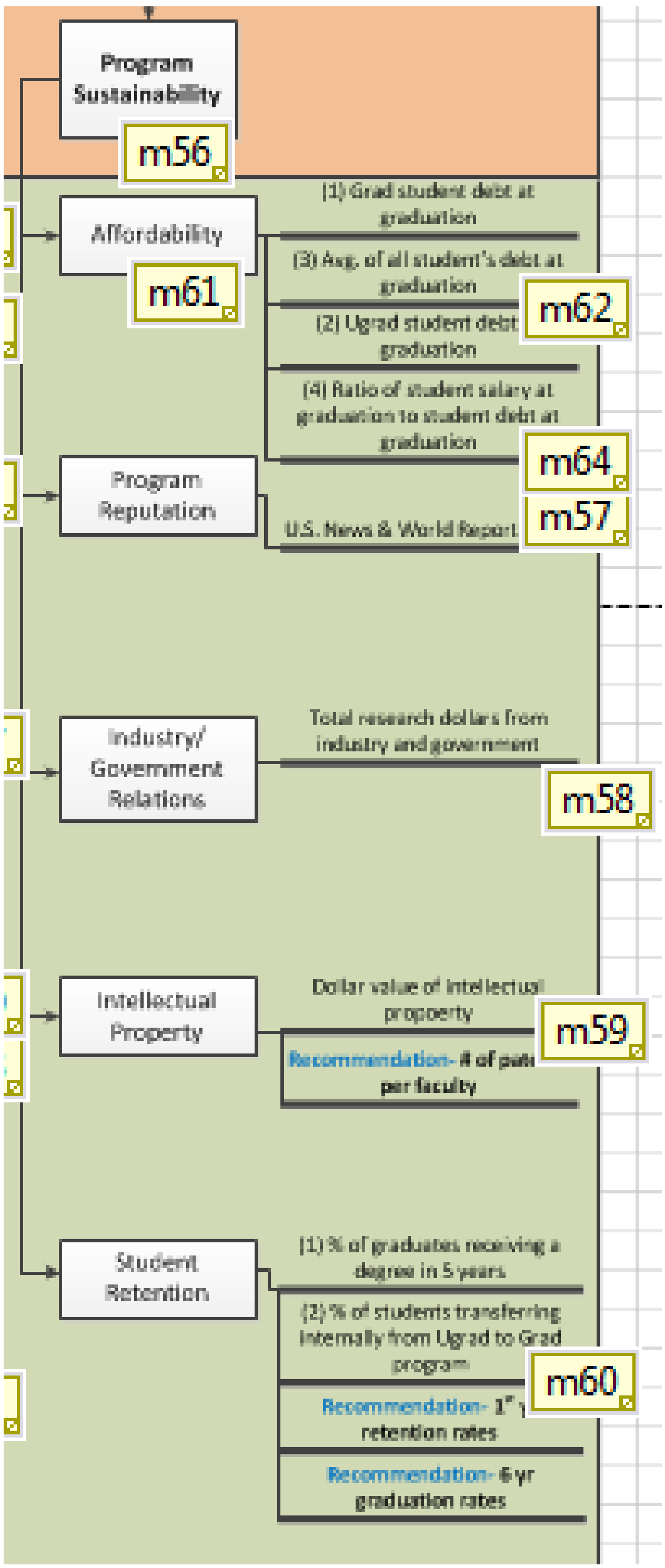
Data/Time: Alternative metrics was requested in the case that any metric is not available. This was done to account for the access/availability issues inherent to the University System. Alternative measures would also be useful in cases where the metric does not share appropriate correlations with other metrics.

APPENDIX M: ROUND 2 RESULTS COMPILATION



Faculty Management
m3
Faculty Qualifications
Ratio of FT to PT Faculty
m2
Recommendation-
% with a terminal degree in the discipline
A yellow box represents a set of comments
Faculty Diversity
Custom Derived Diversity Factor (accounting for diversity & sex)
m7
Faculty Research & Scholarship
(1) Metadata on # of citations of faculty research
(2) # of publications per FTE
(1) # of publications in an A-tier source per FTE
m9
Faculty National Awards & Honors
# of national awards & honors received per FTE
m8
Student Management
m5
Student Qualifications
(2) Entering GPA of students
(1) % students in top 10% of high school class
m28
Recommendation- Entering SAT, ACT scores
Student Diversity
m31
Custom Derived Diversity Factor (accounting for diversity & sex)
m30
Student Research & Scholarship
(2) Metadata on # of citations of student research
m32
(1) # of publications per student
m34
Recommendation- % of students with publications
Enrollment Competitiveness
m37
(1) Ratio of grad students accepted to total grad student applications
(3) Avg. GRE score of accepted grad students
m36
(2) Avg. entering GPA of ugrad students
m35
(4) Avg. entering GPA of accepted grad students
Student National Awards & Honors
# of national awards & honors received per student
m38


Departmental Infrastructure
Curriculum Convenience
m10
(2) % of required classes offered via alternate delivery (i.e. online, FEEDs, etc.)
(1) % of curriculum that are electives (restricted/non-restricted)
Recommendation- % of courses offered multiple semesters
Academic Expenditures
m13
Proportion of program budget dedicated to academic expenditures
Non-Academic Expenditures
m14
Proportion of program budget dedicated to non-academic expenditures
Student Support
m18
(3) % of graduate students receiving UCF supported fellowships/assistantships
m15
(2) % of graduate students receiving internal/external fellowships/assistantships
m16
(1) Avg. amount of graduate student support per graduate student
Faculty-Student Mix
Ratio of FTE faculty to students (undergrad + grad)
m19
Recommendation- FTE classroom to students (undergrad + grad)
Recommendation- Project specific hours to students (undergrad + grad)
Faculty Load
m21
m24
Avg. # of courses taught per FTE
m23
Recommendation- Avg. # of credit hours taught per FTE
Recommendation- Avg. # of credit hours taught per FTE
Program Review
m27
Overall program evaluation rating given in departmental reviews
m25
Service to Community
m11
# of service hours to the community per FTE
Student Learning
m42
Student Employability
m28
m43
m44
Course Evaluations
m30
Course evaluations rating
m45
Program Evaluations
m32
m34
Program evaluation rating
m47
Curriculum Competency
m36
m35
m49
m48
Recommendation- # of years since last major curriculum revision
Recommendation- survey by employers of new hire preparedness
Student Performance
m38
m40
(2) Confirmed Ugrad student's non general education GPA
m50
Student Experiential Learning
m51
(2) Avg amount of experiential experience at Ugrad exit
(1) % of Ugrad students graduating with experiential learning experience (not counting capstone exercise)
Teaching Relevancy/ Quality
(2) Avg. number of courses taught per FTE
m53
(1) Teaching-related student course evaluation rating
m54
Student Competency
m41
% of students passing national exam in field
m55



Program Sustainability
m56
Affordability
m61
(1) Grad student debt at graduation
(3) Avg. of all student's debt at graduation
m62
(2) Ugrad student debt graduation
(4) Ratio of student salary at graduation to student debt at graduation
m64
Program Reputation
U.S. News & World Report
m57
Industry/ Government Relations
Total research dollars from industry and government
m58
Intellectual Property
Dollar value of intellectual property
m59
Recommendation- # of pat per faculty
Student Retention
(1) % of graduates receiving a degree in 5 years
(2) % of students transferring internally from Ugrad to Grad program
m60
Recommendation- 1st retention rates
Recommendation- 6 yr graduation rates

APPENDIX N: QUALITY MODEL INCLUDING ABET MAPPING

Obj.	Dimension	Attribute	Definition	Performance Indicators (PIs)	I/O	ABET Criteria
Departmental Quality	**Faculty Management**	Faculty Qualifications	Academic credentials of faculty	Ratio of tenure earning faculty to instructors + lecturers	**I**	**6gi**
		Faculty Diversity	Demographic mix of faculty	Custom Derived Diversity Factor using M/F, Hispanic or Black/Other)	**I**	**NA**
		Faculty Research & Scholarship	Impact of faculty in academic research	# of publications against impact factor of publication source	**O**	**6i**
		Faculty Load	Balance of faculty responsibilities	Faculty activity matrix	**I**	**6d**
	Academic Infrastructure	Course Access	Regularity of course offerings	% of courses offered multiple semesters	**I**	**8a**
		Academic Expenditures	Budget resources allocated to academic expenditures	$ spent/# graduating UGRAD student	**I**	**8ab**
		Graduate Student Support	Level of financial support provided to students during matriculation	Average amount of FT graduate student support	**I**	**8b**
		Student-Faculty Mix	Distribution of faculty among its students	Ratio of FTE teaching faculty (associate, assistant, tenured track, non-tenured track, lecturers, instructors…FT only) to FTE students	**I**	**6b,8**
		Facilities & Equipment	Adequacy of facilities and equipment	Total classroom space (sq ft)/total # of students enrolled in courses each year	**I**	**7a,8e**
	Student Manage ment	Graduate Student Qualifications	Entering student preparedness level	Avg. graduate student entering GPA	**I**	**1d***
		Student Diversity	Demographic mix of students	Custom Derived Diversity Factor	**I**	**NA**

				using (Consider M/F, Hispanic or Black/Other)		
		Student Research & Scholarship	Presence of students in academic research	Avg. # students published with faculty per faculty published	**O**	**3b**
		Enrollment Competitiveness	Admissions competition	# of GRAD students accepted/# of GRAD accepted applicants enroll	**I**	**1d**
	Student Learning	Student Employability	Students ability to secure "employment" post-graduation	Percentage employed within 1 year of graduation or attending graduate school	**O**	**3a**
		Program Evaluation	Comprehensive evaluation of a program by its graduates	Cumulative program evaluation rating	**O**	**2b,4abc**
		Student Experiential Learning	Student participation in recognized practical experiences while matriculating through a program.	% of UGRAD graduating with formal experiential learning experience (not counting capstone exercise)	**O**	**3ak**
		Graduation Rate	Program's ability to retain its students through graduation from the program	% of students completing UGRAD program in 6 years	**O**	**1b**
	Teaching	Practicality	Experiential context of curriculum and teaching	% of faculty with FT industry experience of $\geq$ 1 yr	**I**	**6fi,3hj**
		Course Evaluations	Comprehensive course evaluation provided by enrolled students	Course evaluation rating	**O**	**4ac**
		Curriculum Competency	Relevancy of the program content to the field	Institutional effectiveness of program	**I**	**2b,5a, 4abc**
		Course Convenience	Level of "flexibility" in program curriculum	% of required GRAD courses offered via alternative delivery	**I**	**8**
	Program Sust	Value	Overall program affordability to its students	Student cost per credit hours per program over national average	**O**	**NA**

		Program Reputation	National reputation of program	US News & World Report Score	**O**	**4d**
		Industry/Government Relations	Program presence in Industry/Government activities	Research $ from industry/government	**O**	**6f,8ab**
		Intellectual Property	Patents, licensures or other intellectual property held by the program	# of patents per faculty	**O**	**7e***

*****_**Blue**_ fields denote a possible indirect relationship to ABET criteria.

APPENDIX O: AHP RESULTS

**Inconsistent *Top 10*		Students		Administrator		Faculty		Employer		Composite				AM	GM
		Local	Global	Local	Global	Local	Global	Local	Global	LocalGM	GlobalGM	LocalAM	GlobalAM	Ranking	Ranking
Faculty Management		**0.0655**		**0.2855**		**0.1491**		**0.1027**		0.1301		0.1507			
Faculty Qualifications	I	0.3896	0.0255	0.4555	0.1300	0.4289	0.06392	0.2642	0.02712	0.3765	0.0490	0.3845	0.0616	6	5
Faculty Diversity	I	0.1071	0.0070	0.0555	0.0158	0.0593	0.00883	0.0572	0.00587	0.0670	0.0087	0.0698	0.0094	22	20
Faculty Research & Scholarship	O	0.2359	0.0155	0.4255	0.1215	0.3210	0.04785	0.2429	0.02494	0.2975	0.0387	0.3064	0.0524	8	9
Faculty Load	I	0.2674	0.0175	0.0635	0.0181	0.1908	0.02845	0.4357	0.04473	0.1939	0.0252	0.2394	0.0272	15	15
Student Management		**0.1264**		**0.0872**		**0.1817**		**0.0747**		0.1106	0.0000	0.1175			
Graduate Student Qualifications	I	0.3102	0.0392	0.4369	0.0381	0.4123	0.0749	0.3563	0.02662	0.3756	0.0415	0.3789	0.0447	10	7
Student Diversity	I	0.1305	0.0165	0.0420	0.0037	0.0715	0.01299	0.0682	0.0051	0.0719	0.0080	0.0781	0.0096	21	21
Student Research & Scholarship	O	0.3476	0.0439	0.4369	0.0381	0.3740	0.06796	0.3100	0.02317	0.3643	0.0403	0.3671	0.0433	11	8
Enrollment Competitiveness	I	0.2116	0.0268	0.0841	0.0073	0.1422	0.02584	0.2655	0.01984	0.1610	0.0178	0.1759	0.0199	18	17
Academic Infrastructure		**0.0743**		**0.0205**		**0.0632**		**0.0503**		0.0469		0.0521			
Course Access	I	0.2435	0.0181	0.0218	0.0004	0.0541	0.00342	0.3341	0.01681	0.0990	0.0046	0.1634	0.0097	20	25
Academic Expenditures	I	0.1445	0.0107	0.1586	0.0032	0.1398	0.00883	0.1223	0.00616	0.1407	0.0066	0.1413	0.0072	25	23
Graduate Student Support	I	0.1711	0.0127	0.1725	0.0035	0.2113	0.01335	0.0821	0.00413	0.1504	0.0071	0.1592	0.0084	24	22
Student-Faculty Mix	I	0.1939	0.0144	0.5830	0.0119	0.4887	0.03089	0.2910	0.01464	0.3561	0.0167	0.3892	0.0180	19	19
Facilities & Equipment	I	0.2470	0.0184	0.0641	0.0013	0.1061	0.00671	0.1705	0.00858	0.1301	0.0061	0.1469	0.0087	23	24
Teaching		**0.3357**		**0.1463**		**0.2455**		**0.4021**		0.2639		0.2824			
Practicality	I	0.3444	0.1156	*0.0893*	0.0131	0.2312	0.05674	0.2327	0.09358	0.2017	0.0532	0.2244	0.0698	5	4
Course Evaluations	O	0.1378	0.0463	*0.0513*	0.0075	0.1904	0.04672	0.3239	0.13025	0.1445	0.0381	0.1759	0.0577	7	10
Curriculum Competency	I	0.3482	0.1169	*0.7289*	0.1067	0.4598	0.11285	0.3635	0.14616	0.4538	0.1198	0.4751	0.1206	1	1
Course Convenience	I	0.1695	0.0569	*0.1305*	0.0191	0.1187	0.02913	0.0798	0.03209	0.1203	0.0317	0.1246	0.0343	13	12
Student Learning		**0.2723**		**0.0464**		**0.2182**		**0.2678**		0.1648		0.2012			
Student Employability	O	0.4614	0.1257	0.5678	0.0263	0.4196	0.09156	0.5104	0.13671	0.4867	0.0802	0.4898	0.0951	2	2
Program Evaluation	O	0.1259	0.0343	0.1517	0.0070	0.1903	0.04152	0.2164	0.05797	0.1675	0.0276	0.1711	0.0352	12	13
Student Experiential Learning	O	0.2431	0.0662	0.2131	0.0099	0.2283	0.04982	0.2023	0.05418	0.2212	0.0365	0.2217	0.0450	9	11
Graduation Rate	O	0.1695	0.0462	0.0674	0.0031	0.1618	0.0353	0.0708	0.01897	0.1070	0.0176	0.1174	0.0259	16	18
Program Sustainability		**0.1259**		**0.4142**		**0.1424**		**0.1024**		0.1661		0.1962			
Value	O	0.2579	0.0325	0.5599	0.2319	0.2008	0.02859	0.1535	0.01571	0.2583	0.0429	0.2930	0.0772	3	6
Program Reputation	O	0.3201	0.0403	0.2865	0.1187	0.4376	0.06231	0.5724	0.0586	0.3893	0.0646	0.4041	0.0700	4	3
Industry/Government Relations	O	0.2427	0.0306	0.0687	0.0285	0.2488	0.03543	0.1785	0.01828	0.1650	0.0274	0.1847	0.0282	14	14
Intellectual Property	O	0.1793	0.0226	0.0849	0.0352	0.1128	0.01606	0.0956	0.00979	0.1132	0.0188	0.1182	0.0209	17	16
Sum Attributes		6.0000	1.0001	6.0000	1.0000	6.0000	1.0000	6.0000	1.0000	5.6124	0.8287	6.0000	1.0000		
Sum Dimensions		1.0001		1.0000		1.0000		1.0000		0.8823	0.0000	1.0000			

