EFFICIENCY ANALYSIS AND STRATEGIC PLANNING FOR COLLEGES OF ENGINEERING

A Thesis By

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science with a major in Industrial Engineering.

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Don Malzahn, Committee Chair

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Abu Masud, Committee Member

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Steven Skinner, Committee Member

DEDICATION

This work is dedicated to my parents

All I have and will accomplish are only possible because of their love and sacrifices

ACKNOWLEDGEMENTS

I would like to use this opportunity to express my gratitude to everyone who supported me throughout my graduate studies at Wichita State University. I am grateful for their aspiring guidance and invaluable advice during my thesis work.

I am deeply indebted to my advisor, Professor Don Malzahn for his continuous support, excellent guidance, patience, immense knowledge and encouragement during my studies at WSU. His advice on both research as well as on my career have been priceless. Besides working with him on my thesis, I have had the opportunity to work with him as his graduate teaching assistant in a course named "Engineer as Leader". During my GTA position and my thesis works, I have learned more than I could've imagined from him. I consider myself very lucky to have had the opportunity working with him for the past two years.

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Finally, a very special thanks to my family. Words cannot express how grateful I am to my father, my mother and my sister for their constant love and support and all of the sacrifices they've made.

ABSTRACT

As the need for engineers increase, there is a parallel decrease in public funding of higher education. The press for increased efficiency in the system of higher education is inevitable. Although each college of engineering has its own unique mission, there may be exemplar programs that can provide guidance to them for the continuous improvement of engineering education.

A Data Envelopment based model is developed using the number of faculty as the educational system input and B.S., M.S., PhD degrees, and research expenditures as measures of output for colleges of engineering in the U.S. Data was drawn from the ASEE data mining tool over a three year period (2010-2012) for 186 colleges of engineering. A non-dominated set of 24 efficient engineering colleges was identified and compare with the set of less efficient colleges. The relationship between the level of funded research and PhD production is the same for the efficient and less efficient programs. There is a marked difference between the efficient set and others in the relationship between BS and MS production and funded research. A regression surface fit to the efficient programs and demonstrates the range of these programs.

This thesis is organized as follows: a brief discussion of the issue of efficiency in engineering education and some relevant studies. A summary of Data Envelopment Analysis method is presented with some relevant applications from literature. The set of relevant programs is selected and an efficient set identified. The efficient and less efficient programs are compared. Based on the results a strategic planning determined for schools. Then an analysis performed for each programs. And a further examination with more inputs and outputs with a comparison of result, and a closer look to programs with similar characteristics.

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LIST OF ABBREVIATIONS/NOMENCLATURE

Acc.	Acceptance Rate
AE	Aerospace Engineering
ASEE	American Society of Engineering Education website
BS	Bachelor Degree
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DMU	decision making units
EE	Electrical Engineering
Fac.	Faculty Members
IE	Industrial Engineering
ME	Mechanical Engineering
MS	Master Degree
Res.	Amount of Research Dollars
Tu.	Tuition
VRS	Variable Return to Scale

CHAPTER 1

BACKGROUND

1.1 Introduction / Motivation

Today the demand for higher education is increasing in the U.S, especially in the field of engineering. As the need for adopting new technologies and technical skills plays a vital role in the survival of individual companies and entire industries. Employees sense the need to enhance their knowledge in order to compete in this new world. On the other hand, the cost of higher education has been increasing in the U.S. Increasing the economic efficiency of education is becoming a major concern for many schools and there is a wide range of new competitors in the education market. The “efficiency” of education from the viewpoint of public policy may be the ratio of economy valued outputs to economy valued inputs with the arbiter of value assumed to be a market based system. Engineering colleges would like to define a feasible and practical strategy to enhance their efficiency based upon their unique objectives.

Data Envelopment Analysis (DEA) is a wieldy used non-parametric method is used to determine the relative efficiency of decision making units (DMU). This paper presents a DEA approach to measure the relative efficiency of different engineering programs in the US, and identify a set of efficient programs. In this chapter, first a brief discussion about efficiency in higher education provided. In addition to that, a brief introduction to Data Envelopment technique on determining efficiency scores and its application provided.

1.2 Efficiency in Higher Education

Efficiency as a concept has been the topic of many studies. There are many studies performed to find promising ways to enhance efficiency in different organizations. Efficiency in higher education also has been the topic of research for a number of studies, many discuss different ways to improve or compare efficiency in higher educations. A literature review performed to find out relevant studies that performed in this area before.

1.2.1 Demand for Higher Education

The demand for higher education is increasing significantly [1]. The world today is facing challenges that motivate the growth of technology in every aspect of life [2]. From 2000 to 2010, the number of full-time undergraduates increased by 45% and the number of part time undergraduates increased by 27%.

In today's world, each company needs to stay up-to-date and use the leading technology in their filed to perform better. In fact, many industries invest a significant amount of money in research to find effective and innovative solutions to overcome their problems and increase their efficiency. Thus, the need for adopting new technologies and knowledge into the industry could is increasing. Managers and stockholders are looking for employers who have the sufficient knowledge could solve the problems innovatively especially in engineering fields [2]. To stay competitive, many want to increase their capability and knowledge. Thus, the demand for higher education is significantly increasing.

Published information also confirmed that the college enrolments have grown rapidly during the past few years. The percentage of all associate degrees that awarded by for profit intuitions increased 12-19% [3]. The percentages of bachelor degrees awarded increased 2-6% [3] and the percentage of all graduate degrees awarded increased 2-9%. [3]. From 2000 to 2010, the number of full-time undergraduates increase 45%, and the number of part time undergraduates increased 27%.

Although the number of engineering BS degrees increased by 5% in 2012 and MS degrees increased by 6%, there are still unmet needs. Each year over 500,000 new engineers come into the world market from China, India and Eastern European, at 20-30% lower cost than an engineer graduated in the US [4]. Therefore, the efficiency of universities and the value of their knowledge creation is a relevant issue. In order to compete, universities have to look for innovative ways to increase their efficiency.

1.2.2 Cost of Higher Education

According to the published information about the tuition and fees in engineering schools in US, there is an obvious increase in the net price that paid by students. The average net price that a full time student pays for public four year colleges increased significantly in 2012-13 [3]. Average published in-state tuition and fees increased by 4.8% and average out-of-state tuition and fees increase by 4.2%, both of which exceed the inflation rate of 2.1%.

Many students will receive financial aides to pay their tuition. Nearly 2/3 of all college students will receive some form of grant, federal financial aids, or assistantship to pay their tuition [3]. Consequently, most students are under loans when they want to start their carrier after college. The question then is, is it really worth it? Is it possible to determine the quality of the knowledge that they gained? In addition, how to compare universities in terms of efficiency? It is very hard to determine the true value of higher education.

1.2.3 Value of Higher Education

The value of education is a very hard to find, since beside the increase in salary, it is not possible to calculate all the opportunities that a student could have because of the knowledge that he gained in university [5, 6]. However it is really hard to determine if "the degree is really worth it". A student may face many opportunity loses during their studying years, and because it is very hard to work full time during school, it would probably cost a lot more that it seems. Besides, many students are using financial aids and student loans to pay for their studies, so they would probably graduate with huge debt on their accounts. Considering all these factors, it is very hard to have an accurate estimation about the true value of higher education, and compare the performance of different schools to each other.

A college degree may have many benefits. Over an adult working time, from ages 25 to 64, average income for a high school graduates is $1.2 million, this amount will increase to $1.6 million for an associate's degree holders; and for a bachelor's degree holders the amount is enhance to $2.1 million [6, 7] Beside income, a college graduate may enjoy a lot of benefits, such as professional mobility, better quality of life, improved consumer decision making, and more leisure activities and hobbies. [6]

It was stated on a report published by the Carnegie Foundation that, "non-monetary individual benefits of higher education include the tendency for postsecondary students to become more open-minded, more cultured, more rational, more consistent and less authoritarian; these benefits are also passed along to succeeding generations" [5]. Moreover, college attendance revealed to have characteristics like: "decrease prejudice, enhance knowledge of world affairs and enhance social status", whereas more economic opportunities and job security for those who earn bachelor's degrees" [6]. Considering all values of a college degree, it is vital to be able to have a better estimation of the efficiency of colleges.

Attempts to "rate" academic programs are always viewed with caution. The most noted is the US News and World Report rankings [8]. These are based on the Carnegie categories of universities using a weighting of both inputs and outputs of up to 16 measures. This model implies that the “value” of an institution is the sum of the values of both inputs and outputs, not an efficiency or effectiveness measure. The quality of the “system” is thus hidden because a higher score on outputs is the natural (unmanaged) result of higher scores for inputs.

In order to stay competitive, each organization must determine its performance compared to others in similar markets and; if possible, an ideal theoretical target. This is valid for industries, governments, as well as educational institutions. Efficiency in general, can be described as the amount of cost, effort, and other resources used to realize an intended purpose. The term is often used with the purpose of assessing the capability to produce a specific amount of output with minimum input, or alternatively to generate a maximum possible outcome with specific inputs.

1.2.4 Determining the Efficiency of Higher Education

Determining the efficiency of higher education institutions is difficult. They are typically non-profit, there is an absence of a standard for documenting outputs and inputs, and each presents a unique mix of inputs and outputs [9]. Each school may have unique objectives depending on the policies of the governing system, geography, current economic situation, mix of programs, public image, and a host of other factors. Comparing schools with the same objective function does not provide the institution with any actionable information for improvement. According to the definition of efficiency, if a school has the highest outcomes, comparing it to others does not mean that the school is the most efficient unless inputs or resources are considered.

Since there is no single objective function describing all universities, the efficiency cannot be measured by direct comparison using a single objective function score. Because of the nature of the variety institutional objectives and resources, there is not one school that can dominate all others in terms of economic efficiency. Thus, many programs could be efficient in terms of their resources and the outcomes. Each school that is efficient lies on the efficient frontier, and those who are not as efficient can define a strategy based similar efficient programs.

We define the value of the outputs of an engineering college to be a function of the number of productive individuals graduated and the value of the knowledge generated by the institution through research. As a proxy for the number of productive units generated to the economy, we use the number of degrees awarded. This measure could be improved with an economic measure of quality of contribution such as starting salaries, but that information was not available and anecdotal evidence indicates that there are not large differences among engineering colleges in starting salaries. The dollars of externally generated research is used as a surrogate measure for the economic contribution of the knowledge produced.

Our model uses number of faculty positions (tenure and non-tenure) as the single input to the engineering education process. Faculty positions are basis for resource allocation within the university system. Many other inputs such as; staff, equipment, and laboratories are considered to be a function of the number of positions allocated to engineering education. In the current model we do not consider the quality of students as an input.

Each institution is assumed to have an objective (output) that is a combination of the number of BS degrees, MS degrees, PhD degrees, and amount of externally funded research. Some programs may have an undergraduate emphasis, other have a focus on professional masters programs, while others emphasize PhDs and funded research.

1.3 Data Envelopment Analysis

To compare schools (or any systems) with each other, in terms of efficiency, there are some numeric methods are useful in determining efficiency. Data Envelopment Analysis (DEA) is a method to evaluate the efficiency of different systems without any specific assumptions about their objective functions.

1.3.1 DEA and Its Application

Data Envelopment Analysis (DEA) is a methodology that has been used to evaluate the efficiency of decision making units with respect to their inputs and outputs [9,10,,11,12,13,14,15,16,17, 18 and 19]. DEA is a non-parametric method to compare the efficiency of decision making units (DMUs), against the best possible decision making unit. In the DEA methodology, there is no specific assumption for objective functions and DMUs are allowed to be compared only based on their inputs and outputs. The method has been used in different areas such as economic, health care, management, business and education [10, 11,12 and 13].

Jill Johnes [9] implemented DEA method to find the technical efficiency of higher education in England. In the study, an output oriented DEA has been used to examine over 100 universities, using multiple inputs and outputs. The result has been statistically tested to find the significant factors that contributed to the outcomes. There was no assumption about the objective functions and the production functions. The efficiency was assumed to be the ratio of outputs to inputs. In another study [14], Reka Toth examined the efficiency of higher education in European countries using the DEA method. In that study, DEA has been used to evaluate the production efficiency of higher education and its relationship to certain elements of the financing mechanism and socio-economic factors. DEA has been used to evaluate the efficiency of candidates for graduate schools at the University of Bridgeport. They implemented the technique to enhance the quality of evaluation process for their graduate school [15, 16]. There are other examples of DEA application in evaluating schools [17], however the proposed method in this study is combining DEA methodology with mathematical analysis to find efficient surface for all engineering schools.

1.3.2 DEA Models

DEA is a non-parametric approach that can provide the relative efficiency scores for different DMUs. Unlike parametric approaches like Regression Analysis, DEA can optimize each DMU based on its inputs and outputs and does not need a single function that can be fit to all DMUs [19].

DEA methods can be clustered into two main categories: input or output oriented. Input-oriented DEA focuses on finding the minimum amount of input to achieve an objective. Output oriented DEA concentrates on maximizing outputs generated from constant inputs. DEA models can also be classified based on their “optimally scale” criterion. Models can assume a Constant Return to Scale (CRS), or Variable Return to Scale (VRS). [19]. VRS was first introduced by Banker et al. [20] as a development of the CRS method. VRS provides for increasing or decreasing efficiency based on size; however CRS assume a linear scale for the inputs and outputs thus providing no scaling efficiency [19]. In this paper we employ an output oriented VRS DEA method. Further explanation for the VRS has been provided below.

A basic DEA method finds the efficiency score of each DMU as a ratio of output/input by allowing multiple inputs and outputs in the model. Defining the efficiency as the weighted sum of outputs over the inputs, in the CRS model, the efficiency score for each DMU can be found by solving the equation (1). Equation (1) can be transformed to a linear program equation and then represented as a dual model as it represented in the equation (2). [18, 19]

$$e_p = \max \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}} \tag{1}$$

s.t.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \qquad \forall\, DMU_j$$

$$v_r, u_i \geq 0 \qquad \forall\, k, j.$$

Where,
y_{ri} = amount of output r produced by DMU_j,
x_{ij} = amount of input i produced by DMU_j
u_r = weight given to the output r,
v_i = weight given to the input i.

$$\min \emptyset_p - \varepsilon\left(\sum_r s_r^+ + \sum_i s_i^-\right) \tag{2}$$

s.t.

$$\sum_j \lambda_j x_{ij} + s_i^- = \emptyset_p x_{ip} \qquad \forall\, input_i$$

$$\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \qquad \forall\, input_i$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \qquad \forall\, k, j.$$

$$\emptyset_p\ unconstraind$$

Adding just one constraint to the equation (2) can change the model from VRS to CRS, which is represented in the equation (3). The result of the model, Øp, is the efficiency for DMUp. Then (1/ Ø), is the technical efficiency for each DMU. The maximum possible technical efficiency score is 1 (100%) for each DMU. In VRS, DMUp is considered efficient if the technical efficiency is equal to 1, and all the slacks (Si+, Sr-) are equal to zero [19].

$$\min \emptyset_p - \varepsilon\left(\sum_r s_r^+ + \sum_i s_i^-\right)$$

s.t.

$$\sum_j \lambda_j x_{ij} + s_i^- = \emptyset_p x_{ip} \qquad \forall\, input_i$$

$$\sum_j \lambda_j y_{rj} - s_r^+ = y_{rp} \qquad \forall\, input_i$$

$$\sum_j \lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- \geq 0 \qquad \forall\, k, j.$$

$$\emptyset_p \; unconstraind$$

(3)

In an output oriented DEA, if a DMU has a score of less than one, which means there is at least one DMU who can produce a better outcome given the input of the inefficient unit. When the best DMUs, with score of 1 are identified and the efficient set identified. Efficient frontier describes the best possible set of inputs and outputs. If a college lies on the efficient frontier, this implies that it is generating the best possible outcome given its inputs.

In this research, DEA model has been built, by using PIM-DEA Software [21, 22]. DEA model built based on an output oriented VRS DEA and efficiency scores calculated with PIM-DEA software [22], which is designed to solve DEA models and generate efficiency score with a range of assumptions.

CHAPTER 2

DATA ANALYSIS

2.1 Introduction

In our study, information for all universities has been gathered from the American Society of Engineering Education ASEE website [23]. ASEE collects a variety of self-reported data for each engineering college and program. The data includes: the number of degrees awarded, enrollment, faculty and other teaching / research personnel, students appointments and research expenditures. The research expenditure includes and budgets from external sources such as federal government state government industry, etc. The accuracy of the self-reported data may be a source of debate, especially when it is used as the basis of the model.

2.2 Data

In this paper, for each college the number of bachelor degrees awarded, the numbers of masters and PhD degrees awarded, and the amount of research dollars are classed as outputs, and the number of faculty members used as a measure of inputs. The simple conceptual model is an engineering college has two fundamental classes of outputs; educated professionals who have the ability to contribute to society throughout their careers and the generation of knowledge. The number of degrees granted and the dollars of funded research are surrogate measures for the value of these outputs. Given that personnel costs are the largest portion of a college of engineering budget, the number of faculty is used as a surrogate for the value of input. For each university, the average of the three years (2009-2012) was calculated to use in the model. Table 1 provides an example of the data set after finding the average inputs and outputs for each university.

Only colleges reported that they had graduated at least one BS, one MS, one PhD in any of the reporting years, was included. It is important to include only those programs that are comparable to the majority of engineering colleges. Also, colleges that did not report funded research were excluded because of the incompleteness of the data. There were outliers (more than 3 standard deviations away from the mean) on each of the measures. Fourteen programs were dropped with these criteria leaving 172 colleges.

TABLE 1

THE MEANS FOR THREE YEARS OF COLLEGES DRAWN FROM THE ASEE WEBSITE

Engineering College	**Total Fac.**	**Total BS Degrees**	**Total MS Degrees**	**Total PhD Degrees**	**Total Res.**
Alfred University-NY State College of Ceramics	18.33	62.67	10.33	4.67	$4,611,811
Arizona State University	225.00	682.00	537.67	118.67	$74,946,845
Auburn University	161.33	500.67	165.33	58.33	$57,631,667
Boise State University	55.33	168.33	46.67	1.67	$7,163,066
Boston University	110.00	266.33	156.67	56.33	$73,401,058
Brigham Young University	76.00	356.67	96.33	21.67	$9,615,157
…	…	…	…	…	…
Wichita State University	43.67	203.00	208.33	9.00	$5,873,451
William Marsh Rice University	123.00	215.33	107.33	75.00	$48,789,853
Worcester Polytechnic Institute	94.33	482.33	301.00	20.00	$10,266,666
Wright State University	76.00	204.00	190.00	18.33	$12,612,333
Yale University	61.33	64.33	70.33	21.67	$27,731,285

2.3 DEA Model of Engineering Colleges

After collecting the required information, a DEA model was created. It was assumed that colleges want to get greater outputs with the current resources, because inputs may be much more difficult to alter. The return scale for different outputs may be different, thus, a variable return to scale (VRS) model is considered. The model generated is based on an input oriented VRS-DEA model with four outputs and one input.

TABLE 2

DATA FROM THE 24 EFFICIENT COLLEGES IDENTIFIED FROM THE DEA ANALYSIS

School	Total Fac.	Total Bachelor's	Total Master's	Total Doctoral	Total Res.	Efficiency Score
Alfred University-NY State College of Ceramics	18.33	62.67	10.33	4.67	$4,611,811	100
Georgia Institute of Technology	428.00	1674.33	992.33	284.33	$207,424,291	100
Purdue University	328.33	1359.33	472.67	214.00	$202,752,123	100
Southern Methodist University	58.00	148.00	346.00	23.00	$5,635,967	100
Stevens Institute of Technology	127.00	328.00	755.50	31.00	$25,786,293	100
Texas A&M University	364.00	1238.00	638.00	197.33	$274,680,333	100
The George Washington University	87.50	95.50	530.00	46.50	$13,966,120	100
The Johns Hopkins University	167.00	325.00	836.33	79.33	$73,477,000	100
University of California-Irvine	115.33	515.33	156.33	72.67	$68,701,000	100
University of California-San Diego	195.00	807.00	341.67	135.33	$151,155,031	100
University of Central Florida	141.00	735.67	325.00	65.00	$66,951,404	100
University of Florida	281.67	994.67	908.00	223.00	$78,595,333	100
University of Illinois at Urbana-Champaign	414.67	1361.33	536.67	285.67	$223,340,012	100
University of Pennsylvania	123.00	365.33	436.33	61.00	$85,842,104	100
Worcester Polytechnic Institute	94.33	482.33	301.00	20.00	$10,266,666	100
Rensselaer Polytechnic Institute	146.67	731.67	228.00	74.00	$48,452,394	99.61
Duke University	105.00	262.00	239.00	49.00	$74,392,134	99.38
University of Maryland-College Park	200.00	646.67	382.33	132.67	$150,514,179	99.37
Lawrence Technological University	37.33	128.00	133.00	4.00	$2,155,104	98.58
University of Michigan	377.67	1294.33	916.00	236.33	$188,390,621	98.39
The University of Texas at Austin	278.00	1029.00	457.00	191.33	$161,379,281	98.37
Texas A&M University - Kingsville	49.33	169.00	205.00	2.33	$1,939,628	97.09
University of California-Riverside	86.67	214.00	60.67	57.33	$35,865,784	96.9
The Pennsylvania State University	374.67	1440.00	381.00	177.33	$138,262,299	95.63

Using the above assumptions, an output oriented VRS DEA model was developed with PIM-DEA software [22], which is designed to solve DEA models and generate efficiency score, with a range of assumptions. Table 2 represents the final DEA set of efficient colleges. It was assumed that programs with 95% or greater efficiency scores are efficient. Presented in Table 2 is the input and output data for the 24 programs is in the efficient set.

A simple comparison of the set of efficient colleges with the less efficient set is presented in Table 3. The ranges for each of the outputs and the input variables are quite similar indicating that the both sets include a wide range of program sizes. There is a significant difference in means between the efficient and less efficient sets. This is to be expected because the objective of DEA analysis is to identify the most efficient set of colleges.

TABLE 3.