APPENDIX P: WILCOXON RESULTS

Wilcoxon Signed Ranks Test

Rank

		N	Mean Rank	Sum of Ranks
Administrator - Student	Negative Ranks	18[a]	11.94	215.00
	Positive Ranks	7[b]	15.71	110.00
	Ties	0[c]		
	Total	25		
Administrator - Faculty	Negative Ranks	19[d]	11.21	213.00
	Positive Ranks	6[e]	18.67	112.00
	Ties	0[f]		
	Total	25		
Administrator - Employer	Negative Ranks	16[g]	12.00	192.00
	Positive Ranks	9[h]	14.78	133.00
	Ties	0[i]		
	Total	25		
Faculty – Student	Negative Ranks	13[j]	12.54	163.00
	Positive Ranks	12[k]	13.50	162.00
	Ties	0[l]		
	Total	25		
Employer - Student	Negative Ranks	16[m]	12.09	193.50
	Positive Ranks	9[n]	14.61	131.50
	Ties	0[o]		
	Total	25		
Employer - Faculty	Negative Ranks	15[p]	12.30	184.50
	Positive Ranks	10[q]	14.05	140.50
	Ties	0[r]		
	Total	25		

a. Stakeholder A < Stakeholder B; b. Stakeholder A > Stakeholder B; c. Stakeholder A = Stakeholder B

Test Statistics[b]

	Administrator - Student	Administrator - Faculty	Administrator - Employer	Faculty - Student	Employer - Student	Employer - Faculty
Z	-1.413[a]	-1.359[a]	-.794[a]	-.013[a]	-.834[a]	-.592[a]
Asymp. Sig. (2-tailed)	.158	.174	.427	.989	.404	.554

a. Based on positive ranks.; b. Wilcoxon Signed Ranks Test

APPENDIX Q: APPLICATION OF DEA TAXONOMY

**Based on DEA taxonomy developed by Gattoufi, Oral and Reisman (2004)*

	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
S1-Data	Sources of data Actual Data from CECS/OIR	Degree of Imprecision in the Data Up to 3 significant digits at program or dept. level				
S2-Envelopment	Stochasticity of the Frontier Deterministic	Special Restrictions 7 IOs, 3 x (I+O) I x O	Orientation and Returns to Scale CCR, Output-oriented BCC	Convexity of the Mathematical Model Continuous & Discrete LP	Solving Method Exact Method using Frontier Analyst	Efficiency Measures of Solution Single values
S3- Analysis	Purpose Descriptive-Efficiency Score, Improvement Potential	Time Horizon 6 years	Efficiency Technical Efficiency	Level of Aggregation in the Analysis Dept. Level in UCF CECS	Sensitivity Analysis & Robustness Effect of IO deletion	Techniques for Sensitivity & Robustness Delete & Rerun Model
S4- Nature & Methodology	Nature Real World Application in Education	Methodology DEA, with OR/MS, Statistics				

APPENDIX R: DMU DATA

				Inputs																											
				Curriculum Competency						Faculty Qualifications				Practicality		Program Reputation	Value			Student Employability											Course Evaluations
				# of course action/special topic requests						*% of T/TE Faculty to (All Faculty, including Adjuncts, Instructors, Lecturers)*				*% of Faculty with reporting active external consulting*		*US News & World Report Score*	*% of graduate students with fellowships, assistantships or center contracts*			*% of Students with Job Offer or an Accepted Graduate School Application at Time of Graduation*											*Avg. Overall Effectiveness of Instructor*
																				BS			MS			PhD		Cumulative			
	Yr		ID	UG	G	∑	#C	∑/#C	Cat	T/TE	Inst/Lec	Adj	%FT	#EC	%	(0-5)	FAC	Tot	%	J	GS	#Resp	J	GS	#Resp	J	#Resp	TotJ/GS	TotResp	%	(1-5)
CECE	1	2007	DMU1	11	7	18	78	0.23	3	21	0	10	0.68	7	0.23	2.22	50	137	0.36											0.70	3.98
	2	2008	DMU2	14	2	16	76	0.21	3	18	0	17	0.51	7	0.20	2.24	50	136	0.37											0.70	3.98
	3	2009	DMU3	1	0	1	76	0.01	1	16	0	18	0.47	7	0.21	2.25	48	150	0.32											0.70	3.98
	4	2010	DMU4	0	3	3	78	0.04	1	19	1	11	0.61	6	0.19	2.25	48	172	0.28											0.70	3.94
	5	2011	DMU5	37	2	39	79	0.49	1	20	2	15	0.54	9	0.24	2.15	46	194	0.24	18	10	48	9	2	14	4	5	43	67	0.64	3.92
	6	2012	DMU6	11	33	44	79	0.56	1	20	2	17	0.51	6	0.15	2.30	57	177	0.32	3	2	8	2	0	2	2	2	9	12	0.75	4.09
EECS	1	2007	DMU7	11	19	30	99	0.30	1	59	6	13	0.76	10	0.13	2.60	197	479	0.41											0.81	3.86
	2	2008	DMU8	20	49	69	97	0.71	1	56	5	16	0.73	10	0.13	2.70	197	499	0.40											0.81	3.86
	3	2009	DMU9	5	4	9	99	0.09	2	53	6	24	0.64	10	0.12	2.45	220	614	0.36											0.81	3.86
	4	2010	DMU10	18	11	29	100	0.29	3	52	7	19	0.67	9	0.12	2.47	198	599	0.33											0.81	3.68
	5	2011	DMU11	7	11	18	102	0.18	3	51	1	1	0.96	9	0.17	2.43	207	608	0.34	73	27	113	29	5	36	12	14	146	163	0.90	3.89
	6	2012	DMU12	26	9	35	95	0.37	1	55	10	9	0.74	12	0.16	2.47	164	562	0.29	6	2	9	1	0	2	1	2	10	11	0.73	4.00
IEMS	1	2007	DMU13	3	0	3	63	0.05	1	21	1	2	0.88	3	0.13	2.27	19	185	0.10											0.84	3.79
	2	2008	DMU14	0	0	0	65	0.00	1	19	1	3	0.83	3	0.13	2.38	19	182	0.10											0.84	3.79
	3	2009	DMU15	2	1	3	65	0.05	1	16	1	6	0.70	3	0.13	2.30	16	244	0.07											0.84	3.79
	4	2010	DMU16	1	1	2	65	0.03	1	16	1	7	0.67	3	0.13	2.30	23	274	0.08											0.84	3.79
	5	2011	DMU17	4	1	5	66	0.08	2	16	1	5	0.73	3	0.14	2.10	16	250	0.06	11	4	15	18	7	32	3	4	43	51	0.84	3.72
	6	2012	DMU18	1	10	11	55	0.20	3	15	1	4	0.75	3	0.15	2.80	21	294	0.07	0	0	0	3	2	5	1	1	6	6	0.83	3.86
MSMAE	1	2007	DMU19	18	2	20	98	0.20	3	34	1	12	0.72	4	0.08	2.09	86	177	0.49											0.69	3.63
	2	2008	DMU20	8	2	10	99	0.10	2	33	1	13	0.70	4	0.08	2.11	86	167	0.51											0.69	3.62
	3	2009	DMU21	14	5	19	99	0.19	3	30	2	13	0.67	4	0.08	2.10	88	199	0.44											0.69	3.63
	4	2010	DMU22	5	8	13	102	0.13	2	20	2	18	0.50	4	0.10	2.10	101	224	0.45											0.69	3.63
	5	2011	DMU23	1	6	7	105	0.07	2	24	1	15	0.60	2	0.05	2.05	122	261	0.47	45	13	74	9	4	17	5	6	76	97	0.78	3.59
	6	2012	DMU24	20	10	30	101	0.30	3	31	4	18	0.58	5	0.09	2.20	33	268	0.12	0	1	2	0	1	1	1	2	3	5	0.60	3.68

Key:

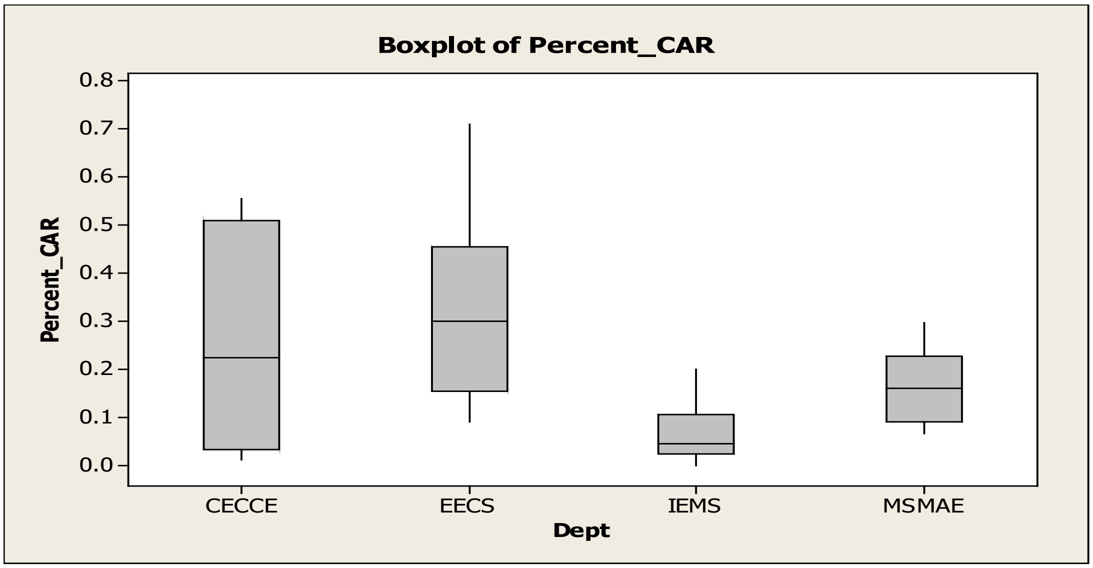
UG= Undergraduate | # Resp = # Responding | FAC= Fellowships, Assistantships, Center Appt. | J= Job | #C= Number of Courses listed in course catalog | Inst/Lec=Instructor/Lecturer

G= Graduate | BS/MS/PhD = Degree Type | GS= Graduate School | T/TE= Tenure=Tenure Earning | Adj= Adjunct | E4:AA1:AG32

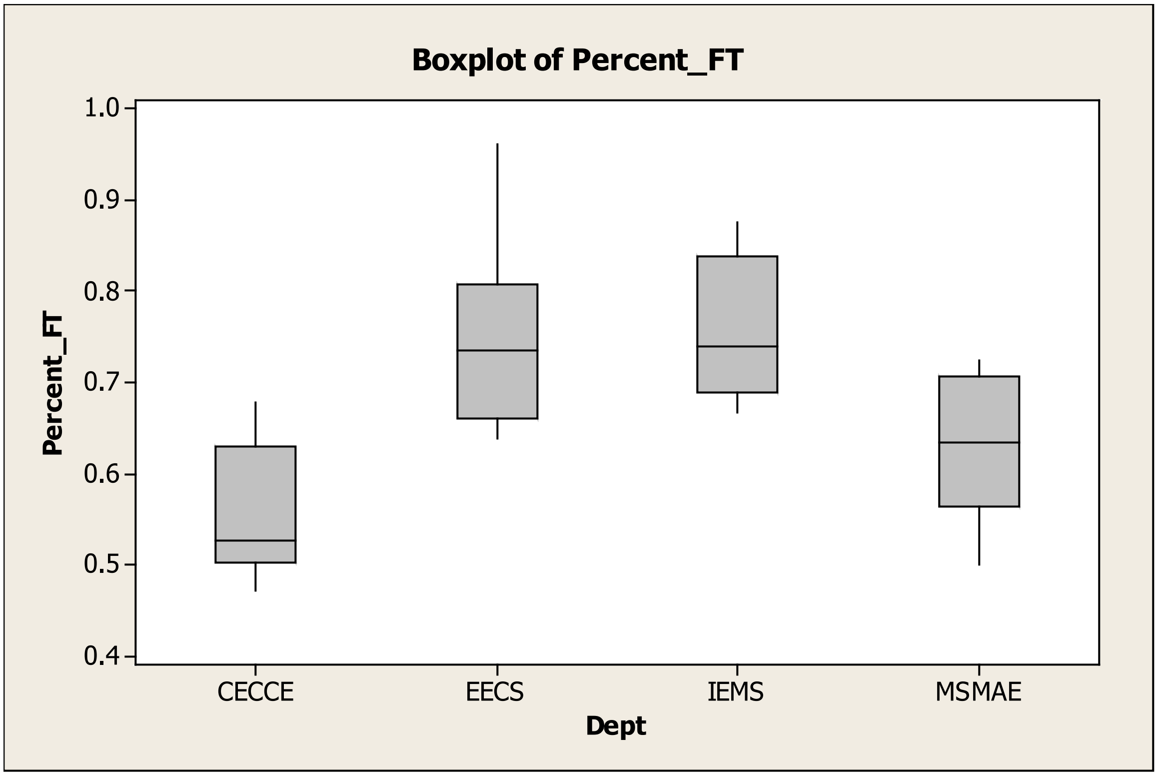
APPENDIX S: DMU DECSRIPTIVE STATISTICS

Curriculum Competency

Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
Percent_CAR	CECCE	6	0.2583	0.2262	0.0132	0.5570
	EECS	6	0.3244	0.2142	0.0909	0.7113
	IEMS	6	0.0665	0.0699	0.0000	0.2000
	MSMAE	6	0.1647	0.0835	0.0667	0.2970

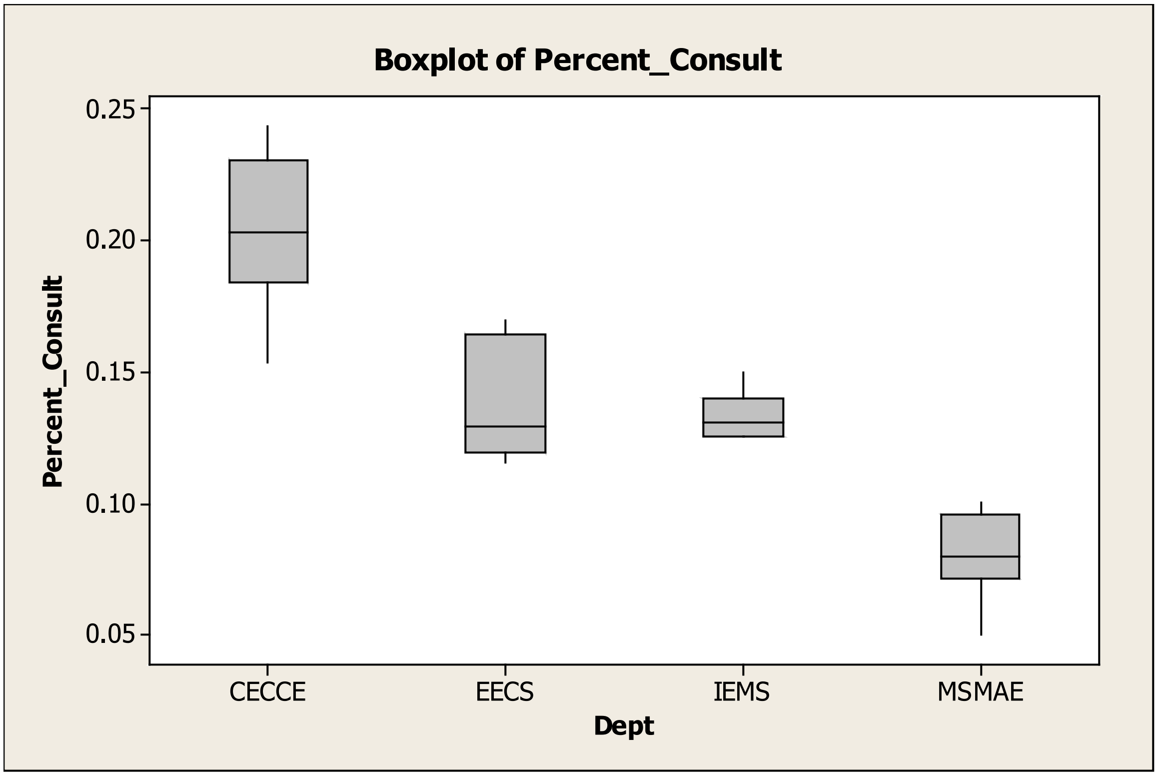


Percent of Full-Time Faculty



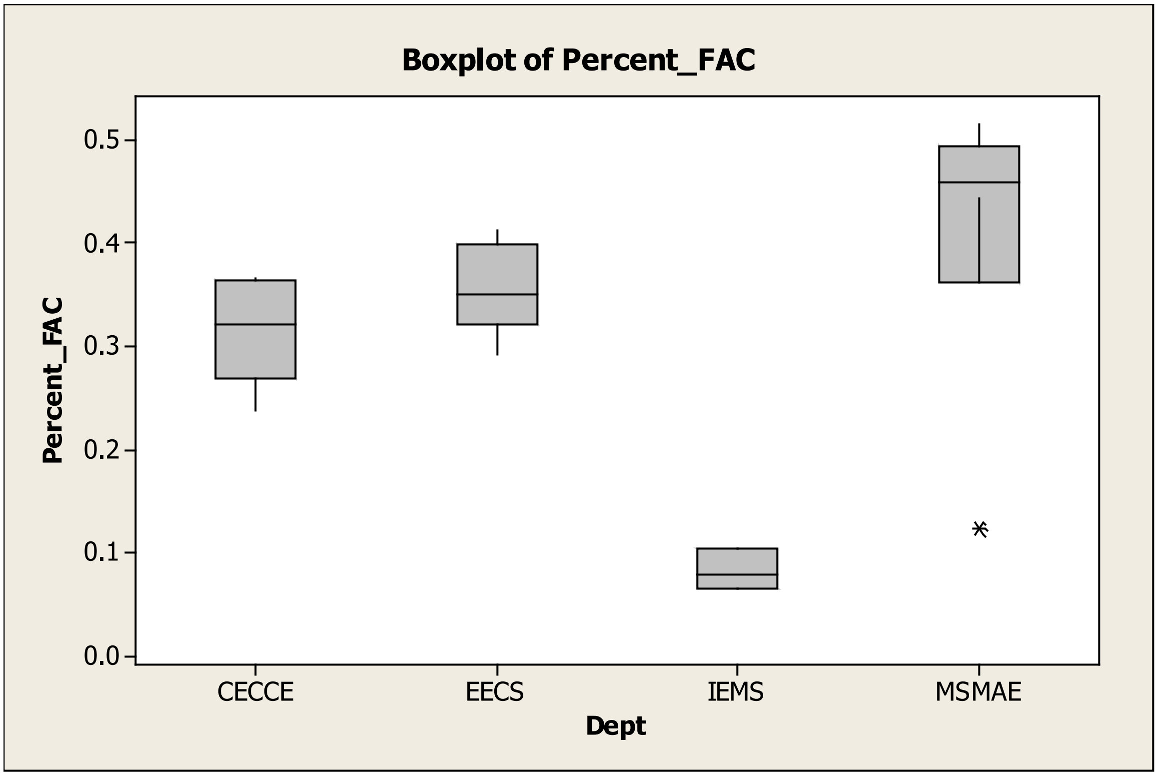
Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
Percent_FT	CECCE	6	0.5548	0.0763	0.4706	0.6774
	EECS	6	0.7491	0.1140	0.6386	0.9623
	IEMS	6	0.7568	0.0794	0.6667	0.8750
	MSMAE	6	0.6295	0.0838	0.5000	0.7234

Practicality: Percent of Faculty Active in Consulting



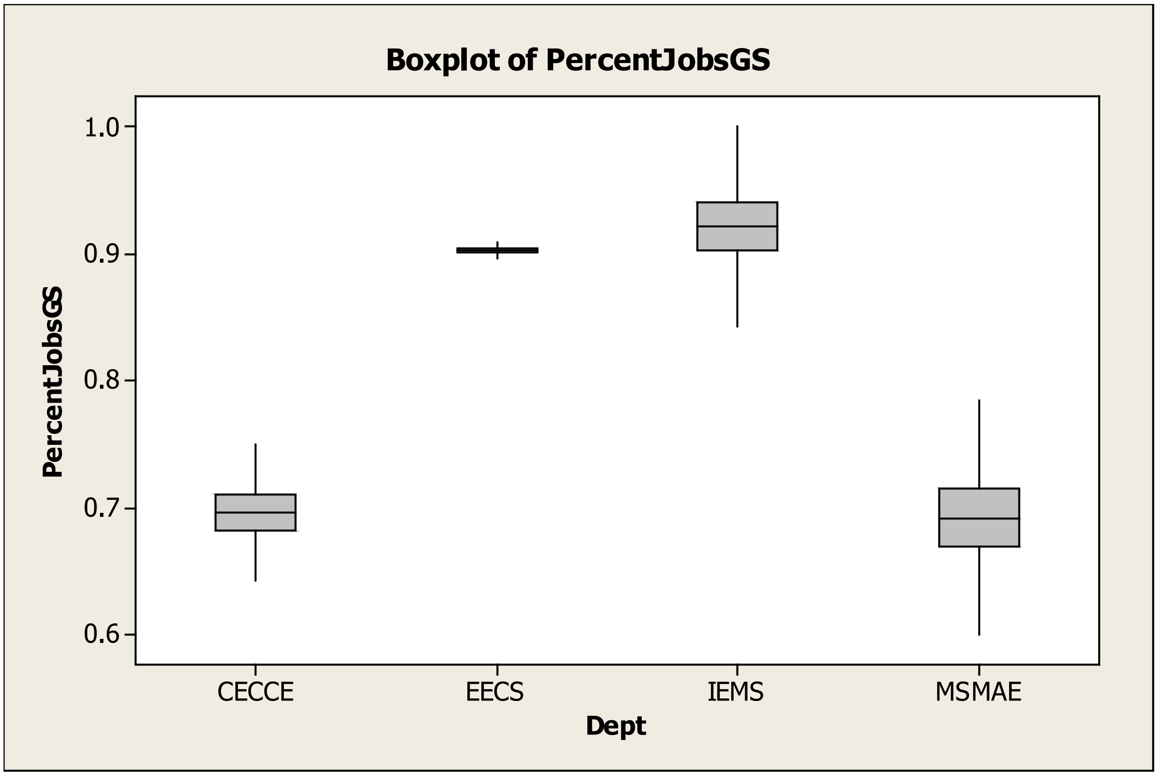
Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
Percent_Consult	CECCE	6	0.2037	0.0305	0.1538	0.2432
	EECS	6	0.13765	0.02270	0.11538	0.16981
	IEMS	6	0.13287	0.00940	0.12500	0.15000
	MSMAE	6	0.08031	0.01741	0.05000	0.10000

Percent of Students with Fellowships and Assistantships



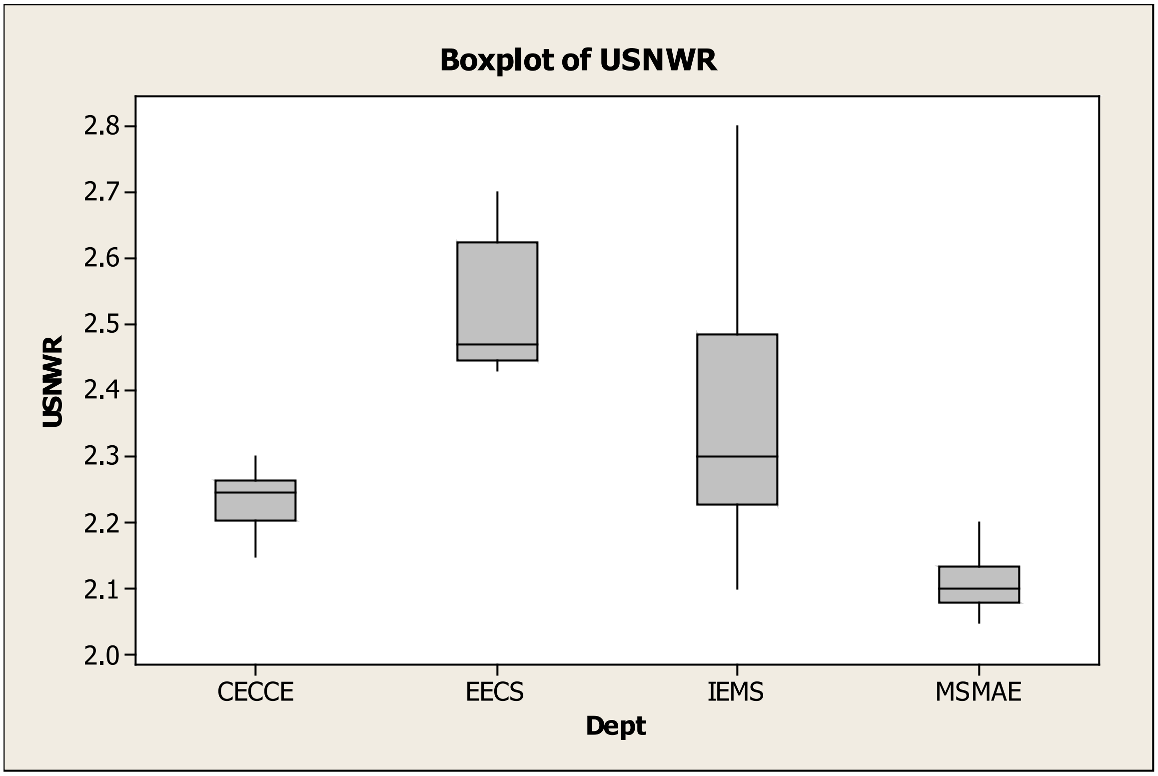
Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
Percent_FAC	CECCE	6	0.3145	0.0497	0.2371	0.3658
	EECS	6	0.3545	0.0441	0.2909	0.4115
	IEMS	6	0.08201	0.01811	0.06400	0.10440
	MSMAE	6	0.4141	0.1449	0.1231	0.5150

Percent of Students with Jobs or Going to Graduate School

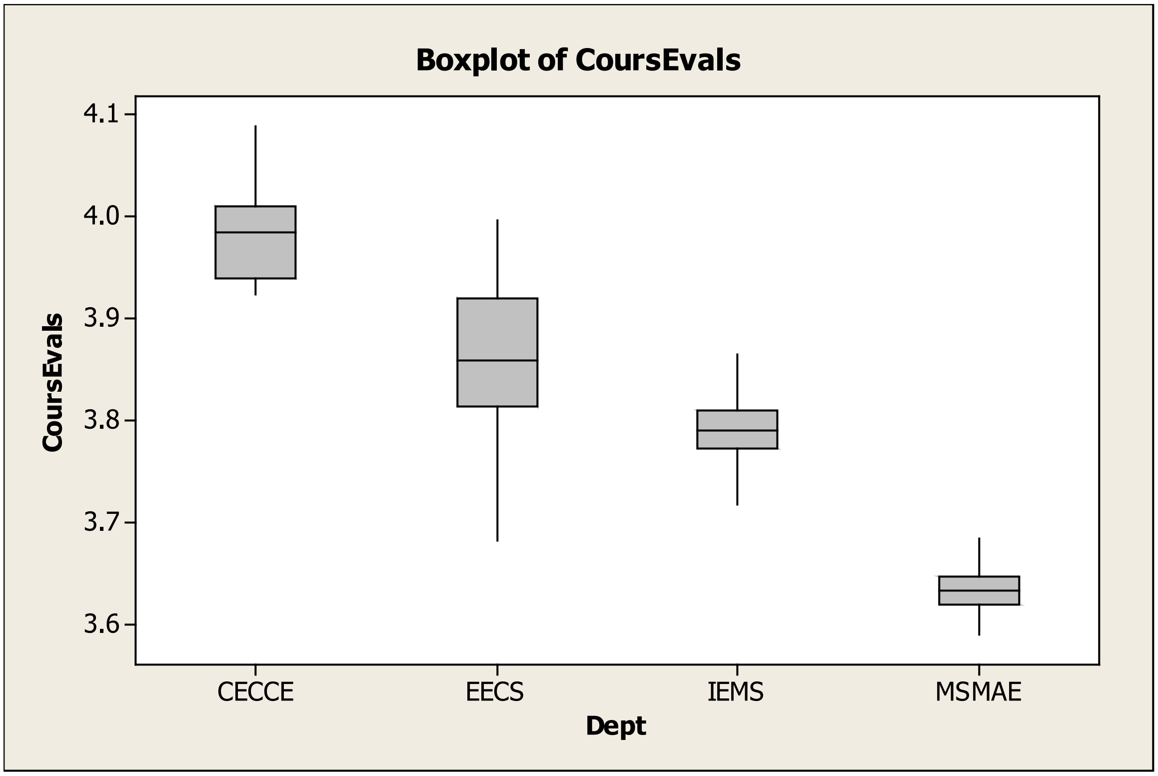


Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
PercentJobsGS	CECCE	6	0.6959	0.0342	0.6418	0.7500
	EECS	6	0.90240	0.00423	0.89571	0.90909
	IEMS	6	0.9216	0.0496	0.8431	1.0000
	MSMAE	6	0.6918	0.0580	0.6000	0.7835

USNWR Evaluations (Theoretical maximum is 5)



Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
USNWR	CECCE	6	2.2350	0.0493	2.1500	2.3000
	EECS	6	2.5200	0.1066	2.4300	2.7000
	IEMS	6	2.3583	0.2353	2.1000	2.8000
	MSMAE	6	2.1083	0.0496	2.0500	2.2000



Variable	Dept	Total Count	Mean	StDev	Minimum	Maximum
CoursEvals	CECCE	6	3.9841	0.0567	3.9220	4.0868
	EECS	6	3.8574	0.1012	3.6822	3.9959
	IEMS	6	3.7901	0.0462	3.7175	3.8636
	MSMAE	6	3.6335	0.0297	3.5899	3.6831

APPENDIX T: DEA OUTPUT

99.87% *CECE, 07 (BCC)* *Peers: 2*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*3.99*	*0.13 %*
Curriculum Competency	*3.00*	*2.90*	*-3.35 %*
Faculty Qualifications	*0.68*	*0.51*	*-24.09 %*
Practicality	*0.23*	*0.20*	*-12.46 %*
Program Reputation	*2.22*	*2.24*	*1.04 %*
Student Employability	*0.70*	*0.70*	*0.39 %*
Value	*0.36*	*0.36*	*0.13 %*

Peer Contributions

CECE, 08	*Course Evaluations*	*94.85 %*
CECE, 08	*Curriculum Competency*	*98.27 %*
CECE, 08	*Faculty Qualifications*	*94.99 %*
CECE, 08	*Practicality*	*96.09 %*
CECE, 08	*Program Reputation*	*94.85 %*
CECE, 08	*Student Employability*	*94.61 %*
CECE, 08	*Value*	*95.55 %*
CECE, 12	*Course Evaluations*	*5.15 %*
CECE, 12	*Curriculum Competency*	*1.73 %*
CECE, 12	*Faculty Qualifications*	*5.01 %*
CECE, 12	*Practicality*	*3.91 %*
CECE, 12	*Program Reputation*	*5.15 %*
CECE, 12	*Student Employability*	*5.39 %*
CECE, 12	*Value*	*4.45 %*

Input / Output Contributions

Curriculum Competency	*37.99 %*	*Input*
Faculty Qualifications	*26.74 %*	*Input*
Practicality	*35.27 %*	*Input*
Course Evaluations	*82.38 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*17.62 %*	*Output*

Peers

CECE, 08
CECE, 12

73.60% *CECE, 07 (CCR)* *Peers: 3*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*5.41*	*35.86 %*
Curriculum Competency	*3.00*	*1.76*	*-41.17 %*
Faculty Qualifications	*0.68*	*0.68*	*0.00 %*
Practicality	*0.23*	*0.23*	*0.00 %*
Program Reputation	*2.22*	*3.07*	*38.45 %*
Student Employability	*0.70*	*0.98*	*40.91 %*
Value	*0.36*	*0.49*	*35.86 %*