A SUMMARY OF INPUT AND OUTPUT DATA FOR THE EFFICIENT AND LESS EFFICIENT PROGRAMS

	Faculty	**BS Degrees**	**MS Degrees**	**PhD Degrees**	**Research**
Efficient					
Min	18.3	62.7	10.3	2.3	$1,939,628
Max	428.0	1674.3	992.3	285.7	$274,680,333
Mean	191.6	683.6	441.2	111.1	$95,605,705
Sdev	127.2	491.7	271.3	90.2	$80,256,853
Less Efficient					
Min	21.0	27.0	7.0	1.0	$1,242,109
Max	441.0	1644.0	948.0	285.0	$267,449,000
Mean	119.2	346.3	181.8	43.1	$36,941,431
Sdev	79.1	285.4	178.5	50.6	$45,255,817
Difference	**72.4**	**337.3**	**259.4**	**68.0**	**$58,664,274**
Z	**2.70**	**3.27**	**4.52**	**3.60**	**3.49**

A comparison of raw efficiency scores provides some insight to the difference between efficient and less efficient colleges. Initial analysis indicated that by combining BS and MS degrees, more robust analysis was obtainable. This does make sense in that both BS and MS degrees require similar amounts of faculty effort for a degree to be earned. Figures 1, 2, and 3 present the relationships between Research/Faculty, (BS+MS)/Faculty, and PhD/Faculty. Table 4 summarizes the regression analysis for pairs of variables.

2.4 Analysis

2.4.1 Relationship among Factors

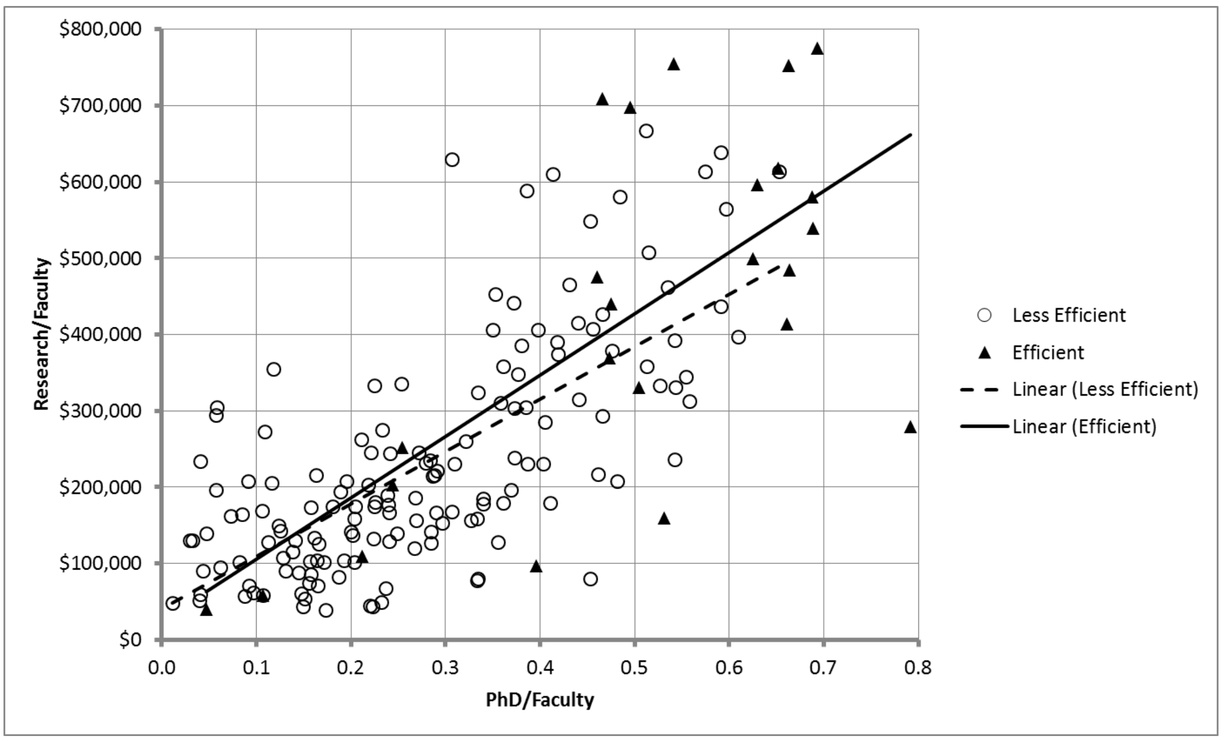

Figure 1.Relationship between the number of PhD degrees granted per faculty and the amount of funded research per faculty

Figure 1 presents the relationship between the number of PhD/Faculty and Research/Faculty. The relationship for both the efficient and less efficient sets are significant with R^2 of 0.50 and 0.46. The plots in Figure 1 indicate that there is no difference between efficient and less efficient programs in the relationship between PhD degree production and research funding with each PhD degree per year having $700,000 to $800,000 in research funding per year for both sets. This may be interpreted as indicating that $700,000 of research is required to support a PhD graduate or the each PhD graduate generates $700,000 in funded research. The interesting point is that this is true for both the efficient and less efficient colleges.

Figure 2 illustrates the relationships between the number of (BS+MS)/Faculty granted per year and the number of PhD/Faculty granted per year. There is no clear relationship for the set of less efficient programs, $R^2 = 0.03$. However, the set of efficient programs indicates a negative relationship, $R^2=0.46$. The more PhD degrees granted the fewer (BS+MS) degrees granted for efficient colleges. There appears to be some constraint that relates (BS+MS)/Faculty and PhD/Faculty for the more efficient programs while the less efficient programs graduate more (BS+MS) for a given levels of PhDs.

In addition to comparing efficient with less efficient programs across input and outputs, a model for the set of efficient colleges was developed. The objective was to identify an “optimal” surface identified by the efficient set. A wide range of models was developed and the model with the highest F score is presented for discussion. The statistics for the ANOVA and regression equation are presented in Table 5.

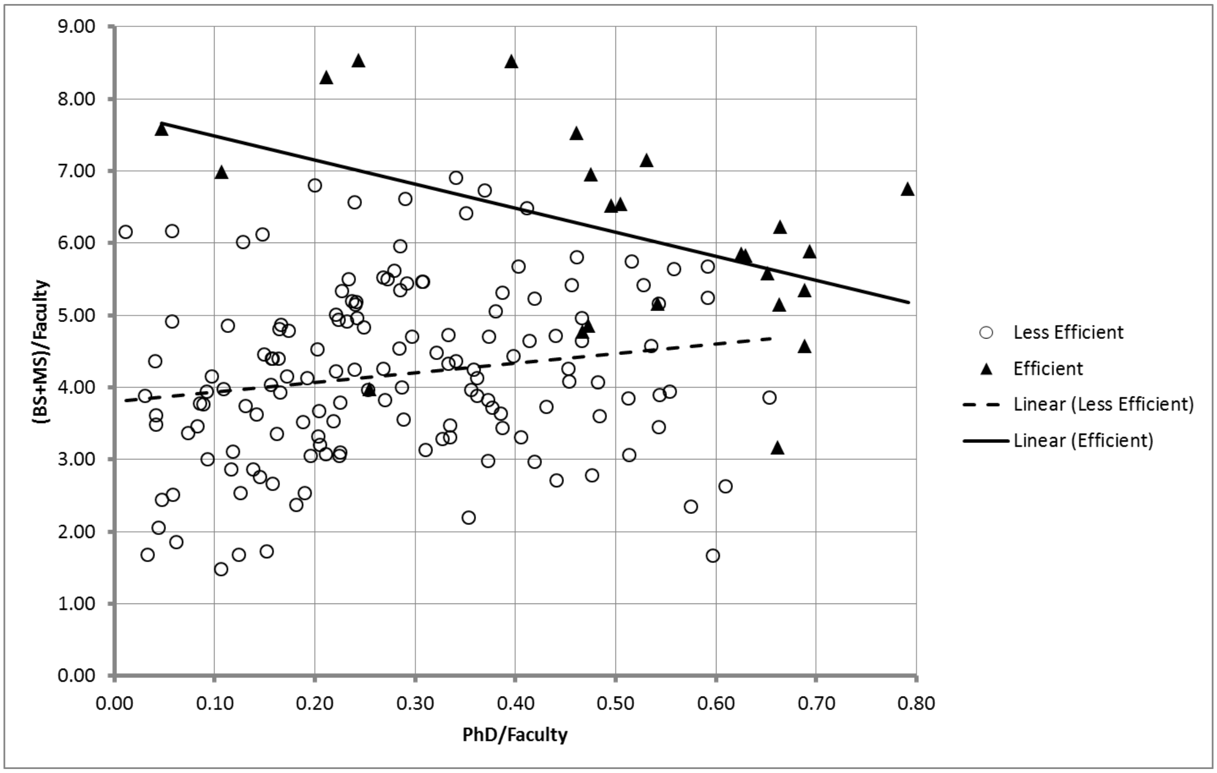

Figure 2. The relationships between the number of BS and MS degrees granted per year and the number of PhD degrees

Figure 3 illustrates the relationship between (BS+MS)/Faculty production and Research/Faculty. Efficient programs demonstrate a negative relationship between degree productivity and research productivity, R^2=0.30. Teaching load and research productivity have a negative relationship. The same cannot be said for the less efficient programs. Teaching load (BS+MS)/Faculty appears to have little effect on research productivity, Research/Faculty, R^2<0.01.

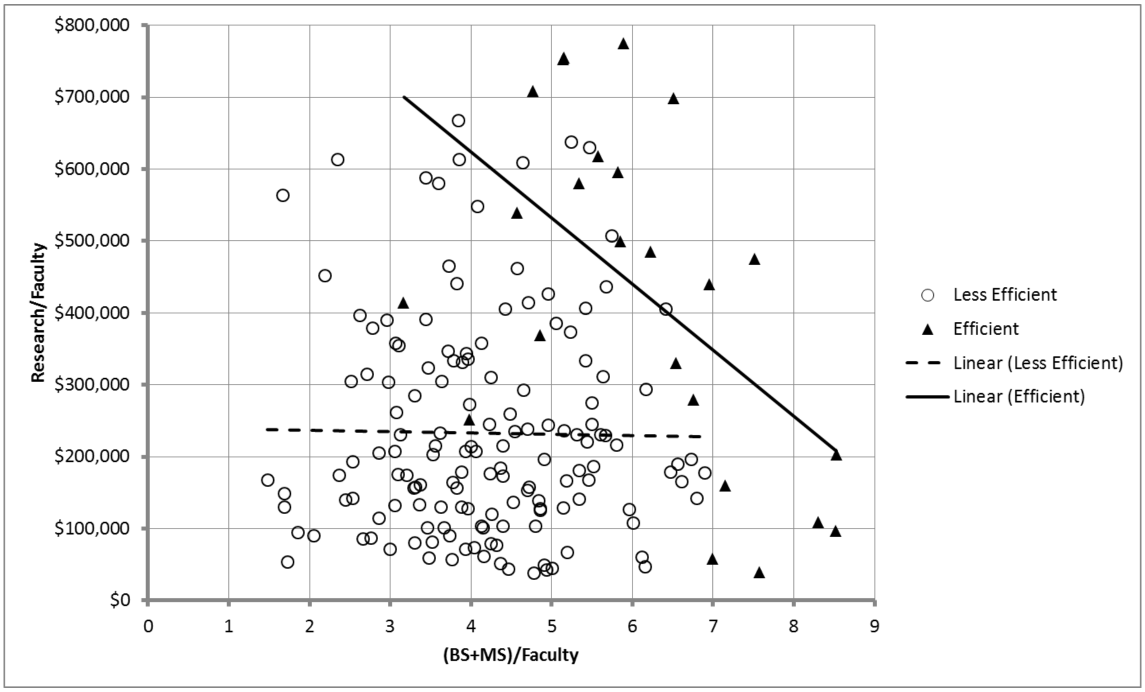

Figure 3. The relationship between (BS+MS) degree production and research productivity

2.4.2 ANOVA and Regression Analysis

TABLE 4

LINEAR REGRESSION EQUATIONS FOR DATA IN FIGURES 1 THROUGH 3

	Research and PhD Figure 1		
Less Efficient	Research/Fac =	$40,909 + $685,763 * PhD/Fac	R^2 = 0.50 *
Efficient	Research/Fac =	$25,275 + $803.768 * PhD/Fac	R^2 = 0.46 *
	(BS+MS) and PhD Figure 2		
Less Efficient	(BS+MS)/Fac =	3.80 + 1.34 * PhD/Fac	R^2 = 0.03
Efficient	(BS+MS)/Fac =	7.81 – 3.33 * PhD/Fac	R^2 = 0.46 *
	Research and (BS+MS) Figure 3		
Less Efficient	Research/Fac =	$241,065 - $1,918 * (BS+MS)/Fac	R^2 < 0.01
Efficient	Research/Fac =	$991,803 - $91,876 * (BS+MS)/Fac	R^2 = 0.30 *

The set of efficient programs may define an “efficient” surface that describes relationships between the input and output variables for a range of objective functions. The slope of this surface at any point indicates the relative contribution among parameters. In order to determine the structural relationship between the output parameters for the efficient set of programs, numerous models were predicting the amount of research dollars per faculty members. The model with the highest F is presented in Table 5.

Table 5

ANOVA and Regression model of the efficient surface

Regression Statistics	
Multiple R	0.851
R Square	0.723
Adjusted R Square	0.647
Standard Error	140,406
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	9.28E+11	1.86E+11	9.413642	0.000152
Residual	18	3.55E+11	1.97E+10		
Total	23	1.28E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2,324,126	909,978	-2.55	0.020
BS+MS	675,493	234,793	2.88	0.010
PhD	4,146,586	1,398,483	2.97	0.008
(BS+MS)^2	-49,681	16,091	-3.09	0.006
PhD^2	-2,143,746	808,432	-2.65	0.016
(BS+MS)*PhD	-300,254	152,030	-1.97	0.064

2.4.3 Efficient Surface

This model defines a nonlinear surface describing the relationship between (BS+MS), PhD, and Research. An illustration of this surface is presented in Figure 4 and may be a representation of the efficient frontier. The slope of this surface is quite different for different sets of parameters indicating a wide range of objective functions in the efficient set.

The efficient surface reveals characteristics of "average" efficient schools in different levels of inputs. The surface demonstrated that, how a school should act in different levels of inputs in order to stay efficient without any assumptions about objective functions. Figure 4 reveals a positive correlation between number of PhD students and the amount of research dollars per faculty in the efficient set. To stay efficient, as the number of PhD students per faculty increase the amount of research dollars should also increase, however, as the number if BS+MS students increase, the amount of research dollars decrease in the efficient set.

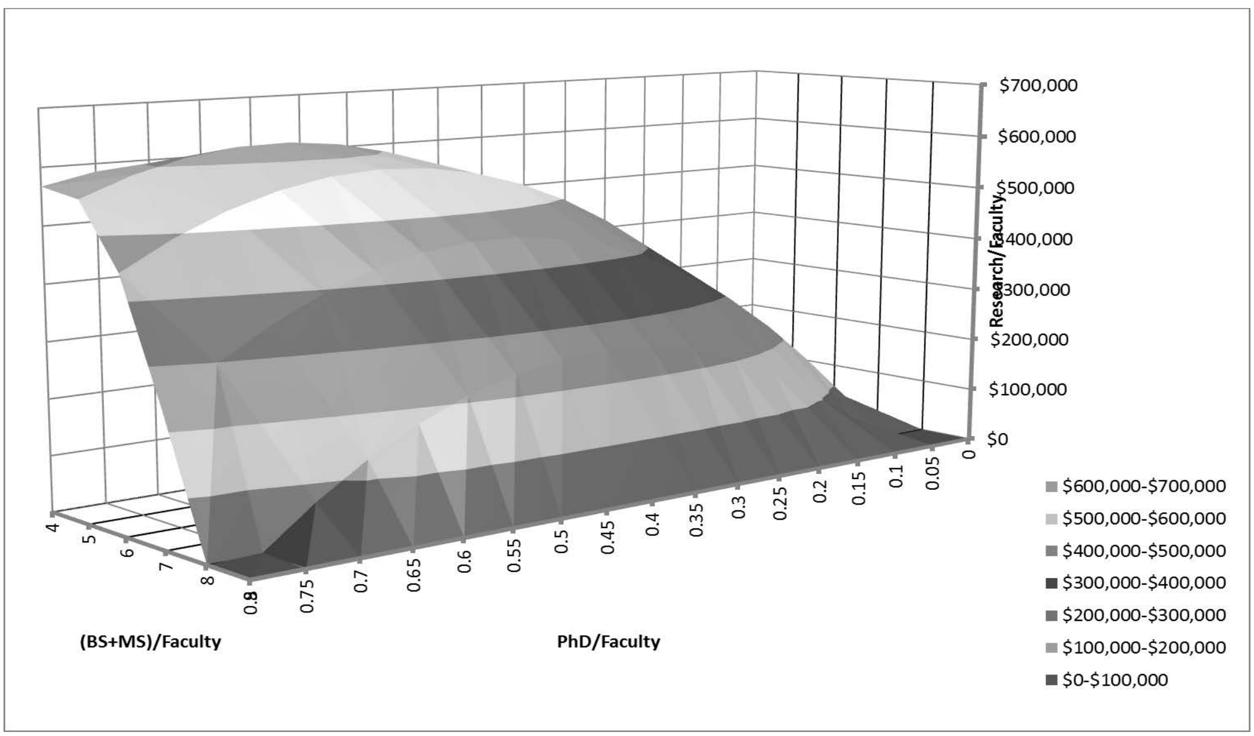

Figure 4. A surface fit though the set of efficient programs

2.5 Summary

Using DEA model, efficient set of engineering colleges determined. Further analysis revealed at least some initial similar characteristics among efficient universities. A surface then was fit through the set of efficient universities that allows predicting the behavior of efficient universities with different inputs and outputs. Using that information any program then can identify the shortest distance from its position to the efficient surface. This path can then be used to determine specific strategies and accurate planning to enhance efficiency and improvement.

CHAPTER 3

PLANNING AND PROGRAMS

3.1 Strategic Planning

After determining the efficient surface, then the next step is to find the closest distance from each university to the surface. That determines a feasible way for each university to become more efficient. Using the efficient surface for each university, it is possible to find the closest path to the surface, and also having a measure of each dimension to get there. It can be done with the formula for the distance to a plane from a point. Using that formula the distance and the direction for non-efficient universities measured. If the distance is very close to zero that means that the university is very close to become efficient, and if it is big, that means the distance is far.

3.1.1 Distance to Surface

Using that information a feasible practical strategic plan can be developed for each non-efficient university. The information consists of the amount of PhD, MS+BS, and research dollars that they should produce to become efficient. If they can improve or reduce their current outputs, based on their current input (faculties) to that number, then they would be acting as efficient universities. The most important part is, this strategic plan is unique for each university, considering its current resources and outcomes and comparing to the closest efficient universities. That means this plan is very practical since each university have their own unique objective and limitations. A sample of the data regarding to this methodology has been represented below in Table 6.

TABLE 6

SAMPLE OF RESULTS FOR DIRECTION TO THE EFFICIENT SURFACE FOR LESS EFFICIENT PROGRAMS

	Current (per Fac.)			**Non-Dominated (per Fac.)**			**Distance to Surface**	**Increase (per Fac.)**		
School	**(BS+MS)**	**PhD**	**Res.* 1M**	**(BS+MS)**	**PhD**	**Res. * 1M**		**(BS+MS)**	**PhD**	**Res.**
Arizona State University	5.42	0.5	0.33	5.4	0.4	0.51	0.24	-0.02	-0.2	$172,988
Auburn University	4.13	0.4	0.36	4.1	0.4	0.37	0.03	-0.03	-0	$10,868
Boise State University	3.89	0	0.13	3.9	0	0	0.13	0.01	0.01	-$129,453
Boston University	3.85	0.5	0.67	3.9	0.6	0.55	0.14	0.05	0.06	-$113,047
Brigham Young University	5.96	0.3	0.13	6	0.1	0.21	0.18	0.04	-0.2	$82,428
…	…	…	…	…	…	…	…	…	…	…
K-State	**4.4**	**0.2**	**0.17**	**4.4**	**0.2**	**0.15**	**0.04**	**0**	**0.03**	**-$26,996**
Lamar University	4.16	0.1	0.06	4.2	0.1	0	0.08	0.04	0	-$61,548
Lehigh University	4.37	0.3	0.18	4.4	0.2	0.24	0.12	0.03	-0.1	$56,494
Louisiana State University	5.34	0.3	0.14	5.3	0.2	0.21	0.15	-0.04	-0.1	$73,199
…	…	…	…	…	…	…	…	…	…	…
KU	**4.24**	**0.2**	**0.18**	**4.2**	**0.2**	**0.19**	**0.05**	**-0.04**	**-0**	**$10,577**
…	…	…	…	…	…	…	…	…	…	…
Wright State University	5.18	0.2	0.17	5.2	0.2	0.2	0.09	0.02	-0.1	$37,873
Yale University	2.2	0.4	0.45	3	0.5	0.33	0.82	0.8	0.14	-$121,176
WSU	**9.42**	**0.2**	**0.13**	**9**	**0.2**	**0**	**0.44**	**-0.42**	**0**	**-$134,507**

As it is presented in Table 6, “Distance to surface” has been calculated for each university. “Distance to surface” refers to the mathematical distance from a point (each university) to the efficient surface. After calculating the shortest distance to the efficient surface, then the shortest vector to the surface can be calculated. That information then can be interpreted as a set of strategies for each university to improve and reach the efficient surface. Since the best vector has been calculated based on the current position of each university to the efficient surface, results are very practical and doable.

It should be noted that, a negative number in the last three columns (Increase) shows how much each university should reduce their outcomes based on the current inputs, and increase the other aspects. However since in a regression has been used, that means there may exist some universities that dominated by others but they are producing more outcomes in some aspects than the regression surface. That happened since the regression provided an average surface based on the efficient schools and therefore there would be some schools that are actually above the surface. For those universities with negative numbers, it is suggested that they only have to improve the areas of their weaknesses, and do not worry about reducing their outcomes in other aspects.

3.1.2 Interpretation of Results

After finding the efficient surface for all colleges of engineering, each university could find their position and determine the shortest path to the surface. That path could then be interpreted as a set of strategies for them to improve. In other words, less efficient universities could find the best feasible and practical way to become efficient without comparing themselves to universities with different objectives. This path is unique for each university, considering its current resources and outcomes and comparing to the closest and most similar efficient universities.