Peer Contributions

CECE, 09	*Course Evaluations*	*47.38 %*
CECE, 09	*Curriculum Competency*	*36.47 %*
CECE, 09	*Faculty Qualifications*	*44.71 %*
CECE, 09	*Practicality*	*58.69 %*
CECE, 09	*Program Reputation*	*47.12 %*
CECE, 09	*Student Employability*	*45.68 %*
CECE, 09	*Value*	*41.75 %*
CECE, 12	*Course Evaluations*	*27.07 %*
CECE, 12	*Curriculum Competency*	*20.31 %*
CECE, 12	*Faculty Qualifications*	*27.14 %*
CECE, 12	*Practicality*	*24.43 %*
CECE, 12	*Program Reputation*	*26.83 %*
CECE, 12	*Student Employability*	*27.42 %*
CECE, 12	*Value*	*23.40 %*
MMAE, 10	*Course Evaluations*	*25.56 %*
MMAE, 10	*Curriculum Competency*	*43.22 %*
MMAE, 10	*Faculty Qualifications*	*28.15 %*
MMAE, 10	*Practicality*	*16.89 %*
MMAE, 10	*Program Reputation*	*26.06 %*
MMAE, 10	*Student Employability*	*26.90 %*
MMAE, 10	*Value*	*34.85 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*84.71 %*	*Input*

Practicality	*15.29 %*	*Input*
Course Evaluations	*90.64 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*9.36 %*	*Output*

Peers
CECE, 09
CECE, 12
MMAE, 10

100.00% *CECE, 08 (BCC)* *Peers: 0*
References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*3.98*	*0.00 %*
Curriculum Competency	*3.00*	*3.00*	*0.00 %*
Faculty Qualifications	*0.51*	*0.51*	*0.00 %*
Practicality	*0.20*	*0.20*	*0.00 %*
Program Reputation	*2.24*	*2.24*	*0.00 %*
Student Employability	*0.70*	*0.70*	*0.00 %*
Value	*0.37*	*0.37*	*0.00 %*

Peer Contributions

CECE, 08	*Course Evaluations*	*100.00 %*
CECE, 08	*Curriculum Competency*	*100.00 %*
CECE, 08	*Faculty Qualifications*	*100.00 %*
CECE, 08	*Practicality*	*100.00 %*
CECE, 08	*Program Reputation*	*100.00 %*
CECE, 08	*Student Employability*	*100.00 %*
CECE, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*42.43 %*	*Input*
Faculty Qualifications	*22.68 %*	*Input*
Practicality	*34.89 %*	*Input*
Course Evaluations	*82.27 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*17.73 %*	*Output*

Peers
CECE, 08

95.50% *CECE, 08 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*4.17*	*4.72 %*
Curriculum Competency	*3.00*	*1.37*	*-54.18 %*
Faculty Qualifications	*0.51*	*0.51*	*0.00 %*
Practicality	*0.20*	*0.19*	*-5.35 %*
Program Reputation	*2.24*	*2.37*	*5.87 %*
Student Employability	*0.70*	*0.75*	*7.23 %*
Value	*0.37*	*0.38*	*4.72 %*

Peer Contributions

CECE, 09	*Course Evaluations*	*73.86 %*
CECE, 09	*Curriculum Competency*	*56.26 %*
CECE, 09	*Faculty Qualifications*	*70.77 %*
CECE, 09	*Practicality*	*84.12 %*
CECE, 09	*Program Reputation*	*73.37 %*
CECE, 09	*Student Employability*	*72.13 %*
CECE, 09	*Value*	*64.61 %*
MMAE, 10	*Course Evaluations*	*26.14 %*
MMAE, 10	*Curriculum Competency*	*43.74 %*
MMAE, 10	*Faculty Qualifications*	*29.23 %*
MMAE, 10	*Practicality*	*15.88 %*
MMAE, 10	*Program Reputation*	*26.63 %*
MMAE, 10	*Student Employability*	*27.87 %*
MMAE, 10	*Value*	*35.39 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*100.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*66.60 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*33.40 %*	*Output*

Peers

100.00% *CECE, 09 (BCC)* *Peers: 0*

References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*3.98*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.47*	*0.47*	*0.00 %*
Practicality	*0.21*	*0.21*	*0.00 %*
Program Reputation	*2.25*	*2.25*	*0.00 %*
Student Employability	*0.70*	*0.70*	*0.00 %*
Value	*0.32*	*0.32*	*0.00 %*

Peer Contributions

CECE, 09	*Course Evaluations*	*100.00 %*
CECE, 09	*Curriculum Competency*	*100.00 %*
CECE, 09	*Faculty Qualifications*	*100.00 %*
CECE, 09	*Practicality*	*100.00 %*
CECE, 09	*Program Reputation*	*100.00 %*
CECE, 09	*Student Employability*	*100.00 %*
CECE, 09	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*100.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*100.00 %*	*Output*

Peers

CECE, 09

100.00% *CECE, 09 (CCR)* *Peers: 0*
References: 3

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.98*	*3.98*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.47*	*0.47*	*0.00 %*
Practicality	*0.21*	*0.21*	*0.00 %*
Program Reputation	*2.25*	*2.25*	*0.00 %*
Student Employability	*0.70*	*0.70*	*0.00 %*
Value	*0.32*	*0.32*	*0.00 %*

Peer Contributions

CECE, 09	*Course Evaluations*	*100.00 %*
CECE, 09	*Curriculum Competency*	*100.00 %*
CECE, 09	*Faculty Qualifications*	*100.00 %*
CECE, 09	*Practicality*	*100.00 %*
CECE, 09	*Program Reputation*	*100.00 %*
CECE, 09	*Student Employability*	*100.00 %*
CECE, 09	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*100.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
CECE, 09

96.80% *CECE, 10 (BCC)* *Peers: 2*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.94*	*4.07*	*3.31 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.61*	*0.55*	*-10.94 %*
Practicality	*0.19*	*0.16*	*-19.90 %*
Program Reputation	*2.25*	*2.32*	*3.31 %*
Student Employability	*0.70*	*0.75*	*7.31 %*
Value	*0.28*	*0.32*	*13.80 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*85.93 %*
CECE, 12	*Curriculum Competency*	*85.66 %*
CECE, 12	*Faculty Qualifications*	*80.47 %*
CECE, 12	*Practicality*	*85.00 %*
CECE, 12	*Program Reputation*	*84.76 %*
CECE, 12	*Student Employability*	*86.03 %*
CECE, 12	*Value*	*86.86 %*
EECS, 12	*Course Evaluations*	*14.07 %*
EECS, 12	*Curriculum Competency*	*14.34 %*
EECS, 12	*Faculty Qualifications*	*19.53 %*
EECS, 12	*Practicality*	*15.00 %*
EECS, 12	*Program Reputation*	*15.24 %*
EECS, 12	*Student Employability*	*13.97 %*
EECS, 12	*Value*	*13.14 %*

Input / Output Contributions

Curriculum Competency	*99.97 %*	*Input*
Faculty Qualifications	*0.01 %*	*Input*
Practicality	*0.02 %*	*Input*
Course Evaluations	*76.62 %*	*Output*
Program Reputation	*23.38 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

96.80% *CECE, 10 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.94*	*4.07*	*3.31 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.61*	*0.55*	*-10.94 %*
Practicality	*0.19*	*0.16*	*-19.90 %*
Program Reputation	*2.25*	*2.32*	*3.31 %*
Student Employability	*0.70*	*0.75*	*7.31 %*
Value	*0.28*	*0.32*	*13.80 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*85.93 %*
CECE, 12	*Curriculum Competency*	*85.66 %*
CECE, 12	*Faculty Qualifications*	*80.47 %*
CECE, 12	*Practicality*	*85.00 %*
CECE, 12	*Program Reputation*	*84.76 %*
CECE, 12	*Student Employability*	*86.03 %*
CECE, 12	*Value*	*86.86 %*
EECS, 12	*Course Evaluations*	*14.07 %*
EECS, 12	*Curriculum Competency*	*14.34 %*
EECS, 12	*Faculty Qualifications*	*19.53 %*
EECS, 12	*Practicality*	*15.00 %*
EECS, 12	*Program Reputation*	*15.24 %*
EECS, 12	*Student Employability*	*13.97 %*
EECS, 12	*Value*	*13.14 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*76.62 %*	*Output*
Program Reputation	*23.38 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

CECE, 12
EECS, 12

95.97% CECE, 11 (BCC)

Peers: 1
References: 0

Potential Improvements

Variable	Actual	Target	Potential Improvement
Course Evaluations	3.92	4.09	4.20 %
Curriculum Competency	1.00	1.00	0.00 %
Faculty Qualifications	0.54	0.51	-5.13 %
Practicality	0.24	0.15	-36.75 %
Program Reputation	2.15	2.30	6.98 %
Student Employability	0.64	0.75	16.86 %
Value	0.24	0.32	35.81 %

Peer Contributions

CECE, 12	Course Evaluations	100.00 %
CECE, 12	Curriculum Competency	100.00 %
CECE, 12	Faculty Qualifications	100.00 %
CECE, 12	Practicality	100.00 %
CECE, 12	Program Reputation	100.00 %
CECE, 12	Student Employability	100.00 %
CECE, 12	Value	100.00 %

Input / Output Contributions

Curriculum Competency	17.59 %	Input
Faculty Qualifications	29.64 %	Input
Practicality	52.77 %	Input
Course Evaluations	100.00 %	Output
Program Reputation	0.00 %	Output
Student Employability	0.00 %	Output
Value	0.00 %	Output

Peers

CECE, 12

95.97% *CECE, 11 (CCR)* *Peers: 1*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.92*	*4.09*	*4.20 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.54*	*0.51*	*-5.13 %*
Practicality	*0.24*	*0.15*	*-36.75 %*
Program Reputation	*2.15*	*2.30*	*6.98 %*
Student Employability	*0.64*	*0.75*	*16.86 %*
Value	*0.24*	*0.32*	*35.81 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*100.00 %*
CECE, 12	*Curriculum Competency*	*100.00 %*
CECE, 12	*Faculty Qualifications*	*100.00 %*
CECE, 12	*Practicality*	*100.00 %*
CECE, 12	*Program Reputation*	*100.00 %*
CECE, 12	*Student Employability*	*100.00 %*
CECE, 12	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*100.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

CECE, 12

100.00% *CECE, 12 (BCC)* *Peers: 0*

References: 7

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*4.09*	*4.09*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.51*	*0.51*	*0.00 %*
Practicality	*0.15*	*0.15*	*0.00 %*
Program Reputation	*2.30*	*2.30*	*0.00 %*
Student Employability	*0.75*	*0.75*	*0.00 %*
Value	*0.32*	*0.32*	*0.00 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*100.00 %*
CECE, 12	*Curriculum Competency*	*100.00 %*
CECE, 12	*Faculty Qualifications*	*100.00 %*
CECE, 12	*Practicality*	*100.00 %*
CECE, 12	*Program Reputation*	*100.00 %*
CECE, 12	*Student Employability*	*100.00 %*
CECE, 12	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*84.84 %*	*Input*
Practicality	*15.16 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

CECE, 12

100.00% CECE, 12 (CCR) *Peers: 0*

References: 7

Potential Improvements

Variable	Actual	Target	Potential Improvement
Course Evaluations	4.09	4.09	0.00 %
Curriculum Competency	1.00	1.00	0.00 %
Faculty Qualifications	0.51	0.51	0.00 %
Practicality	0.15	0.15	0.00 %
Program Reputation	2.30	2.30	0.00 %
Student Employability	0.75	0.75	0.00 %
Value	0.32	0.32	0.00 %

Peer Contributions

CECE, 12	Course Evaluations	100.00 %
CECE, 12	Curriculum Competency	100.00 %
CECE, 12	Faculty Qualifications	100.00 %
CECE, 12	Practicality	100.00 %
CECE, 12	Program Reputation	100.00 %
CECE, 12	Student Employability	100.00 %
CECE, 12	Value	100.00 %

Input / Output Contributions

Curriculum Competency	0.00 %	Input
Faculty Qualifications	97.57 %	Input
Practicality	2.43 %	Input
Course Evaluations	0.00 %	Output
Program Reputation	0.00 %	Output
Student Employability	100.00 %	Output
Value	0.00 %	Output

Peers

CECE, 12

100.00% *EECS, 07 (BCC)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.76*	*0.76*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.60*	*2.60*	*0.00 %*
Student Employability	*0.81*	*0.81*	*0.00 %*
Value	*0.41*	*0.41*	*0.00 %*

Peer Contributions

EECS, 07	*Course Evaluations*	*100.00 %*
EECS, 07	*Curriculum Competency*	*100.00 %*
EECS, 07	*Faculty Qualifications*	*100.00 %*
EECS, 07	*Practicality*	*100.00 %*
EECS, 07	*Program Reputation*	*100.00 %*
EECS, 07	*Student Employability*	*100.00 %*
EECS, 07	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*51.03 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*48.97 %*	*Output*

Peers

EECS, 07

100.00% *EECS, 07 (CCR)* *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.76*	*0.76*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.60*	*2.60*	*0.00 %*
Student Employability	*0.81*	*0.81*	*0.00 %*
Value	*0.41*	*0.41*	*0.00 %*

Peer Contributions

EECS, 07	*Course Evaluations*	*100.00 %*
EECS, 07	*Curriculum Competency*	*100.00 %*
EECS, 07	*Faculty Qualifications*	*100.00 %*
EECS, 07	*Practicality*	*100.00 %*
EECS, 07	*Program Reputation*	*100.00 %*
EECS, 07	*Student Employability*	*100.00 %*
EECS, 07	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*30.58 %*	*Input*
Faculty Qualifications	*24.37 %*	*Input*
Practicality	*45.05 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*91.18 %*	*Output*
Value	*8.82 %*	*Output*

Peers
EECS, 07

100.00%   EECS, 08 (BCC)   *Peers: 0*
References: 3

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.73*	*0.73*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.70*	*2.70*	*0.00 %*
Student Employability	*0.81*	*0.81*	*0.00 %*
Value	*0.40*	*0.40*	*0.00 %*

Peer Contributions

EECS, 08	*Course Evaluations*	*100.00 %*
EECS, 08	*Curriculum Competency*	*100.00 %*
EECS, 08	*Faculty Qualifications*	*100.00 %*
EECS, 08	*Practicality*	*100.00 %*
EECS, 08	*Program Reputation*	*100.00 %*
EECS, 08	*Student Employability*	*100.00 %*
EECS, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*21.76 %*	*Output*
Student Employability	*78.24 %*	*Output*
Value	*0.00 %*	*Output*

Peers
EECS, 08

100.00% *EECS, 08 (CCR)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.73*	*0.73*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.70*	*2.70*	*0.00 %*
Student Employability	*0.81*	*0.81*	*0.00 %*
Value	*0.40*	*0.40*	*0.00 %*

Peer Contributions

EECS, 08	*Course Evaluations*	*100.00 %*
EECS, 08	*Curriculum Competency*	*100.00 %*
EECS, 08	*Faculty Qualifications*	*100.00 %*
EECS, 08	*Practicality*	*100.00 %*
EECS, 08	*Program Reputation*	*100.00 %*
EECS, 08	*Student Employability*	*100.00 %*
EECS, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*52.99 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*47.01 %*	*Output*

Peers

EECS, 08

100.00% *EECS, 09 (BCC)* *Peers: 0*
References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.64*	*0.64*	*0.00 %*
Practicality	*0.12*	*0.12*	*0.00 %*
Program Reputation	*2.45*	*2.45*	*0.00 %*
Student Employability	*0.81*	*0.81*	*0.00 %*
Value	*0.36*	*0.36*	*0.00 %*

Peer Contributions

EECS, 09	*Course Evaluations*	*100.00 %*
EECS, 09	*Curriculum Competency*	*100.00 %*
EECS, 09	*Faculty Qualifications*	*100.00 %*
EECS, 09	*Practicality*	*100.00 %*
EECS, 09	*Program Reputation*	*100.00 %*
EECS, 09	*Student Employability*	*100.00 %*
EECS, 09	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*68.56 %*	*Input*
Practicality	*31.44 %*	*Input*
Course Evaluations	*27.47 %*	*Output*
Program Reputation	*69.71 %*	*Output*
Student Employability	*2.82 %*	*Output*
Value	*0.00 %*	*Output*