3.2 Analyzing Academic Models

Using the same methodology for each program can be very beneficial. It can provide a better estimate of efficient universities in each program and a unique strategic plan for less efficient programs to improve. To enhance the quality of this research a detailed analysis performed to a few engineering departments.

3.2.1 Efficient Schools in Industrial Engineering

Using data available at ASEE website for industrial engineering departments, same methodology has been implemented to all IE programs. Among 57 IE programs, 15 were identified in the efficient frontier. A regression analysis implemented on the efficient universities to determine the efficient surface for IE schools. Using the results of the regression analysis a surface then exemplified as the efficient surface for IE schools. A list of efficient IE schools has been represented in Table 7 with the relative efficient surface.

In figure 5 a surface has been fit through efficient IE programs. That would help to determine the behavior of non-dominated IE schools in different levels of input. As shown in the figure 5 efficient IE programs has a very similar behavior to the surface created for all schools, except for the situation when the ratio of PhD students per faculty is high. Efficient IE programs are producing more research dollars when the ratio of PhD per faculty is higher.

TABLE 7

EFFICIENT INDUSTRIAL ENGINEERING PROGRAMS

School	Fac.	Total BS	Total MS	Total PhD	Res.
Georgia Institute of Technology	48	299	185.3	21.7	$9,514,333
Stanford University	27	62.7	177	15.3	$5,677,056
University of Michigan	23	174	109.3	9.7	$3,765,341
Virginia Polytechnic Institute and State University	23	117	55.3	14.3	$4,974,992
The Pennsylvania State University	23	138	43	14.3	$1,548,308
Purdue University	22	141	30.3	12.3	$3,727,070
Cornell University	22	90.7	145.7	6.67	$1,815,602
Texas A&M University	19	117	94	8.7	$10,413,000
University of Florida	18	95	130	10	$2,454,333
University of Wisconsin-Madison	17	65	68	8.3	$21,845,135
The University of Texas at Arlington	13	27.5	67	10.5	$710,500
University of Arizona	8.3	31.3	14.3	7	$1,029,524
The University of Alabama in Huntsville	8	13.3	28	5.3	$8,279,562
The University of Iowa	7	25.3	9.7	4	$4,194,333
New Mexico State University	6.7	9.3	44.3	1.3	$68,010

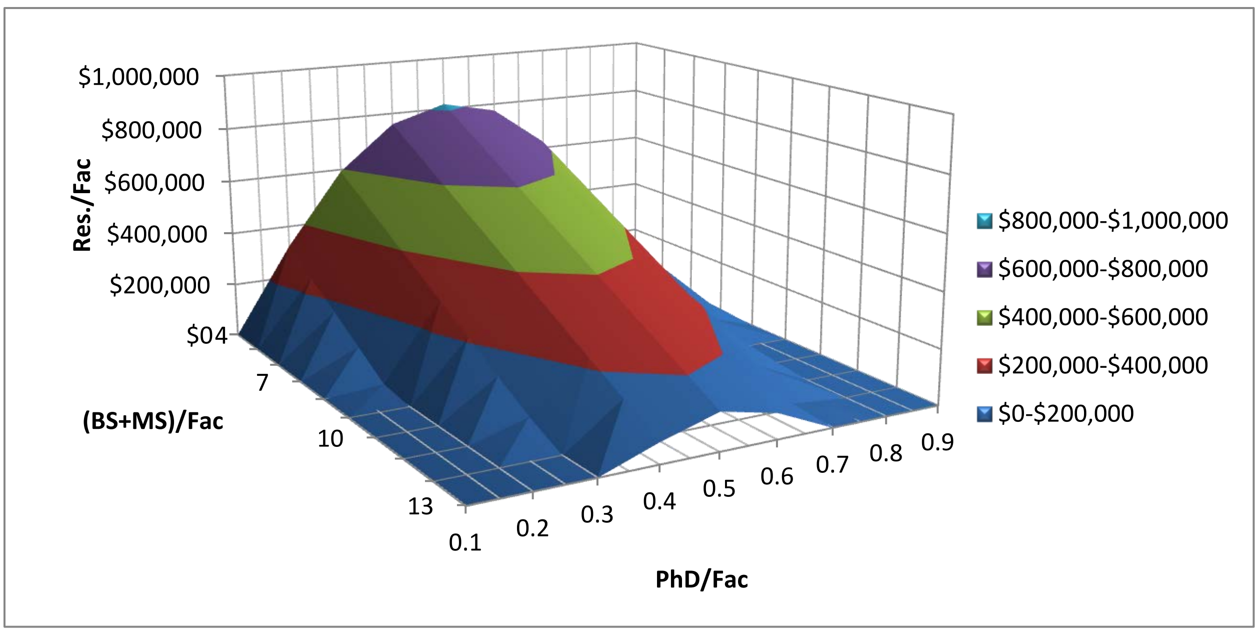

Figure 5. A surface fit though the set of efficient IE programs

Using the efficient surface, a set of strategies could be defined for IE programs. As it was calculated in the previous section for all universities, the shortest mathematical distance to the efficient surface can be calculated for each IE program. After that, the best vector to the surface calculated and a set of strategies could be designed for each IE program to improve and become efficient. This plan is unique for each university, according to its current resources and outcomes and considering the closest efficient universities. Appendix2 represents the results of the above calculations for all IE programs in the US.

In addition to the results, further analysis performed to reveal the relationship between the contributing factors in the model. It should be noted that, since the efficient set of universities only contains 15 schools, the conclusion may not be statistically meaningful. Figure 6 represents the relationship between different factors in the model for the efficient set of IE programs.

Figure 6 reveals the relationship between different factors contributing in the model for the efficient surface. From the relationships, it could be concluded there is no significant correlation between different factors ($R^2<0.1$). That means increasing or decreasing one factor do not have an impact on the other factors in the model. Although the model itself is statistically significant, the correlations between factors are not. It could be possible to have a better correlation and an even stronger model if the number of universities in the efficient set was higher.

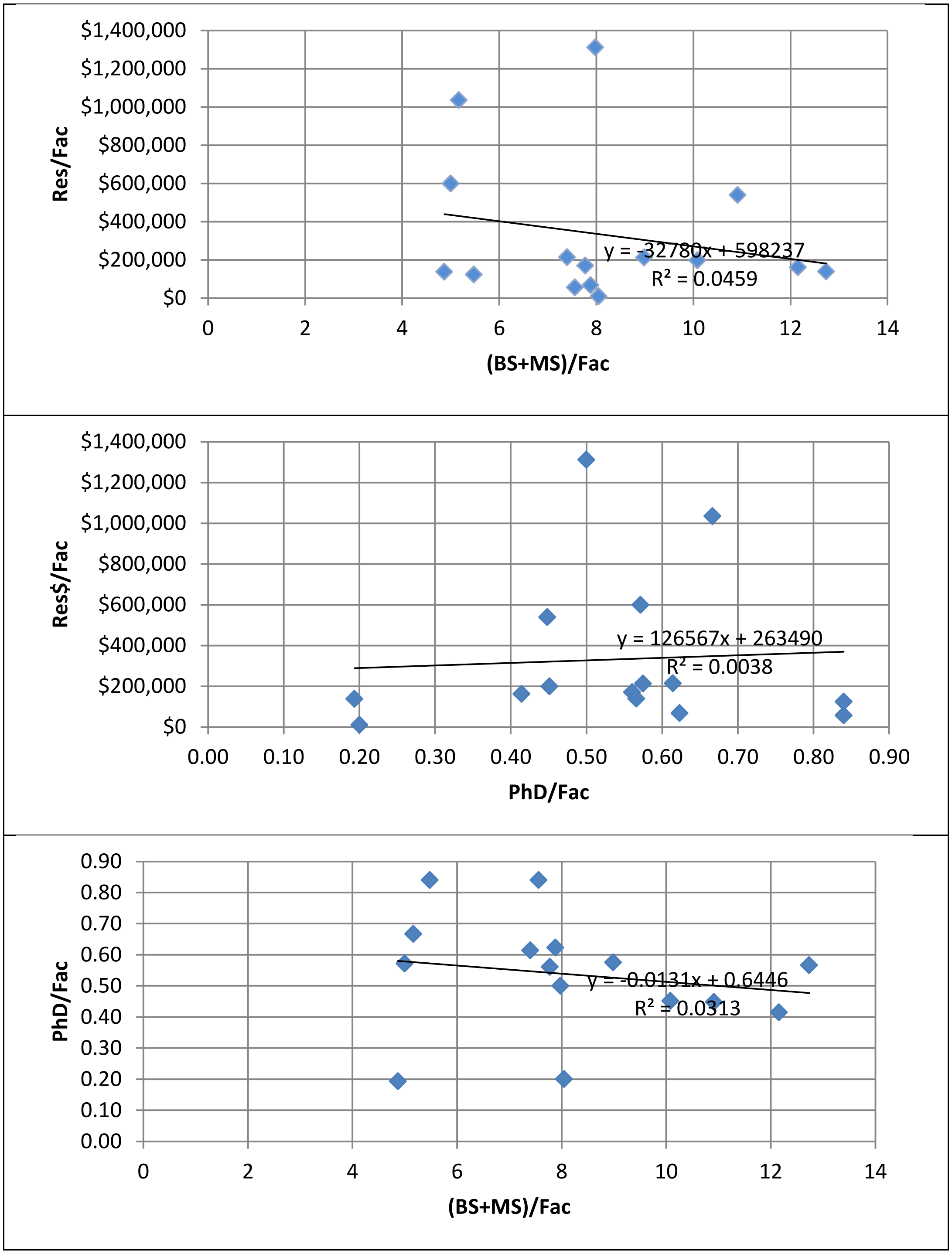

Figure 6. Relationship between factors for efficient set of IE programs

3.2.2 Efficient Schools in Mechanical Engineering

Using data for all mechanical engineering schools, a similar analysis has been done to calculate the non-dominated set of mechanical programs in the US. Results revealed that among 141 mechanical engineering schools in the US, 25 are in the efficient frontier. Table 8 represents the efficient set of universities for mechanical engineering in the US.

After finding the efficient sets of ME schools, a surface was fit through the efficient set of ME programs. The efficient surface can be interpreted as the efficient frontiers and represents the behavior of the efficient programs for different levels of inputs. Figure 7 shows the efficient surface of mechanical engineering schools in the US.

From the results it could be concluded that efficient ME programs have a different behavior than IE programs and also their behavior is different from other programs. The difference between the surfaces is high especially when the number of PhD students per faculty members and the number of BS+MS students per faculty members are high. In efficient mechanical programs, when the number of students per faculty are high, the optimum amount of research dollars is high, however efficient IE schools in such situation produce minimum amount of research dollars per faculty members.

Further analysis revealed the relationship among different contributing factors in the model. Figure 8 represent the relationship between the factors, it can be concluded that the relationship among the factors is not very statistically strong.