Peers
EECS, 09

95.67% *EECS, 09 (CCR)* *Peers: 4*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*4.31*	*11.79 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.64*	*0.64*	*0.00 %*
Practicality	*0.12*	*0.12*	*0.00 %*
Program Reputation	*2.45*	*2.56*	*4.53 %*
Student Employability	*0.81*	*0.85*	*4.53 %*
Value	*0.36*	*0.50*	*38.78 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*14.32 %*
CECE, 12	*Curriculum Competency*	*7.56 %*
CECE, 12	*Faculty Qualifications*	*12.14 %*
CECE, 12	*Practicality*	*19.30 %*
CECE, 12	*Program Reputation*	*13.57 %*
CECE, 12	*Student Employability*	*13.36 %*
CECE, 12	*Value*	*9.79 %*
EECS, 08	*Course Evaluations*	*15.22 %*
EECS, 08	*Curriculum Competency*	*8.51 %*
EECS, 08	*Faculty Qualifications*	*19.38 %*
EECS, 08	*Practicality*	*18.34 %*
EECS, 08	*Program Reputation*	*17.94 %*
EECS, 08	*Student Employability*	*16.28 %*
EECS, 08	*Value*	*13.52 %*
MMAE, 10	*Course Evaluations*	*55.79 %*
MMAE, 10	*Curriculum Competency*	*66.32 %*
MMAE, 10	*Faculty Qualifications*	*51.93 %*
MMAE, 10	*Practicality*	*55.05 %*
MMAE, 10	*Program Reputation*	*54.39 %*
MMAE, 10	*Student Employability*	*54.09 %*
MMAE, 10	*Value*	*60.14 %*
MMAE, 11	*Course Evaluations*	*14.66 %*
MMAE, 11	*Curriculum Competency*	*17.61 %*
MMAE, 11	*Faculty Qualifications*	*16.55 %*
MMAE, 11	*Practicality*	*7.31 %*
MMAE, 11	*Program Reputation*	*14.10 %*

MMAE, 11	*Student Employability*	*16.27 %*
MMAE, 11	*Value*	*16.55 %*

Input / Output Contributions

Curriculum Competency	*11.13 %*	*Input*
Faculty Qualifications	*61.79 %*	*Input*
Practicality	*27.08 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*96.94 %*	*Output*
Student Employability	*3.06 %*	*Output*
Value	*0.00 %*	*Output*

Peers
CECE, 12
EECS, 08
MMAE, 10
MMAE, 11

99.96% *EECS, 10 (BCC)* *Peers: 5*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.68*	*3.81*	*3.55 %*
Curriculum Competency	*3.00*	*2.08*	*-30.79 %*
Faculty Qualifications	*0.67*	*0.67*	*0.00 %*
Practicality	*0.12*	*0.12*	*0.00 %*
Program Reputation	*2.47*	*2.47*	*0.04 %*
Student Employability	*0.81*	*0.81*	*0.04 %*
Value	*0.33*	*0.33*	*0.04 %*

Peer Contributions

EECS, 08	*Course Evaluations*	*11.60 %*
EECS, 08	*Curriculum Competency*	*5.52 %*
EECS, 08	*Faculty Qualifications*	*12.51 %*
EECS, 08	*Practicality*	*12.91 %*
EECS, 08	*Program Reputation*	*12.53 %*
EECS, 08	*Student Employability*	*11.46 %*
EECS, 08	*Value*	*13.70 %*
EECS, 09	*Course Evaluations*	*52.86 %*
EECS, 09	*Curriculum Competency*	*50.33 %*
EECS, 09	*Faculty Qualifications*	*50.05 %*
EECS, 09	*Practicality*	*54.56 %*
EECS, 09	*Program Reputation*	*51.81 %*
EECS, 09	*Student Employability*	*52.23 %*
EECS, 09	*Value*	*56.61 %*
EECS, 11	*Course Evaluations*	*1.58 %*
EECS, 11	*Curriculum Competency*	*2.24 %*
EECS, 11	*Faculty Qualifications*	*2.24 %*
EECS, 11	*Practicality*	*2.28 %*
EECS, 11	*Program Reputation*	*1.52 %*
EECS, 11	*Student Employability*	*1.71 %*
EECS, 11	*Value*	*1.60 %*
IEMS, 12	*Course Evaluations*	*17.77 %*
IEMS, 12	*Curriculum Competency*	*25.34 %*
IEMS, 12	*Faculty Qualifications*	*19.73 %*
IEMS, 12	*Practicality*	*22.80 %*
IEMS, 12	*Program Reputation*	*19.88 %*

IEMS, 12	*Student Employability*	*18.00 %*
IEMS, 12	*Value*	*3.79 %*
MMAE, 11	*Course Evaluations*	*16.18 %*
MMAE, 11	*Curriculum Competency*	*16.56 %*
MMAE, 11	*Faculty Qualifications*	*15.47 %*
MMAE, 11	*Practicality*	*7.45 %*
MMAE, 11	*Program Reputation*	*14.26 %*
MMAE, 11	*Student Employability*	*16.59 %*
MMAE, 11	*Value*	*24.30 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*56.51 %*	*Input*
Practicality	*43.49 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*18.02 %*	*Output*
Student Employability	*80.74 %*	*Output*
Value	*1.24 %*	*Output*

Peers
EECS, 08
EECS, 09
EECS, 11
IEMS, 12
MMAE, 11

92.18% *EECS, 10 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.68*	*4.64*	*26.04 %*
Curriculum Competency	*3.00*	*2.56*	*-14.53 %*
Faculty Qualifications	*0.67*	*0.67*	*0.00 %*
Practicality	*0.12*	*0.12*	*0.00 %*
Program Reputation	*2.47*	*2.68*	*8.48 %*
Student Employability	*0.81*	*0.91*	*12.19 %*
Value	*0.33*	*0.58*	*76.16 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*80.17 %*
MMAE, 10	*Curriculum Competency*	*80.00 %*
MMAE, 10	*Faculty Qualifications*	*76.92 %*
MMAE, 10	*Practicality*	*88.89 %*
MMAE, 10	*Program Reputation*	*80.38 %*
MMAE, 10	*Student Employability*	*77.93 %*
MMAE, 10	*Value*	*79.42 %*
MMAE, 11	*Course Evaluations*	*19.83 %*
MMAE, 11	*Curriculum Competency*	*20.00 %*
MMAE, 11	*Faculty Qualifications*	*23.08 %*
MMAE, 11	*Practicality*	*11.11 %*
MMAE, 11	*Program Reputation*	*19.62 %*
MMAE, 11	*Student Employability*	*22.07 %*
MMAE, 11	*Value*	*20.58 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*71.09 %*	*Input*
Practicality	*28.91 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
MMAE, 10
MMAE, 11

100.00%	EECS, 11 (BCC)	Peers: 0
		References: 3

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.89*	*3.89*	*0.00 %*
Curriculum Competency	*3.00*	*3.00*	*0.00 %*
Faculty Qualifications	*0.96*	*0.96*	*0.00 %*
Practicality	*0.17*	*0.17*	*0.00 %*
Program Reputation	*2.43*	*2.43*	*0.00 %*
Student Employability	*0.90*	*0.90*	*0.00 %*
Value	*0.34*	*0.34*	*0.00 %*

Peer Contributions

EECS, 11	*Course Evaluations*	*100.00 %*
EECS, 11	*Curriculum Competency*	*100.00 %*
EECS, 11	*Faculty Qualifications*	*100.00 %*
EECS, 11	*Practicality*	*100.00 %*
EECS, 11	*Program Reputation*	*100.00 %*
EECS, 11	*Student Employability*	*100.00 %*
EECS, 11	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*100.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
EECS, 11

67.79% *EECS, 11 (CCR)* *Peers: 2*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.89*	*6.58*	*68.95 %*
Curriculum Competency	*3.00*	*2.64*	*-12.16 %*
Faculty Qualifications	*0.96*	*0.96*	*0.00 %*
Practicality	*0.17*	*0.17*	*0.00 %*
Program Reputation	*2.43*	*3.73*	*53.48 %*
Student Employability	*0.90*	*1.32*	*47.52 %*
Value	*0.34*	*0.69*	*101.83 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*50.11 %*
CECE, 12	*Curriculum Competency*	*30.61 %*
CECE, 12	*Faculty Qualifications*	*42.99 %*
CECE, 12	*Practicality*	*73.08 %*
CECE, 12	*Program Reputation*	*49.74 %*
CECE, 12	*Student Employability*	*45.78 %*
CECE, 12	*Value*	*37.80 %*
MMAE, 11	*Course Evaluations*	*49.89 %*
MMAE, 11	*Curriculum Competency*	*69.39 %*
MMAE, 11	*Faculty Qualifications*	*57.01 %*
MMAE, 11	*Practicality*	*26.92 %*
MMAE, 11	*Program Reputation*	*50.26 %*
MMAE, 11	*Student Employability*	*54.22 %*
MMAE, 11	*Value*	*62.20 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*90.71 %*	*Input*
Practicality	*9.29 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

CECE, 12
MMAE, 11

100.00% *EECS, 12 (BCC)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*4.00*	*4.00*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.74*	*0.74*	*0.00 %*
Practicality	*0.16*	*0.16*	*0.00 %*
Program Reputation	*2.47*	*2.47*	*0.00 %*
Student Employability	*0.73*	*0.73*	*0.00 %*
Value	*0.29*	*0.29*	*0.00 %*

Peer Contributions

EECS, 12	*Course Evaluations*	*100.00 %*
EECS, 12	*Curriculum Competency*	*100.00 %*
EECS, 12	*Faculty Qualifications*	*100.00 %*
EECS, 12	*Practicality*	*100.00 %*
EECS, 12	*Program Reputation*	*100.00 %*
EECS, 12	*Student Employability*	*100.00 %*
EECS, 12	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*99.98 %*	*Input*
Faculty Qualifications	*0.01 %*	*Input*
Practicality	*0.01 %*	*Input*
Course Evaluations	*72.87 %*	*Output*
Program Reputation	*27.13 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

EECS, 12

100.00% *EECS, 12 (CCR)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*4.00*	*4.00*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.74*	*0.74*	*0.00 %*
Practicality	*0.16*	*0.16*	*0.00 %*
Program Reputation	*2.47*	*2.47*	*0.00 %*
Student Employability	*0.73*	*0.73*	*0.00 %*
Value	*0.29*	*0.29*	*0.00 %*

Peer Contributions

EECS, 12	*Course Evaluations*	*100.00 %*
EECS, 12	*Curriculum Competency*	*100.00 %*
EECS, 12	*Faculty Qualifications*	*100.00 %*
EECS, 12	*Practicality*	*100.00 %*
EECS, 12	*Program Reputation*	*100.00 %*
EECS, 12	*Student Employability*	*100.00 %*
EECS, 12	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*73.19 %*	*Output*
Program Reputation	*25.01 %*	*Output*
Student Employability	*1.80 %*	*Output*
Value	*0.00 %*	*Output*

Peers

EECS, 12

100.00% *IEMS, 07 (BCC)* *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.88*	*0.88*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.27*	*2.27*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.10*	*0.10*	*0.00 %*

Peer Contributions

IEMS, 07	*Course Evaluations*	*100.00 %*
IEMS, 07	*Curriculum Competency*	*100.00 %*
IEMS, 07	*Faculty Qualifications*	*100.00 %*
IEMS, 07	*Practicality*	*100.00 %*
IEMS, 07	*Program Reputation*	*100.00 %*
IEMS, 07	*Student Employability*	*100.00 %*
IEMS, 07	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*8.18 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*91.82 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
IEMS, 07

100.00%   IEMS, 07 (CCR)   *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.88*	*0.88*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.27*	*2.27*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.10*	*0.10*	*0.00 %*

Peer Contributions

IEMS, 07	*Course Evaluations*	*100.00 %*
IEMS, 07	*Curriculum Competency*	*100.00 %*
IEMS, 07	*Faculty Qualifications*	*100.00 %*
IEMS, 07	*Practicality*	*100.00 %*
IEMS, 07	*Program Reputation*	*100.00 %*
IEMS, 07	*Student Employability*	*100.00 %*
IEMS, 07	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*99.60 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.40 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*98.95 %*	*Output*
Value	*1.05 %*	*Output*

Peers
IEMS, 07

100.00% *IEMS, 08 (BCC)* *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.83*	*0.83*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.38*	*2.38*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.10*	*0.10*	*0.00 %*

Peer Contributions

IEMS, 08	*Course Evaluations*	*100.00 %*
IEMS, 08	*Curriculum Competency*	*100.00 %*
IEMS, 08	*Faculty Qualifications*	*100.00 %*
IEMS, 08	*Practicality*	*100.00 %*
IEMS, 08	*Program Reputation*	*100.00 %*
IEMS, 08	*Student Employability*	*100.00 %*
IEMS, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*19.64 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*80.36 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*8.65 %*	*Output*
Student Employability	*90.74 %*	*Output*
Value	*0.61 %*	*Output*

Peers
IEMS, 08

100.00% IEMS, 08 (CCR) *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.83*	*0.83*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.38*	*2.38*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.10*	*0.10*	*0.00 %*

Peer Contributions

IEMS, 08	*Course Evaluations*	*100.00 %*
IEMS, 08	*Curriculum Competency*	*100.00 %*
IEMS, 08	*Faculty Qualifications*	*100.00 %*
IEMS, 08	*Practicality*	*100.00 %*
IEMS, 08	*Program Reputation*	*100.00 %*
IEMS, 08	*Student Employability*	*100.00 %*
IEMS, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*90.17 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*9.83 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*8.65 %*	*Output*
Student Employability	*90.74 %*	*Output*
Value	*0.61 %*	*Output*

Peers
IEMS, 08

100.00% *IEMS, 09 (BCC)* *Peers: 0*

References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.70*	*0.70*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.30*	*2.30*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.07*	*0.07*	*0.00 %*

Peer Contributions

IEMS, 09	*Course Evaluations*	*100.00 %*
IEMS, 09	*Curriculum Competency*	*100.00 %*
IEMS, 09	*Faculty Qualifications*	*100.00 %*
IEMS, 09	*Practicality*	*100.00 %*
IEMS, 09	*Program Reputation*	*100.00 %*
IEMS, 09	*Student Employability*	*100.00 %*
IEMS, 09	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.03 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*99.97 %*	*Output*
Value	*0.00 %*	*Output*

Peers

IEMS, 09

100.00% *IEMS, 09 (CCR)* *Peers: 0*

References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.70*	*0.70*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.30*	*2.30*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.07*	*0.07*	*0.00 %*

Peer Contributions

IEMS, 09	*Course Evaluations*	*100.00 %*
IEMS, 09	*Curriculum Competency*	*100.00 %*
IEMS, 09	*Faculty Qualifications*	*100.00 %*
IEMS, 09	*Practicality*	*100.00 %*
IEMS, 09	*Program Reputation*	*100.00 %*
IEMS, 09	*Student Employability*	*100.00 %*
IEMS, 09	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*100.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.03 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*99.97 %*	*Output*
Value	*0.00 %*	*Output*

Peers

IEMS, 09

100.00% IEMS, 10 (BCC) *Peers: 0*
References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.67*	*0.67*	*0.00 %*
Practicality	*0.13*	*0.13*	*0.00 %*
Program Reputation	*2.30*	*2.30*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.08*	*0.08*	*0.00 %*

Peer Contributions

IEMS, 10	*Course Evaluations*	*100.00 %*
IEMS, 10	*Curriculum Competency*	*100.00 %*
IEMS, 10	*Faculty Qualifications*	*100.00 %*
IEMS, 10	*Practicality*	*100.00 %*
IEMS, 10	*Program Reputation*	*100.00 %*
IEMS, 10	*Student Employability*	*100.00 %*
IEMS, 10	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*8.18 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*91.82 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
IEMS, 10

100.00% *IEMS, 10 (CCR)* *Peers: 0*
References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.79*	*3.79*	*0.00 %*
Curriculum Competency	*1.00*	*1.00*	*0.00 %*
Faculty Qualifications	*0.67*	*0.67*	*0.00 %*
Practicality	*0.13*	*0.12*	*0.00 %*
Program Reputation	*2.30*	*2.30*	*0.00 %*
Student Employability	*0.84*	*0.84*	*0.00 %*
Value	*0.08*	*0.08*	*0.00 %*

Peer Contributions

IEMS, 10	*Course Evaluations*	*100.00 %*
IEMS, 10	*Curriculum Competency*	*100.00 %*
IEMS, 10	*Faculty Qualifications*	*100.00 %*
IEMS, 10	*Practicality*	*100.00 %*
IEMS, 10	*Program Reputation*	*100.00 %*
IEMS, 10	*Student Employability*	*100.00 %*
IEMS, 10	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*12.64 %*	*Input*
Faculty Qualifications	*66.49 %*	*Input*
Practicality	*20.87 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
IEMS, 10

99.19% *IEMS, 11 (BCC)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.72*	*3.81*	*2.51 %*
Curriculum Competency	*2.00*	*1.41*	*-29.50 %*
Faculty Qualifications	*0.73*	*0.73*	*0.00 %*
Practicality	*0.14*	*0.13*	*-1.60 %*
Program Reputation	*2.10*	*2.33*	*10.79 %*
Student Employability	*0.84*	*0.85*	*0.82 %*
Value	*0.06*	*0.14*	*113.34 %*