TABLE 8

EFFICIENT SET OF UNIVERSITIES FOR MECHANICAL ENGINEERING IN THE US

School	Faculty	Total Bachelor's	Total Master's	Total Doctoral	Res.
Clemson University	26.67	150.33	78.67	19.00	$3,155,108
Cleveland State University	10.67	70.33	21.67	1.67	$1,490,726
Georgia Institute of Technology	83.67	398.00	202.00	27.00	$31,042,667
Illinois Institute of Technology	15.50	56.00	48.50	4.50	$2,381,856
Iowa State University	35.67	221.00	33.33	12.67	$13,880,000
Massachusetts Institute of Technology	68.33	150.00	139.67	48.67	$50,150,667
Mississippi State University	17.33	82.67	9.67	7.33	$12,592,371
Princeton University	23.00	41.33	2.33	12.67	$16,593,623
Purdue University	57.33	275.67	89.33	36.67	$34,345,406
Santa Clara University	10.00	48.67	28.00	2.00	$716,044
Stevens Institute of Technology	22.50	93.00	80.50	2.50	$3,240,618
Tennessee State University	6.00	17.00	2.00	1.00	$1,565,000
Texas A&M University	53.00	216.33	85.33	23.33	$41,241,667
The Johns Hopkins University	18.67	36.67	54.33	8.00	$6,756,000
The Pennsylvania State University	39.00	237.67	45.00	18.00	$28,454,999
The University of Alabama in Huntsville	25.33	71.00	14.67	1.33	$19,755,108
The University of Iowa	13.67	68.00	11.67	6.67	$8,243,700
The University of Mississippi	7.00	24.50	6.00	2.00	$830,596
University of California-Los Angeles	29.67	124.67	68.00	22.33	$15,935,928
University of Maryland-College Park	42.67	196.67	41.00	29.00	$26,261,521
University of Michigan	62.33	212.00	125.67	43.67	$30,035,614
University of South Florida	16.67	116.67	23.33	3.00	$3,337,973
Virginia Polytechnic Institute and State University	48.67	282.67	48.33	21.33	$17,359,148
Washington University in St. Louis	10.67	54.00	22.67	4.67	$1,331,333

As presented in Figure 8, the correlation between the number of PhD students per faculty members and the amount of research productivity not very strong, (R^2= 0.33). However although not very strong there is a positive correlation between these factors. That means as the number of PhD students per faculty members in the efficient ME schools increases, the research productivity increases. Besides that, the correlation between the number of (BS+MS) per faculty members and the research productivity are not very strong, (R^2= 0.21). However while not very strong there is a negative correlation between these factors, meaning that by increasing the number of BS+MS students per faculty members, research productivity decreases in the efficient set of ME schools. Moreover, the correlation between the number of PhD studensts and (BS+MS) students per faculty members are very week (R^2= 0.005). That means there is not a statistically correlation between these factors, and increasing or decreasing one, may not have a direct impact on the other.

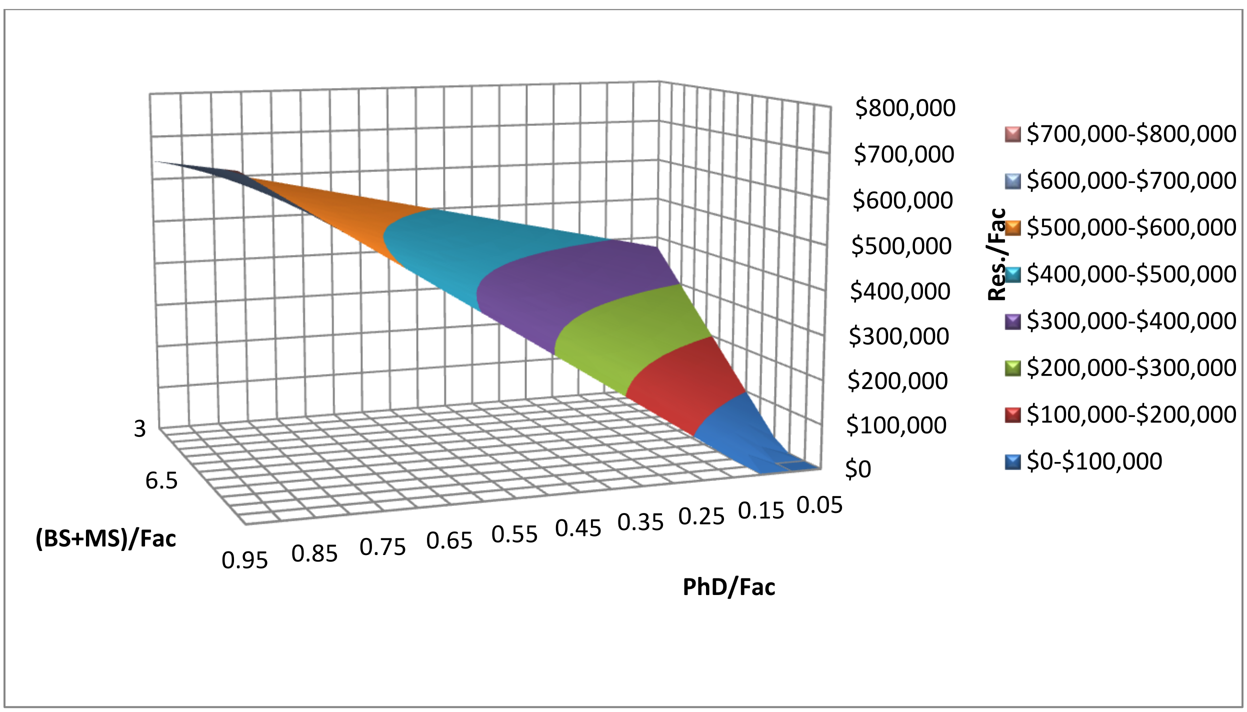

Figure 7. Efficient surface of mechanical engineering schools in the US

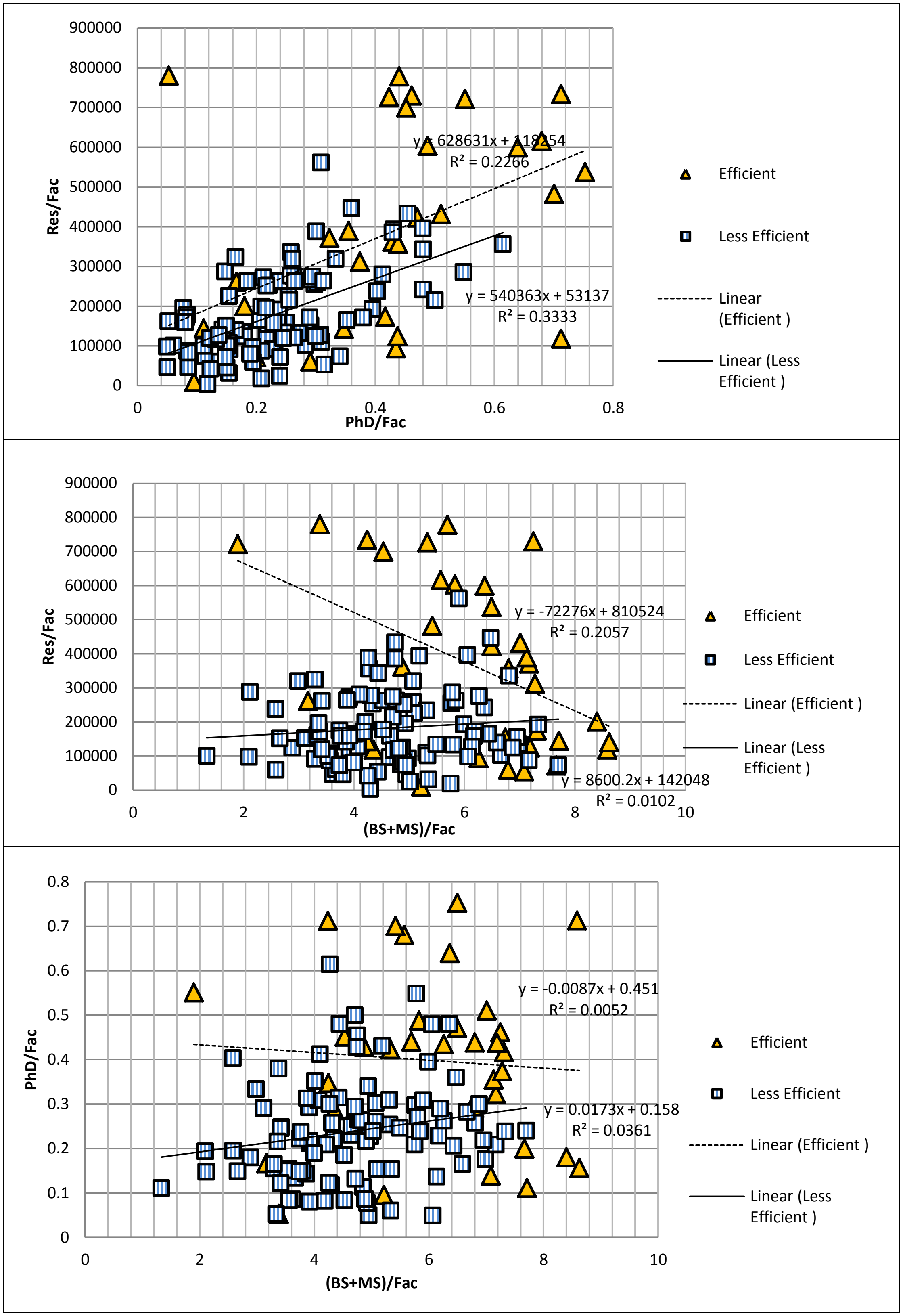

Figure 8. Relationship between factors for efficient set of ME programs

3.2.3 Efficient Schools in Electrical Engineering

Using data from ASEE website for all electrical engineering schools, a similar analysis was performed to find the non-dominated set of electrical programs in the US. Results demonstrated that that among 35 electrical engineering schools in the US, 12 are in the efficient frontier. Table 9 represents the efficient set of universities for electrical engineering in the US.

After determining the efficient set, a surface was fit through the set of efficient programs. The efficient surface can be interpreted as the efficient frontiers and could be helpful in demonstrating the behavior of efficient programs with different levels of inputs. Figure 9 represents the efficient surface of mechanical engineering schools in the US.

Efficient electrical programs have similar behavior to efficient IE schools. Maximum research dollars can be produced when the number of PhD students per faculty members is around 0.45 and the number of BS+MS students per faculty members is around 5.

Further analysis revealed that the relationship the number of PhD students per faculty members and the amount of research dollars per faculty members among efficient programs is significant with R^2= 0.5. The relationship between factors in efficient electrical engineering programs represented in Figure 10.

As it is represented in Figure 10, the correlation between the number of PhD students per faculty and research productivity is positively strong with R^2=0.53. That means, as the number of PhD students per faculty members in efficient electrical programs increases, the research productivity increase. Figure 10 also revealed that, the correlation between other factors in the model are not statistically significant since R^2<0.1. That means increase or decrease in the number of BS+MS students per faculty members would not have an impact on research productivity or the number of PhD students per faculty members.

TABLE 9

EFFICIENT SET OF UNIVERSITIES FOR ELECTRICAL ENGINEERING IN THE US

School	Fac.	Total Bachelor's	Total Master's	Total Doctoral	Res.
Arizona State University	57.55	95.33	201.00	39.33	$30,637,376
California Institute of Technology	14.50	21.33	25.00	12.33	$9,480,026
The Pennsylvania State University	34.67	163.00	40.33	22.33	$13,961,051
University of California-Los Angeles	52.13	158.33	91.00	40.33	$30,669,182
University of Dayton	8.41	22.00	34.67	3.00	$874,667
University of New Orleans	9.25	28.50	9.50	2.00	$743,656
University of Vermont	7.50	15.00	7.00	1.00	$364,891
University of Washington	40.27	160.33	71.33	27.67	$14,230,000
Texas A&M University	58.89	99.00	82.00	32.33	$32,255,667
The University of Texas at Arlington	28.32	57.33	127.67	13.33	$4,518,333
Stevens Institute of Technology	13.50	29.00	68.50	5.50	$2,823,933
University of California-Riverside	23.00	28.67	18.33	21.67	$6,756,858

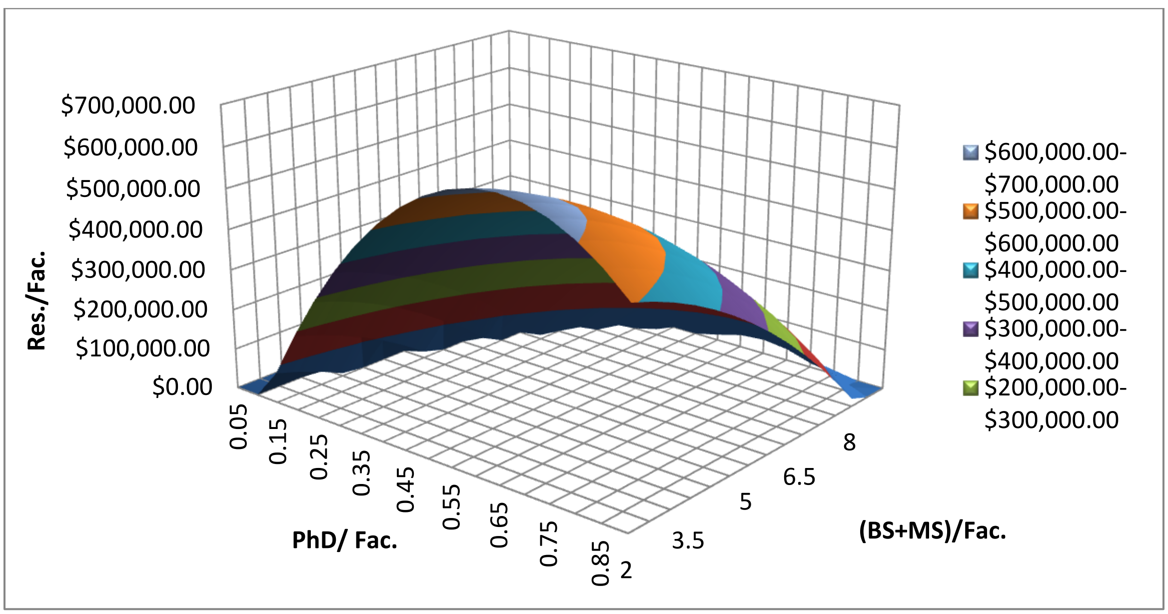

Figure 9. Efficient surface of electrical engineering schools in the US

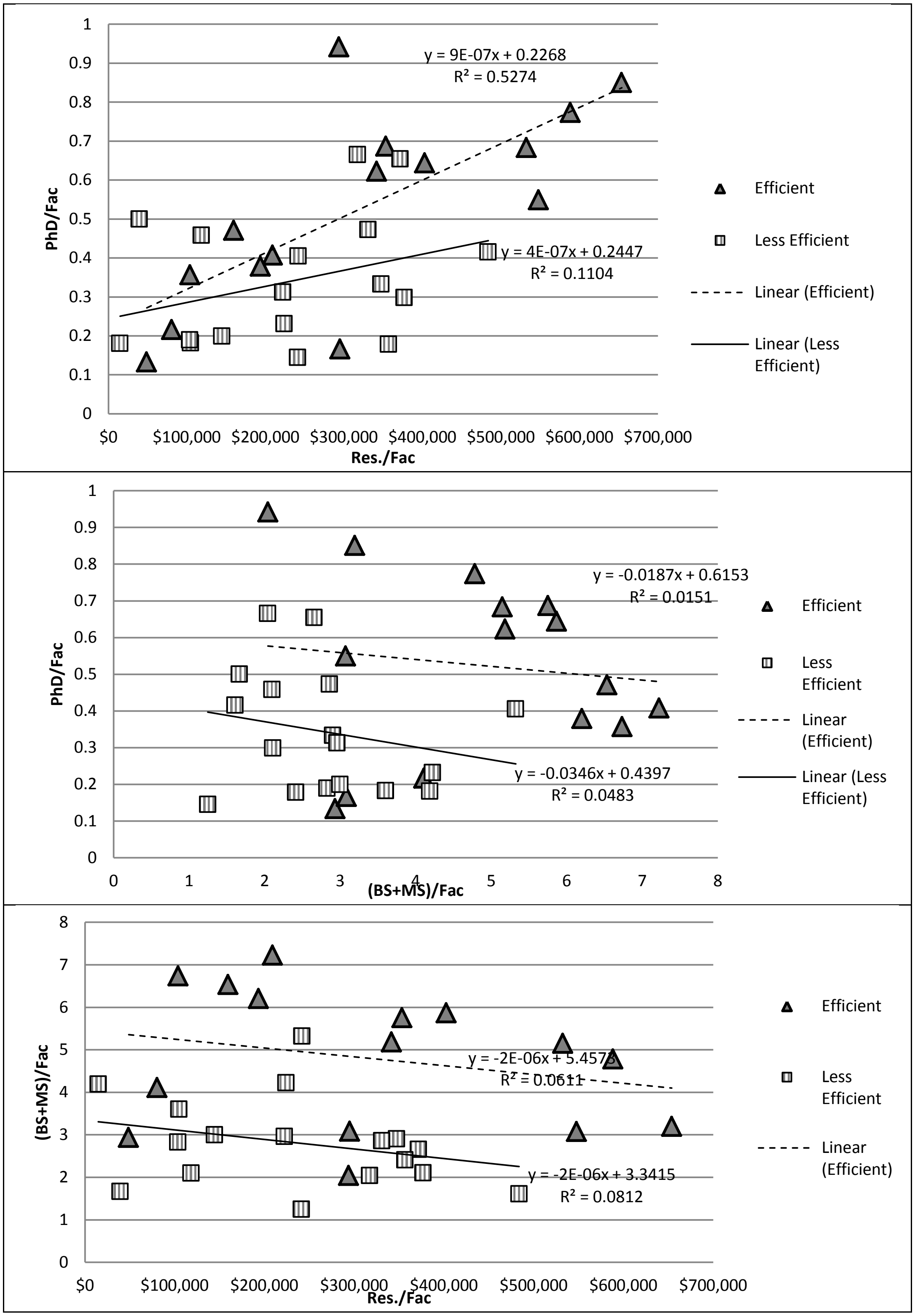

Figure 10. Relationship between factors for efficient set of EE programs

3.2.4 Efficient Schools in Aerospace engineering

With data from ASEE website for all aerospace engineering schools, a similar analysis has been done to calculate the non-dominated set of aerospace programs in the US. Results demonstrated that that among 25 aerospace engineering schools in the US, 10 are in the efficient frontier. Table 10 represents the efficient set of universities for aerospace engineering in the US. However since the total number of aerospace programs are very low, and consequently the number of efficient programs it is difficult to rely on the results of the analysis. Besides, since there are only 10 universities in the efficient frontier, it is very hard to fit a statistically significant surface through the data. Further analysis revealed that the relationship between PhD/Fac. and (BS+MS)/Fac. is significant with R^2=0.6. And also relationship between PhD/Fac and Research/Fac. is significant with R^2= 0.63.

TABLE 10

EFFICIENT SET OF UNIVERSITIES FOR AEROSPACE ENGINEERING IN THE US

School	Total Bachelor's	Total Master's	Total Doctoral	Fac.	Res.
Auburn University	46.00	10.00	1.00	10.00	$1,196,000
Georgia Institute of Technology	143.00	136.33	32.67	38.00	$35,560,333
Massachusetts Institute of Technology	54.67	61.33	17.67	34.33	$27,359,667
Purdue University	150.33	92.33	18.00	24.67	$10,746,333
Texas A&M University	80.00	21.33	10.67	27.00	$21,612,000
The Pennsylvania State University	98.33	21.00	9.67	14.67	$8,645,710
University of Kansas	24.50	8.50	1.00	9.00	$1,588,001
University of Maryland-College Park	68.67	32.33	9.00	20.00	$18,259,699
University of Michigan	128.67	60.67	17.00	25.67	$10,352,445
Wichita State University	43.33	20.67	1.33	10.33	$2,740,579

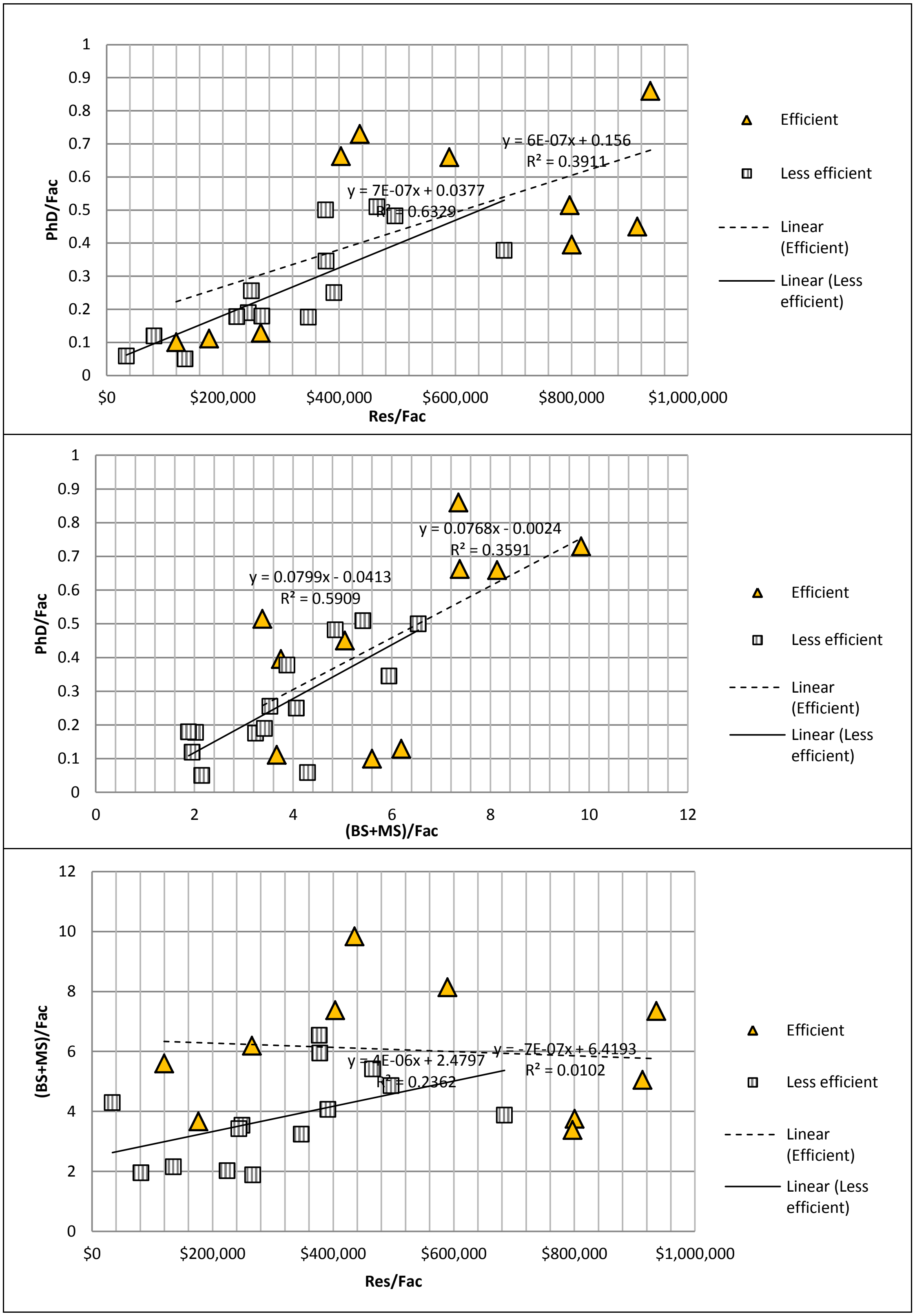

Figure 11. Relationship between factors for efficient set of AE programs

As represented in Figure 11, the correlation between the number of PhD students per faculty members and research productivity is positively strong with R^2= .63. That means as the number of PhD students per faculty members increases, the research productivity will increase in the efficient aerospace programs. Furthermore, the correlation between the number of (BS+MS) students per faculty and PhD students per faculty members is also positively strong with R^2=0.6. That means, as an efficient AE program increases its size and accepts more BS+MS students, it will also accept more PhD students. On the other hand, results revealed that there is no correlation between the number of BS+MS students per faculty and research productivity in the efficient AE schools (R^2=0.01).