Peer Contributions

EECS, 11	*Course Evaluations*	*20.95 %*
EECS, 11	*Curriculum Competency*	*43.62 %*
EECS, 11	*Faculty Qualifications*	*27.13 %*
EECS, 11	*Practicality*	*25.95 %*
EECS, 11	*Program Reputation*	*21.41 %*
EECS, 11	*Student Employability*	*21.60 %*
EECS, 11	*Value*	*51.13 %*
IEMS, 10	*Course Evaluations*	*79.05 %*
IEMS, 10	*Curriculum Competency*	*56.38 %*
IEMS, 10	*Faculty Qualifications*	*72.87 %*
IEMS, 10	*Practicality*	*74.05 %*
IEMS, 10	*Program Reputation*	*78.59 %*
IEMS, 10	*Student Employability*	*78.40 %*
IEMS, 10	*Value*	*48.87 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*100.00 %*	*Input*
Practicality	*0.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

EECS, 11
IEMS, 10

83.94% *IEMS, 11 (CCR)* *Peers: 2*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.72*	*5.05*	*35.73 %*
Curriculum Competency	*2.00*	*1.94*	*-2.97 %*
Faculty Qualifications	*0.73*	*0.73*	*0.00 %*
Practicality	*0.14*	*0.14*	*0.00 %*
Program Reputation	*2.10*	*2.86*	*36.11 %*
Student Employability	*0.84*	*1.00*	*19.14 %*
Value	*0.06*	*0.51*	*702.75 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*55.22 %*
CECE, 12	*Curriculum Competency*	*35.14 %*
CECE, 12	*Faculty Qualifications*	*48.08 %*
CECE, 12	*Practicality*	*76.92 %*
CECE, 12	*Program Reputation*	*54.86 %*
CECE, 12	*Student Employability*	*50.91 %*
CECE, 12	*Value*	*42.74 %*
MMAE, 11	*Course Evaluations*	*44.78 %*
MMAE, 11	*Curriculum Competency*	*64.86 %*
MMAE, 11	*Faculty Qualifications*	*51.92 %*
MMAE, 11	*Practicality*	*23.08 %*
MMAE, 11	*Program Reputation*	*45.14 %*
MMAE, 11	*Student Employability*	*49.09 %*
MMAE, 11	*Value*	*57.26 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*90.18 %*	*Input*
Practicality	*9.82 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*100.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

100.00% *IEMS, 12 (BCC)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*3.86*	*0.00 %*
Curriculum Competency	*3.00*	*3.00*	*0.00 %*
Faculty Qualifications	*0.75*	*0.75*	*0.00 %*
Practicality	*0.15*	*0.15*	*0.00 %*
Program Reputation	*2.80*	*2.80*	*0.00 %*
Student Employability	*0.83*	*0.83*	*0.00 %*
Value	*0.07*	*0.07*	*0.00 %*

Peer Contributions

IEMS, 12	*Course Evaluations*	*100.00 %*
IEMS, 12	*Curriculum Competency*	*100.00 %*
IEMS, 12	*Faculty Qualifications*	*100.00 %*
IEMS, 12	*Practicality*	*100.00 %*
IEMS, 12	*Program Reputation*	*100.00 %*
IEMS, 12	*Student Employability*	*100.00 %*
IEMS, 12	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*100.00 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

IEMS, 12

88.89% *IEMS, 12 (CCR)* *Peers: 1*
References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.86*	*5.44*	*40.83 %*
Curriculum Competency	*3.00*	*3.00*	*0.00 %*
Faculty Qualifications	*0.75*	*0.75*	*0.00 %*
Practicality	*0.15*	*0.15*	*0.00 %*
Program Reputation	*2.80*	*3.15*	*12.50 %*
Student Employability	*0.83*	*1.04*	*24.52 %*
Value	*0.07*	*0.68*	*846.88 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*100.00 %*
MMAE, 10	*Curriculum Competency*	*100.00 %*
MMAE, 10	*Faculty Qualifications*	*100.00 %*
MMAE, 10	*Practicality*	*100.00 %*
MMAE, 10	*Program Reputation*	*100.00 %*
MMAE, 10	*Student Employability*	*100.00 %*
MMAE, 10	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*13.25 %*	*Input*
Faculty Qualifications	*59.59 %*	*Input*
Practicality	*27.16 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers
MMAE, 10

99.37% MMAE, 07 (BCC) *Peers: 3*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*3.65*	*0.64 %*
Curriculum Competency	*3.00*	*1.92*	*-36.03 %*
Faculty Qualifications	*0.72*	*0.66*	*-8.15 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.09*	*2.11*	*1.06 %*
Student Employability	*0.69*	*0.72*	*3.58 %*
Value	*0.49*	*0.49*	*0.64 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*9.06 %*
CECE, 12	*Curriculum Competency*	*4.21 %*
CECE, 12	*Faculty Qualifications*	*6.24 %*
CECE, 12	*Practicality*	*15.95 %*
CECE, 12	*Program Reputation*	*8.81 %*
CECE, 12	*Student Employability*	*8.46 %*
CECE, 12	*Value*	*5.33 %*
MMAE, 08	*Course Evaluations*	*69.41 %*
MMAE, 08	*Curriculum Competency*	*72.98 %*
MMAE, 08	*Faculty Qualifications*	*73.99 %*
MMAE, 08	*Practicality*	*70.03 %*
MMAE, 08	*Program Reputation*	*69.95 %*
MMAE, 08	*Student Employability*	*67.60 %*
MMAE, 08	*Value*	*73.75 %*
MMAE, 11	*Course Evaluations*	*21.53 %*
MMAE, 11	*Curriculum Competency*	*22.81 %*
MMAE, 11	*Faculty Qualifications*	*19.76 %*
MMAE, 11	*Practicality*	*14.03 %*
MMAE, 11	*Program Reputation*	*21.24 %*
MMAE, 11	*Student Employability*	*23.93 %*
MMAE, 11	*Value*	*20.92 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*

Practicality	*100.00 %*	*Input*
Course Evaluations	*85.82 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*14.18 %*	*Output*

Peers
CECE, 12
MMAE, 08
MMAE, 11

83.45% *MMAE, 07 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*4.52*	*24.70 %*
Curriculum Competency	*3.00*	*2.51*	*-16.24 %*
Faculty Qualifications	*0.72*	*0.72*	*0.00 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.09*	*2.59*	*23.96 %*
Student Employability	*0.69*	*0.96*	*38.27 %*
Value	*0.49*	*0.58*	*19.83 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*24.39 %*
MMAE, 10	*Curriculum Competency*	*24.19 %*
MMAE, 10	*Faculty Qualifications*	*21.01 %*
MMAE, 10	*Practicality*	*38.96 %*
MMAE, 10	*Program Reputation*	*24.64 %*
MMAE, 10	*Student Employability*	*21.98 %*
MMAE, 10	*Value*	*23.54 %*
MMAE, 11	*Course Evaluations*	*75.61 %*
MMAE, 11	*Curriculum Competency*	*75.81 %*
MMAE, 11	*Faculty Qualifications*	*78.99 %*
MMAE, 11	*Practicality*	*61.04 %*
MMAE, 11	*Program Reputation*	*75.36 %*
MMAE, 11	*Student Employability*	*78.02 %*
MMAE, 11	*Value*	*76.46 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*85.90 %*	*Input*
Practicality	*14.10 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*100.00 %*	*Output*

Peers

MMAE, 10
MMAE, 11

100.00% *MMAE, 08 (BCC)* *Peers: 0*

References: 3

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.62*	*3.62*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.70*	*0.70*	*0.00 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.11*	*2.11*	*0.00 %*
Student Employability	*0.69*	*0.69*	*0.00 %*
Value	*0.51*	*0.51*	*0.00 %*

Peer Contributions

MMAE, 08	*Course Evaluations*	*100.00 %*
MMAE, 08	*Curriculum Competency*	*100.00 %*
MMAE, 08	*Faculty Qualifications*	*100.00 %*
MMAE, 08	*Practicality*	*100.00 %*
MMAE, 08	*Program Reputation*	*100.00 %*
MMAE, 08	*Student Employability*	*100.00 %*
MMAE, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*100.00 %*	*Input*
Course Evaluations	*85.07 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*14.93 %*	*Output*

Peers

MMAE, 08

100.00% *MMAE, 08 (CCR)* *Peers: 0*

References: 1

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.62*	*3.62*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.70*	*0.70*	*0.00 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.11*	*2.11*	*0.00 %*
Student Employability	*0.69*	*0.69*	*0.00 %*
Value	*0.51*	*0.51*	*0.00 %*

Peer Contributions

MMAE, 08	*Course Evaluations*	*100.00 %*
MMAE, 08	*Curriculum Competency*	*100.00 %*
MMAE, 08	*Faculty Qualifications*	*100.00 %*
MMAE, 08	*Practicality*	*100.00 %*
MMAE, 08	*Program Reputation*	*100.00 %*
MMAE, 08	*Student Employability*	*100.00 %*
MMAE, 08	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*51.03 %*	*Input*
Faculty Qualifications	*46.07 %*	*Input*
Practicality	*2.90 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*100.00 %*	*Output*

Peers

MMAE, 08

98.08% *MMAE, 09 (BCC)* *Peers: 4*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*3.70*	*1.96 %*
Curriculum Competency	*3.00*	*1.76*	*-41.25 %*
Faculty Qualifications	*0.67*	*0.62*	*-6.94 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.10*	*2.14*	*1.96 %*
Student Employability	*0.69*	*0.75*	*8.73 %*
Value	*0.44*	*0.45*	*1.96 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*20.88 %*
CECE, 12	*Curriculum Competency*	*10.74 %*
CECE, 12	*Faculty Qualifications*	*15.65 %*
CECE, 12	*Practicality*	*35.74 %*
CECE, 12	*Program Reputation*	*20.33 %*
CECE, 12	*Student Employability*	*18.87 %*
CECE, 12	*Value*	*13.52 %*
EECS, 07	*Course Evaluations*	*5.03 %*
EECS, 07	*Curriculum Competency*	*2.74 %*
EECS, 07	*Faculty Qualifications*	*5.89 %*
EECS, 07	*Practicality*	*7.60 %*
EECS, 07	*Program Reputation*	*5.86 %*
EECS, 07	*Student Employability*	*5.21 %*
EECS, 07	*Value*	*4.41 %*
MMAE, 08	*Course Evaluations*	*28.05 %*
MMAE, 08	*Curriculum Competency*	*32.60 %*
MMAE, 08	*Faculty Qualifications*	*32.52 %*
MMAE, 08	*Practicality*	*27.51 %*
MMAE, 08	*Program Reputation*	*28.31 %*
MMAE, 08	*Student Employability*	*26.42 %*
MMAE, 08	*Value*	*32.82 %*
MMAE, 11	*Course Evaluations*	*46.04 %*
MMAE, 11	*Curriculum Competency*	*53.92 %*
MMAE, 11	*Faculty Qualifications*	*45.95 %*
MMAE, 11	*Practicality*	*29.16 %*
MMAE, 11	*Program Reputation*	*45.49 %*

MMAE, 11	*Student Employability*	*49.49 %*
MMAE, 11	*Value*	*49.26 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*0.00 %*	*Input*
Practicality	*100.00 %*	*Input*
Course Evaluations	*82.28 %*	*Output*
Program Reputation	*5.27 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*12.44 %*	*Output*

Peers

CECE, 12	*MMAE, 08*
EECS, 07	*MMAE, 11*

85.65% *MMAE, 09 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*4.27*	*17.56 %*
Curriculum Competency	*3.00*	*2.37*	*-20.99 %*
Faculty Qualifications	*0.67*	*0.67*	*0.00 %*
Practicality	*0.08*	*0.08*	*0.00 %*
Program Reputation	*2.10*	*2.45*	*16.75 %*
Student Employability	*0.69*	*0.89*	*28.34 %*
Value	*0.44*	*0.55*	*23.62 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*37.74 %*
MMAE, 10	*Curriculum Competency*	*37.50 %*
MMAE, 10	*Faculty Qualifications*	*33.33 %*
MMAE, 10	*Practicality*	*54.55 %*
MMAE, 10	*Program Reputation*	*38.07 %*
MMAE, 10	*Student Employability*	*34.63 %*
MMAE, 10	*Value*	*36.66 %*
MMAE, 11	*Course Evaluations*	*62.26 %*
MMAE, 11	*Curriculum Competency*	*62.50 %*
MMAE, 11	*Faculty Qualifications*	*66.67 %*
MMAE, 11	*Practicality*	*45.45 %*
MMAE, 11	*Program Reputation*	*61.93 %*
MMAE, 11	*Student Employability*	*65.37 %*
MMAE, 11	*Value*	*63.34 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*77.69 %*	*Input*
Practicality	*22.31 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

100.00% *MMAE, 10 (BCC)* *Peers: 0*

References: 2

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*3.63*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.50*	*0.50*	*0.00 %*
Practicality	*0.10*	*0.10*	*0.00 %*
Program Reputation	*2.10*	*2.10*	*0.00 %*
Student Employability	*0.69*	*0.69*	*0.00 %*
Value	*0.45*	*0.45*	*0.00 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*100.00 %*
MMAE, 10	*Curriculum Competency*	*100.00 %*
MMAE, 10	*Faculty Qualifications*	*100.00 %*
MMAE, 10	*Practicality*	*100.00 %*
MMAE, 10	*Program Reputation*	*100.00 %*
MMAE, 10	*Student Employability*	*100.00 %*
MMAE, 10	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*89.35 %*	*Input*
Practicality	*10.65 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

MMAE, 10

100.00% *MMAE, 10 (CCR)* *Peers: 0*
References: 9

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.63*	*3.63*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.50*	*0.50*	*0.00 %*
Practicality	*0.10*	*0.10*	*0.00 %*
Program Reputation	*2.10*	*2.10*	*0.00 %*
Student Employability	*0.69*	*0.69*	*0.00 %*
Value	*0.45*	*0.45*	*0.00 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*100.00 %*
MMAE, 10	*Curriculum Competency*	*100.00 %*
MMAE, 10	*Faculty Qualifications*	*100.00 %*
MMAE, 10	*Practicality*	*100.00 %*
MMAE, 10	*Program Reputation*	*100.00 %*
MMAE, 10	*Student Employability*	*100.00 %*
MMAE, 10	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*90.09 %*	*Input*
Practicality	*9.91 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*97.91 %*	*Output*
Value	*2.09 %*	*Output*

Peers
MMAE, 10

100.00% *MMAE, 11 (BCC)* *Peers: 0*
References: 5

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.59*	*3.59*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.60*	*0.60*	*0.00 %*
Practicality	*0.05*	*0.05*	*0.00 %*
Program Reputation	*2.05*	*2.05*	*0.00 %*
Student Employability	*0.78*	*0.78*	*0.00 %*
Value	*0.47*	*0.47*	*0.00 %*

Peer Contributions

MMAE, 11	*Course Evaluations*	*100.00 %*
MMAE, 11	*Curriculum Competency*	*100.00 %*
MMAE, 11	*Faculty Qualifications*	*100.00 %*
MMAE, 11	*Practicality*	*100.00 %*
MMAE, 11	*Program Reputation*	*100.00 %*
MMAE, 11	*Student Employability*	*100.00 %*
MMAE, 11	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*88.75 %*	*Input*
Practicality	*11.25 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*100.00 %*	*Output*

Peers
MMAE, 11

100.00% *MMAE, 11 (CCR)* *Peers: 0*
References: 8

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.59*	*3.59*	*0.00 %*
Curriculum Competency	*2.00*	*2.00*	*0.00 %*
Faculty Qualifications	*0.60*	*0.60*	*0.00 %*
Practicality	*0.05*	*0.05*	*0.00 %*
Program Reputation	*2.05*	*2.05*	*0.00 %*
Student Employability	*0.78*	*0.78*	*0.00 %*
Value	*0.47*	*0.47*	*0.00 %*

Peer Contributions

MMAE, 11	*Course Evaluations*	*100.00 %*
MMAE, 11	*Curriculum Competency*	*100.00 %*
MMAE, 11	*Faculty Qualifications*	*100.00 %*
MMAE, 11	*Practicality*	*100.00 %*
MMAE, 11	*Program Reputation*	*100.00 %*
MMAE, 11	*Student Employability*	*100.00 %*
MMAE, 11	*Value*	*100.00 %*

Input / Output Contributions

Curriculum Competency	*54.26 %*	*Input*
Faculty Qualifications	*42.61 %*	*Input*
Practicality	*3.13 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*0.00 %*	*Output*
Student Employability	*5.32 %*	*Output*
Value	*94.68 %*	*Output*

Peers
MMAE, 11

98.82% *MMAE, 12 (BCC)* *Peers: 4*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.68*	*3.73*	*1.19 %*
Curriculum Competency	*3.00*	*1.66*	*-44.83 %*
Faculty Qualifications	*0.58*	*0.58*	*0.00 %*
Practicality	*0.09*	*0.09*	*0.00 %*
Program Reputation	*2.20*	*2.23*	*1.19 %*
Student Employability	*0.60*	*0.76*	*26.61 %*
Value	*0.12*	*0.43*	*246.75 %*

Peer Contributions

CECE, 12	*Course Evaluations*	*16.75 %*
CECE, 12	*Curriculum Competency*	*9.23 %*
CECE, 12	*Faculty Qualifications*	*13.39 %*
CECE, 12	*Practicality*	*24.90 %*
CECE, 12	*Program Reputation*	*15.78 %*
CECE, 12	*Student Employability*	*15.08 %*
CECE, 12	*Value*	*11.52 %*
EECS, 08	*Course Evaluations*	*19.90 %*
EECS, 08	*Curriculum Competency*	*11.62 %*
EECS, 08	*Faculty Qualifications*	*23.91 %*
EECS, 08	*Practicality*	*26.47 %*
EECS, 08	*Program Reputation*	*23.32 %*
EECS, 08	*Student Employability*	*20.54 %*
EECS, 08	*Value*	*17.79 %*
MMAE, 10	*Course Evaluations*	*25.55 %*
MMAE, 10	*Curriculum Competency*	*31.72 %*
MMAE, 10	*Faculty Qualifications*	*22.44 %*
MMAE, 10	*Practicality*	*27.83 %*
MMAE, 10	*Program Reputation*	*24.76 %*
MMAE, 10	*Student Employability*	*23.90 %*
MMAE, 10	*Value*	*27.72 %*
MMAE, 11	*Course Evaluations*	*37.81 %*
MMAE, 11	*Curriculum Competency*	*47.43 %*
MMAE, 11	*Faculty Qualifications*	*40.27 %*
MMAE, 11	*Practicality*	*20.80 %*
MMAE, 11	*Program Reputation*	*36.14 %*

MMAE, 11	*Student Employability*	*40.48 %*
MMAE, 11	*Value*	*42.97 %*

Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*70.83 %*	*Input*
Practicality	*29.17 %*	*Input*
Course Evaluations	*32.00 %*	*Output*
Program Reputation	*68.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

Peers

CECE, 12	*MMAE, 10*
EECS, 08	*MMAE, 11*

95.46% *MMAE, 12 (CCR)* *Peers: 2*

References: 0

Potential Improvements

Variable	*Actual*	*Target*	*Potential Improvement*
Course Evaluations	*3.68*	*4.00*	*8.51 %*
Curriculum Competency	*3.00*	*2.21*	*-26.33 %*
Faculty Qualifications	*0.58*	*0.58*	*0.00 %*
Practicality	*0.09*	*0.09*	*0.00 %*
Program Reputation	*2.20*	*2.30*	*4.75 %*
Student Employability	*0.60*	*0.79*	*32.36 %*
Value	*0.12*	*0.50*	*309.02 %*

Peer Contributions

MMAE, 10	*Course Evaluations*	*70.95 %*
MMAE, 10	*Curriculum Competency*	*70.73 %*
MMAE, 10	*Faculty Qualifications*	*66.82 %*
MMAE, 10	*Practicality*	*82.86 %*
MMAE, 10	*Program Reputation*	*71.23 %*
MMAE, 10	*Student Employability*	*68.09 %*
MMAE, 10	*Value*	*69.98 %*
MMAE, 11	*Course Evaluations*	*29.05 %*
MMAE, 11	*Curriculum Competency*	*29.27 %*
MMAE, 11	*Faculty Qualifications*	*33.18 %*
MMAE, 11	*Practicality*	*17.14 %*
MMAE, 11	*Program Reputation*	*28.77 %*
MMAE, 11	*Student Employability*	*31.91 %*
MMAE, 11	*Value*	*30.02 %*

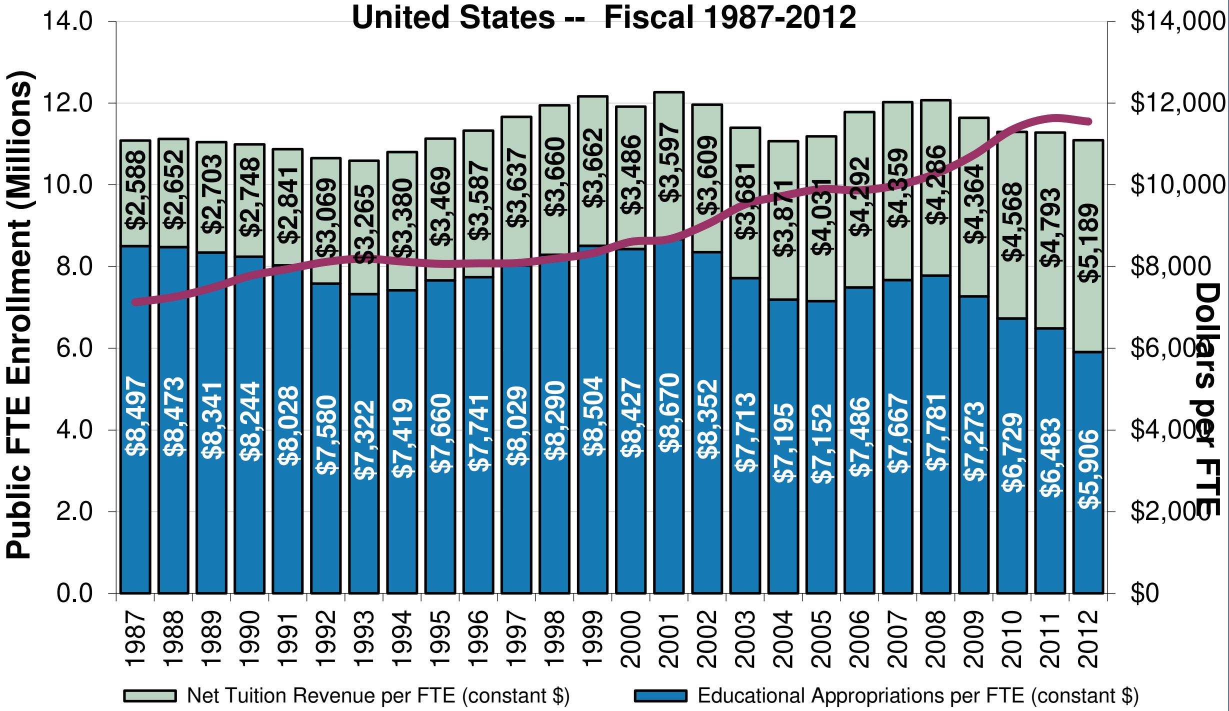
Input / Output Contributions

Curriculum Competency	*0.00 %*	*Input*
Faculty Qualifications	*72.51 %*	*Input*
Practicality	*27.49 %*	*Input*
Course Evaluations	*0.00 %*	*Output*
Program Reputation	*100.00 %*	*Output*
Student Employability	*0.00 %*	*Output*
Value	*0.00 %*	*Output*

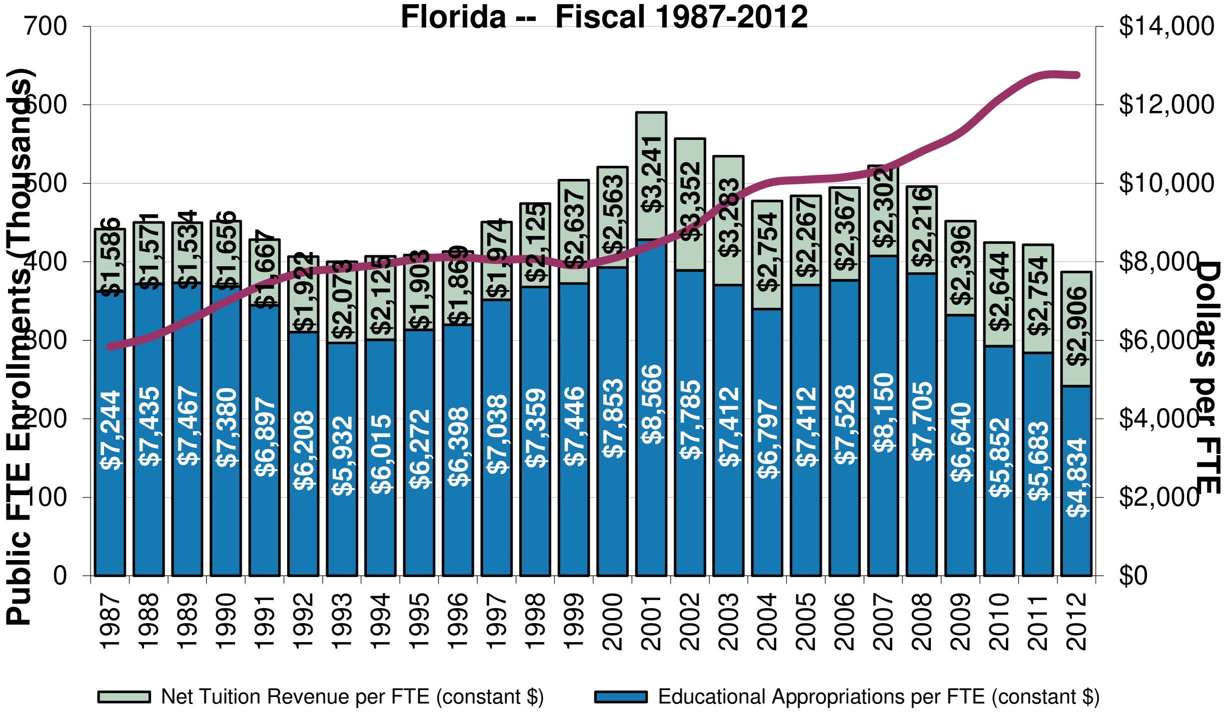
Peers

MMAE, 10
MMAE, 11

APPENDIX U: STATE OF HIGHER EDUCATION



Note: Constant 2012 dollars adjusted by SHEEO Higher Education Cost Adjustment. Educational Appropriations include



Note: Constant 2012 dollars adjusted by SHEEO Higher Education Cost Adjustment (HECA). Educational Appropriations

REFERENCES

Agasisti, T. and Bianco, A. D. (2007). Cost structure of Italian Public Universities: An empirical analysis. *Higher Education in Europe*, 32(2/3), 261-275.

Agasisti, T. and Salerno, C. (2007). Measuring the cost efficiency of Italian Universities. *Education Economics, 15(4), 455-471.*

Alemu, D. S. (2010). Expansion vs. Quality: Emerging Issues of For-Profit Private Higher Education Institutions in Ethiopia. *International Review of Education*, *56*(1), 51-61. doi:10.1007/s11159-009-9150-3

Alonso, J. and Lamata M. (2006). Consistency in the Analytic Hierarchy Process: A New Approach. *International Journal of Uncertainty- Fuzziness and Knowledge-Based Systems,* 14(4), 445-459.

Altbach, P. G., Reisberg, L., & Rumbley, L. E. (2010). Tracking a global academic revolution. *Change: The Magazine of Higher Learning*, *42*(2), 30–39.

Anderson, D. K., Milner, B. J., & Foley, C. J. (2008). From complex data to actionable information: Institutional research supporting enrollment management. *New Directions for Institutional Research*, *2008*(137), 71-82. doi:10.1002/ir.239

Armacost, R., Hosseini, J. & Pet-Edwards. J. (1999). Using the analytic network process as a two-phase integrated decision approach for large nominal groups. *Group Decision and Negotiation,* 8, 535-555.

Athanassopoulos, A. D., & Shale, E. (1997). Assessing the Comparative Efficiency of Higher Education Institutions in the UK by the Means of Data Envelopment Analysis. *Education Economics*, *5*(2), 117-134.

Avkiran, N. (2001). Investigating technical and scale efficiencies of Australian University through data envelopment analysis. *Socio-Economic Planning Sciences*, 35, 57-80. Beasley, J. E. (1995). Determining Teaching and Research Efficiencies. *The Journal of the Operations Research Society*, 46(4), 441-452.

Bell, J. (2011). Taking the “State” Out of State Universities. Retrieved September, 2011, from http://www.ncsl.org/?tabid=23006

Bell, D., Raiffa, H., & Tversky, A. (1988). Descriptive, Normative and Prescriptive Interactions in Decision Making. *In Decision making: descriptive, normative, and prescriptive interactions* (pp. 9-18). Cambridge University Press.

Berger, M. C., & Kostal, T. (2002). Financial resources, regulation, and enrollment in US public higher education. *Economics of Education Review*, *21*(2), 101–110.

Berquist, W. H. (1995). Quality through access, access with quality: The new imperative for higher education. San Francisco, CA: Jossey-Bass Publishers.

Bertrand, J. W. M., & Fransoo, J. C. (2002). Operations management research methodologies using quantitative modeling. *International Journal of Operations & Production Management*, *22*(2), 241–264.

Bessent, A., Bessent, E., Charnes, A., Cooper, W. & Thorogood, N. (1983). Evaluation of educational program proposal by means of DEA. *Educational Administration Quarterl*y, 19(2) 82-107.

Bessent, A., Bessent, E., Elam, J. & Long, D. (1984). Educational Productivity Council Employs Management Science Methods to Improve Educational Quality. *Interfaces*, 14(6), 1-8.

Bleau, B. (1981). Planning models in higher education: Historical review and survey of currently available models. *Higher Education*, 10(2), 153-168.

Breneman, D. (2002, June 14). For Colleges, This Is Not Just Another Recession. *The Chronicles of Higher Education*.

Brennan, J. & Shah, T. 2000, *Managing Quality in Higher Education. An International Perspective on Institutional Assessment and Change* (Buckingham, Open University Press).

Buffa, E. S. (1980). Research in operations management. *Journal of Operations Management*, *1*(1), 1–7.

Capaldi E. & Abbey, C. Performance Costs in Higher Education: A Proposal for Better Data. Change: The Magazine of Higher Learning, 43(2), 8-15.

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

Cheng, Y. C. (2003). Quality assurance in education: internal, interface, and future. *Quality Assurance in Education*, *11*(4), 202-213. doi:10.1108/09684880310501386

Chung, S., Lee, A. & Pearn, W. (2005). Analytic network process (ANP) approach for product mix planning in semiconductor fabricator. *International Journal of Production Economics*, 96(1), 15-36.

Cohn, E., Rhine S. L. & Santos M. (1989). Institutions of Higher Education as multi-product firms: economies of scale and scope. *The Review of Economics and Statistics*, 71(2), 284-290.

Cooper, W., Seiford, L. & Tone, K. (2006). *Introduction to Data Envelopment Analysis and Its Uses.* New York, NY: Springer.

DesJardins, S., Ahlburg D. & McCall, B. (2006). An Integrated model of application, admission, enrollment, and financial aid. *The Journal of Higher Education*, 77(3), 381-429.

Doyle, C., & Cicarelli, J. (1980). The demand for higher education: a disaggregate approach. *The American Economist*, *24*(2), 53–55.

Edmonds, B., Hernandez, C. & Troitzsch, K. (2008). *Social Simulation: Technologies, Advances, and New Discoveries*. Hershey, PA: IGI Publishing.

Emrouznejad, A., Parker, B., & Tavares, G. (2008). Evaluation of research on efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-Economic Planning Sciences*, 42, 151-157.

Evans, G. W. (1984). An overview of techniques for solving multiobjective mathematical programs. *Management Science*, *30*(11), 1268–1282.

Farid, D., Mirfakhredini, H., & Nejati, M. (2008). Prioritizing higher education balanced scorecard performance indicators using fuzzy approach in Iranian context. *Lex et Scientia*, *15*.

Federkeil, G. (2008). Rankings and Quality Assurance in Higher Education. *Higher Education in Europe*, *33*(2-3), 219-231.

Flegg, A. T., Allen, D. O., Field, K., & Thurlow, T. W. (2004). Measuring the efficiency of British universities: a multi-period data envelopment analysis. *Education Economics*, *12*(3), 231-249.

Filippakou, O. (2011). The idea of quality in higher education: a conceptual approach. *Discourse: Studies in the Cultural Politics of Education*, *32*(1), 15-28.

Foreman, L. (1974). Impact of the CAMPUS Model on the Decision Process in the Ontarios Community College. In A. Heinlein (Eds.), *Decision Models in Academic Administration* (pp. 47-64). Kent, Ohio: Kent State University Press.

Gattoufi, S., Oral, M., & Reisman, A. (2004). A taxonomy for data envelopment analysis. *Socio-Economic Planning Sciences*, 38, 141-158.

Geoffrion, A. M., Dyer, J. S., & Feinberg, A. (1972). An interactive approach for multi-criterion optimization, with an application to the operation of an academic department. *Management Science*, *19*(4), 357–368.

Green, D. (1994). What Is Quality in Higher Education? Concepts, Policy and Practice. In D. Green (Eds.), *What Is Quality in Higher Education?* (pp. 13-30). Bristol, PA: Taylor & Francis.

Grünig, R., & Kühn, R. (2009). Decision problems. *Successful Decision-making*, 7–15.

Haines, S. (2000). *Complete Guide to Systems Thinking and Learning*. Amherst, MA: Human Resource Development Press.

Hansson, S. O. (1994). Decision theory. *A Brief Introduction. Department of Philosophy and the History of Technology, Royal Institute of Technology, Stockholm.*

Hardré, P., & Cox, M. (2009). Evaluating faculty work: expectations and standards of faculty performance in research universities. *Research Papers in Education*, *24*(4), 383-419.

Harvey, L. (2008). Rankings of Higher Education Institutions: A Critical Review. *Quality in Higher Education*, *14*(3), 187-207.

Harvey, L. & Green, D. (1993). 'Defining quality', *Assessment & Evaluation in Higher Education,* 18(1), pp. 9–34.

Harvey, L., & Williams, J. (2010). Fifteen Years of *Quality in Higher Education*. *Quality in Higher Education*, *16*(1), 3-36.

Hitzing, H. (2013, January 13). UCF ranks 42 for best value education. *Central Florida Future*, pp. 1.

Ho, W. (2008). Integrated analytic hierarchy process and its applications- A literature review. *European Journal of Operations Research*, 186, 211-228.

Hoenack, S. & Pierro, D. (1990). An econometric model of a public university's income and enrollments. *Journal of Economic Behavior & Organization*, 14(3), 403-423.

Hopkins, D. S. P. (1979). Computer Models Employed in University Administration: The Stanford Experience. *Interfaces*, 13–23.

Hsu, C. and Sandford, B. (2007). The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation*, 12 (10), 1-8.

Hwarng, H. B., & Teo, C. (2001). Translating customers' voices into operations requirements-A QFD application in higher education. *International Journal of Quality & Reliability Management*, *18*(2), 195–226.

Iacovidou, M., Gibbs, P., & Zopiatis, A. (2009). An Exploratory Use of the Stakeholder Approach to Defining and Measuring Quality: The Case of a Cypriot Higher Education Institution. *Quality in Higher Education*, *15*(2), 147-165.

Ibrahim, A. M. (2001). Assessment of distance education quality using fuzzy sets model. *Complement*, *1*, 3.

Immerwahr, J. & Johnson, J. (2010). Squeeze play 2010: Continued public anxiety on cost, harsher judgments on how colleges are run. *Public Agenda. Retrieved from: http://www. publicagenda. org/files/pdf/SqueezePlay2010report_0. pdf.*

Inbar, D. E. (1980). Educational Planning: A Review and a Plea. *Review of Educational Research*, *50*(3), 377.

Jantzen, R. (2000). Price and quality effects on demand for U.S. graduate business programs. *International Advances in Economic Research*, 6(4), 730-740.

Johnes, J. (2006a). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, 25, 273-288.

Johnes, J. (2006b). Measuring teaching efficiency in higher education: An application of data envelopment analysis to economics graduates from UK Universities 1993. European Journal of Operations Research, 174, 443-456.

Johnes, J. (2006c). Measuring Efficiency: A Comparison of Multilevel Modelling and Data Envelopment Analysis in the Context of Higher Education. *Bulletin of Economic Research*, *58*(2), 75-104.

Johnes, J. & Johnes, G. (1995). Research funding and performance in U.K. university departments of Economics: A frontier analysis. *Economics of Education Review*, 14(3), 301-314.

Johnes, J. & Taylor, J. (1990). Performance indicators in higher education: UK universities. Milton Keynes: Open University Press and The Society of Research in Higher Education.

Jones, M. E., & Song, I. Y. (2005). Dimensional modeling: identifying, classifying & applying patterns. *Proceedings of the 8th ACM international workshop on Data warehousing and OLAP* (pp. 29–38).

Kabnurkar, A. (2001). *Mathematical Modeling for data envelopment analysis with fuzzy restrictions on weights* (Master's Thesis). Available from Citeseerx Database (http://citeseerx.ist.psu.edu/viewdoc/download?

Karsak, E., Sozer, S. & Alptekin, S. (2002). Product planning in quality function deployment using a combined analytic network process and goal programming approach. Computers & Industrial Engineering, 44(1), 171-190.

Kassicieh, S. K., & Nowak, J. W. (1986). Decision support systems in academic planning: Important considerations and issues. *Information processing & management*, *22*(5), 395–403.

Kennedy, M. (1998). A Pilot System Dynamics Model to Capture and Monitor Quality Issues in Higher Education Institutions Experiences Gained. *Proc. 16th System Dynamics Conference, Quebec City, Canada*.

Kirby, M. W. (2007). Paradigm change in operations research: Thirty years of debate. Operations Research- Baltimore then Linticum, *55*(1), 1.

Köksal, G., & Egitman, A. (1998). Planning and design of industrial engineering education quality. *Computers & Industrial Engineering*, *35*(3-4), 639–642.

Kuah, C. & Wong, K. (2011). Efficiency assessment of universities through data envelopment analysis. Procedia Computer Science, 3, 499-506.

Law, D. (2010). Quality assurance in post-secondary education: Some common approaches. *Quality Assurance in Education, 18*(1), 64-77.

Landeta, J. (2006). Current validity of the Delphi method in social sciences. *Technological Forecasting & Social Change*, 73, 467–482.

Lee, M. (2010). The Analytic Hierarchy and the Network Process in Multicriteria Decision Making: Performance Evaluation and Selecting Key Performance Indicators Based on ANP Model. In M. Crisan (Ed.), *Convergence and Hybrid Information Technologies* (pp. 125-147). Croatia: INTECH.

Libertore, M. & Nydick, R. (1997). Group decision making in higher education using the analytic hierarchy process. *Research in Higher Education*, 38(5), 593-614. Maguad, B. A. (2011). Deming's "Profound Knowledge": Implications for Higher Education. *Education*, 131(4), 768-774.

Maltz, E. N., Murphy, K. E., & Hand, M. L. (2007). Decision support for university enrollment management: Implementation and experience. *Decision Support Systems*, *44*(1), 106–123.

Masland, A. T. (1983). Simulators, myth, and ritual in higher education. *Research in Higher Education*, *18*(2), 161–177.

McNamara, J. F. (1971). Mathematical programming models in educational planning. *Review of Educational Research*, *41*(5), 419–446.

Mihm, J., Loch, C., Wilkinson, D. & Huberman, B. (2010). Hierarchical structure and search in complex organizations. *Management Science*, 56(5), 831-848.

Mikhailov, L., & Singh, M. G. (2003). Fuzzy analytic network process and its application to the development of decision support systems. *IEEE Transactions on Systems, Man and Cybernetics, Part C (Applications and Reviews)*, *33*(1), 33-41.

Murias, P. & Carlos de Miguel, J. & Rodriguez, D. (2008). A composite indicator for University Quality Assessment: The Case of Spanish Higher Education System. Social Indicators Research, 89, 129-146.

Mustafa, M., & Goh, M. (1996). Multi-criterion models for higher education administration. *Omega*, *24*(2), 167–178.

Newton, J. (2010). A Tale of Two "Qualitys": Reflections on the Quality Revolution in Higher Education. *Quality in Higher Education*, *16*(1), 51-53.

Newton, P., Burgess, D., & Burns, D. P. (2010). Models in Educational Administration: Revisiting Willower's "Theoretically Oriented" Critique. *Educational Management Administration & Leadership*, *38*(5), 578-590

Nunamaker, T. (1985). Using data envelopment analysis to measure the efficiency of non-profit organizations: A critical evaluation. *Managerial and Decision Economics*, 6(1), 50-58.

Okoli, C. and Pawlowski, S. (2004). The Delphi method as a research tool: an example, design considerations and applications. *Information & Management*, 42, 15-29.

O'Meara, K., Terosky, A. L. and Neumann, A. (2008). Faculty Careers and Work Lives: A Professional Growth Perspective. *ASHE Higher Education Report*, 34 (3).

Oppedisano, V. (2011). The (Adverse) Effects of Expanding Higher Education: Evidence from Italy. *Economics of Education Review*.

Owlia, M. S., & Aspinwall, E. M. (1998). Application of Quality Function Deployment for the Improvement of Quality in an Engineering Department. *European Journal of Engineering Education*, *23*(1), 105-115. Pastor, J., Ruiz, J. & Sirvent, I. (2002). A Statistical Test for Nested Radial DEA Models. *Operations Research*, 50(4), 728-735.

Pavlou, P. A., & El Sawy, O. A. (2011). Understanding the Elusive Black Box of Dynamic Capabilities. *Decision Sciences*, *42*(1), 239–273.

Pill, J. (1971). The Delphi method: Substance, Context, A Critique and an Annotated Bibliography. *Socio-Economic Planning Science*, 5, 57-71.

Plourde, P. (1976). Institutional use of models: hope or continued frustration? *New Directions for Institutional Research*, 9, 17-33.

Pratasavitskaya, H., & Stensaker, B. (2010). Quality Management in Higher Education: Towards a Better Understanding of an Emerging Field. *Quality in Higher Education*, *16*(1), 37-50.

Raharjo, H., Xie, M., Goh, T. N., & Brombacher, A. C. (2007). A Methodology to Improve Higher Education Quality using the Quality Function Deployment and Analytic Hierarchy Process. *Total Quality Management & Business Excellence*, *18*(10), 1097-1115.

Ramanathan, R. (2006). Data Envelopment Analysis for Weight Derivation and Aggregation in the Analytic Hierarchy Process. *Journal of Computer and Operations Research*, 33(5), 313-328.

Rath, G. J., Dean, B. V., & Griffin, M. A. (1968). Management science in university operation. *Management Science*, *14*(6), 373–390.

Ray, S. (2004). Data Envelopment Analysis: Theory and Techniques for Economics and Operations Research. Cambridge, United Kingdom: Cambridge University Press.

Remington, K. & Pollack, J. (2007). Tools for complex projects. Available from http://common.books24x7/book/id_37487/book.aspx

Rich, D. (2006). Academic leadership and the restructuring of higher education. *New Directions for Higher Education*, *2006*(134), 37-48.

Rouyendegh, B. & Erol, S. (2010). The DEA-Fuzzy ANP department ranking model applied in iran amirkabir university. *Acta Polytechnica Hungarica*, 7(4), 103-114.

Saarinen, T. (2010). What I Talk About When I Talk About Quality. *Quality in Higher Education*, *16*(1), 55-57.

Saaty, T. (2001). Decision Making for Leaders: The Analytic Hierarchy Hierarchy Process for Decisions in a Complex World. Pittsburgh, PA: RWS Publications.

Saaty, T. (2001). The seven pillars of the analytic hierarchy process. In T. Saaty & L. Vargas (Eds.), *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process: International Series in Operations Research & Management Science* (pp. 27-46). US: Springer.

Saaty, T. (2004). Fundamentals of the analytic network process- dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering*, 13(2), 129-157.

Sahney, S., Banwet, D. K., & Karunes, S. (2004). A SERVQUAL and QFD approach to total quality education: A student perspective. *International Journal of Productivity and Performance Management*, *53*(2), 143–166.

Sarrico, C. S., Rosa, M. J., Teixeira, P. N., & Cardoso, M. F. (2010). Assessing Quality and Evaluating Performance in Higher Education: Worlds Apart or Complementary Views? *Minerva*, *48*(1), 35-54.

Schroeder, R. G. (1973). A survey of management science in university operations. *Management Science*, *19*(8), 895–906.

Seifert, L. & Zhu, J. (1998). Identifying excesses and deficits in Chinese industrial productivity (1953-1990): a weighted data envelopment analysis approach. *Omega*, 26(2), 279-296.

Seiford, L. (1996). Data Envelopment Analysis: The Evolution of the State of the Art (1978-1995). *The Journal of Productivity Analysis*, 7, 99-137.

Shelton, K. 2010. A Quality Scorecard for the Administration of Online Education Programs: A Delphi Study. Doctoral Dissertation, University of Nebraska-Lincoln.

Simar, L. & Wilson, P. (2004). Performance of the bootstrap for DEA estimators and iterating the principle. In W. Cooper, L. Seiford and J. Zhu (Eds), *Handbook on data envelopment analysis*, New York: Kluwer Academic Publishers, Inc., New York (pp. 265–298).

Simon, S., & Ranchero, S. (2010, October 22). Putting a Price on Professors: A battle in Texas over whether academic value can be measured in dollars and cents. *Wall Street Journal*, *26*.

Singh, M. (2010). Quality Assurance in Higher Education: Which Pasts to Build on, What Futures to Contemplate? *Quality in Higher Education*, *16*(2), 189-194.

Singh, V., Grover, S., & Kumar, A. (2008). Evaluation of quality in an educational institute: a quality function deployment approach. *Educational Research and Reviews*, *3*(5), 156–162.

Sinuany-Stern, Z., Mehrez, A. & Barboy, A. (1994). Academic departments efficiency via DEA. Computers & Operations Research, 21(5), 543-556.

Sipahi, S. & Timor, M. (2010). The analytic hierarchy process and analytic network process: an overview of applications. Management Decision, 48(5), 775 – 808.

Smith, P. (1990). Data envelopment analysis applied to financial statements. *Omega*, 18(2), 131-138.

Srikanthan, G. and Dalrymple J. (2002). Developing a Holistic Model for Quality in Higher Education. *Quality in Higher Education*, *8*(3), 215-224.

Subhash, C. (1988). Data envelopment analysis, nondiscretionary inputs and efficiency: an alternative interpretation. *Socio-Economic Planning Sciences*, 22(4), 167-176.

Takamura, Y. & Tone, K. (2003). A comparative site evaluation study for relocating Japanese government agencies out of Tokyo. Socio-Economic Planning Sciences, 37(2), 85-102.

Talluri, S. (2000). Data Envelopment Analysis: Models and Extensions. *Decision Line*, 8-11.

Tam, M. (2001). Measuring Quality and Performance in Higher Education. *Quality in Higher Education, 7*(1), 47-54.

Trow, M. (1973). Problems in the Transition from Elite to Mass Higher Education. Carnegie Commission on Higher Education.

Tsinidou, M., Vassilis, G. & Fitsilis, P. (2010) Evaluation of the factors that determine quality in higher education: an empirical study. *Quality Assurance in Education*, 18(3), 227-244.

Vaidya, O. & Kumar, S. (2006). Analytic Hierarchy Process: An overview of applications. *European Journal of Operations Research*, 169(1), 1-29.

Weinzimmer, L. G. (2001). Fast growth how to attain it, how to sustain it. Retrieved from http://www.netlibrary.com/urlapi.asp?action=summary&v=1&bookid=56135

White, D. J. (1990). A bibliography on the applications of mathematical programming multiple-objective methods. *The Journal of the Operational Research Society*, *41*(8), 669–691.

White, G. P. (1987). A survey of recent management science applications in higher education administration. *Interfaces*, 97–108.

Wiseman, C. (1979). New foundations for planning models. *The Journal of Higher Education*, *50*(6), 726–744.

Yang, T. & Kuo, C. (2003). A hierarchial AHP/DEA methodology for the facilities layout design problem. *European Journal of Operations Research*, 147(1), 128-136.

Zhang, L. (2009). A value-added estimate of higher education quality of US states. *Education Economics*, *17*(4), 469-489.

Zineldin, M., Akdao, H. & Vasicheva, V. (2011). Assessing quality in higher education: A new criteria for evaluating students' satisfaction. Quality in Higher Education, 17(2), 231-243.