3.3 Summary

In this chapter it has been revealed that the proposed model could be helpful in determining the efficient set of programs in various engineering majors. After determining the efficient frontier a surface could be fit through them, to reveal the behavior of efficient colleges with different levels of inputs. Results could be very helpful in defining accurate and practical strategies for different programs to improve.

It has been revealed that, considering different engineering majors, efficient sets of engineering schools may have a different behavior. Therefore, it may be very beneficial to separately analyzing them. Doing so, each program could find its position to the relevant efficient surface, and more wisely find its unique path to improve with regards to its resources.

CHAPTER 4

ADDING MORE INPUTS

4.1 Strategic Planning

To increase the accuracy of this study, it has been decided to increase the number of inputs of the model. In reality there are many inputs that should be taken into accounts to accurately determine efficiency. However, determining all the inputs and resources and having access to accurate data for all schools is difficult. For the next step, a few more inputs identified and further analysis performed to build a more accurate model for efficient schools. Furthermore programs with same characteristics classified and compared to each other in terms of their outputs and efficiencies.

4.2 Adding More Inputs

It would be helpful to try other possible inputs that could measure the quality of education. The first additional input used in the model was “the amount of tuition and fees” in each school. It has been assumed that in a competitive economic environment, tuition will be determined by the quality of the education in each school, and if a university has more tuition, it has more resources to spend, and should generate more quality. It means that a good school has higher tuition than a less capable school, because of its more available resources. And if a university can generate the same output with less tuition (resources) then it is relevantly more efficient. Data gathered from ASEE website [23] for the amount of tuition in each school. Same as other inputs, average of the three recent years (2010-2012) has been calculated for tuition in this study. The amount of tuition provided was in terms of US dollars.

In addition, it would be very helpful to consider another input for the model, the quality of students entering the programs. One possible measure of the quality of the students could be the "acceptance rate". It can be assumed that if a university has a low acceptance rate, it is more likely have better students (inputs); therefore, it has a more efficient input. Since this input has the same effect as having more faculties, current programs in the efficient list may become less efficient. Similar to the rest of data, the ratio of acceptance rate was calculated using data gathered from ASEE website [23]. It has been calculated based on the ratio of the number of students accepted to a college over the total number of students applied for the college. Thus if a schools accept a majority of its applicants it would have a higher acceptance rate, than a schools who wouldn't accept as much.

With these additional inputs, the overall model then could generate a better estimation of efficiency. And the Pareto surface may be more useful for dominating universities develop practical strategies to become more efficient. Using the same assumptions as previous analysis, a regression model has been built with the new inputs. 48 universities represented as efficient. Appendix 3 represents a list of all efficient universities.

4.3 Acceptance Rate as an Input

Every program has an acceptance rate, depending on its capacity, number of applicants, and its policies. It has been assumed that if a program has a lower acceptance rate it has relatively better quality students, since it is only selecting the best applicants. Thus the acceptance rate can be assumed as an input for measuring quality.

To calculate the efficacy and regression model it has been assumed that tuition and acceptance rate could be in two different levels: Low and High. If the amount of acceptance rate is below the median, the university has low acceptance rate. The same method applied to tuition, if the amount of tuition is below the median then the university assumed to have low tuition and otherwise it presumed that the tuition level is high.

With the high and low acceptance rate, a regression analysis then implemented to create a surface for each group. Results revealed that although the two efficient surfaces have some similarities, they can have different behavior at different levels. It should be noted that the best fit regression model is different in the two groups, since they have different behavior.

4.3.1 Acceptance Rate Low

Considering acceptance rate as an input a separate DEA model has been built for universities with different levels of acceptance (low or high). Using this methodology, universities could be compared to their similar group, and plan to increase their efficiency more accurately. Table 11 is a list of all efficient universities that have acceptance rate below the median (low) and their inputs and outputs.

TABLE 11

EFFICIENT PROGRAMS WITH LOW ACCEPTANCE RATE

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
The George Washington University	Low	High	University of Michigan	Low	High
Rensselaer Polytechnic Institute	Low	High	University of California-San Diego	Low	High
Dartmouth College	Low	High	University of California-Riverside	Low	High
The Johns Hopkins University	Low	High	The University of Texas at Austin	Low	High
Brown University	Low	High	William Marsh Rice University	Low	High
University of Pennsylvania	Low	High	University of Maryland-College Park	Low	Low
Washington University in St. Louis	Low	High	Lawrence Technological University	Low	Low
Duke University	Low	High	University of Minnesota -Twin Cities	Low	Low
Northwestern University	Low	High	California State University-Long Beach	Low	Low
Stevens Institute of Technology	Low	High	Stony Brook University	Low	Low
Cornell University	Low	High	New Mexico Institute of Mining & Technology	Low	Low
Yale University	Low	High	City College of the City University of New York	Low	Low
Princeton University	Low	High	University of Wisconsin-Madison	Low	Low

Using the above information, a surface was fit though the set of efficient programs with low acceptance rate as shown in Figure 12. The surface may reveal important information about how programs with such characteristics would behave in different levels of inputs.

Efficient universities with low acceptance rates produce more research when they have more PhD and more BS+MS. However if the number of BS+MS decreases, the amount of research dollars drops but the reduction rate is less than the similar surface with high acceptance rate (Fig 13). Minimum research will be produce when they have a lot of BS+MS and small amount of PhD per faculty.

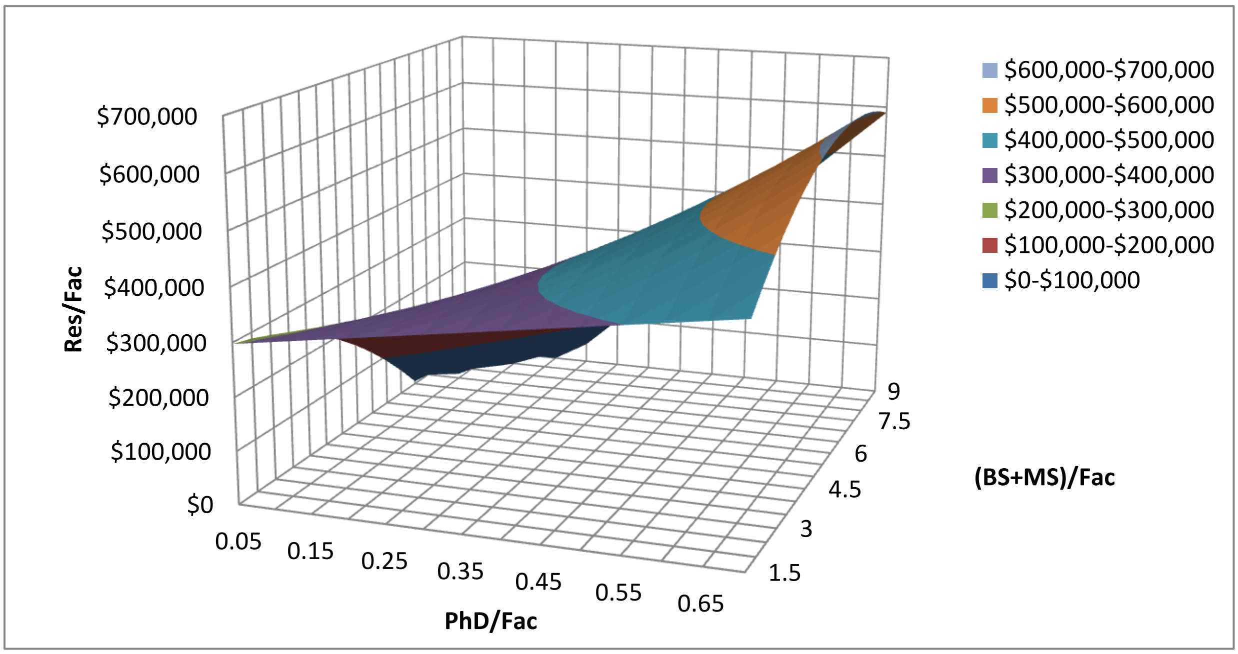

Figure 12. A surface fit though the set of efficient programs with low acceptance rate

4.3.2 Acceptance Rate High

Same methodology applied to programs with high acceptance rate. A DEA model has been built for universities with high acceptance rate. Results are the set of efficient colleges that are accepting more applicants than others. Table 12 is a list of all efficient universities that have high acceptance rate and their inputs and outputs.

TABLE 12

EFFICIENT PROGRAMS WITH HIGH ACCEPTANCE RATE

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
Worcester Polytechnic Institute	High	High	University of Colorado Colorado Springs	High	Low
Southern Methodist University	High	High	Texas A&M University - Kingsville	High	Low
University of California-Irvine	High	High	Idaho State University	High	Low
University of Illinois at Urbana-Champaign	High	High	State University of New York at Buffalo	High	Low
Georgia Institute of Technology	High	High	The University of Texas at Arlington	High	Low
Purdue University	High	High	The State University of New York at Binghamton	High	Low
Alfred University-NY State College of Ceramics	High	High	University of New Orleans	High	Low
Texas A&M University	High	Low	Cleveland State University	High	Low
University of Central Florida	High	Low	Brigham Young University	High	Low
North Carolina State University	High	Low	University of Puerto Rico-Mayaguez Campus	High	Low
The University of Alabama in Huntsville	High	Low			

Using the above information, a surface was fit though the set of efficient programs with high acceptance rate as shown in Figure 13. The surface could reveal important information about how programs with such characteristics would behave in different levels of inputs.

Universities with high acceptance rate seems to be more sensitive to number of PhD students when they have more BS+MS. Efficient universities in this category are producing more research when they have more PhD and more BS+MS. However if the number of BS+MS decreases, the amount of reassert dollars drops even with a lot of PhD students.

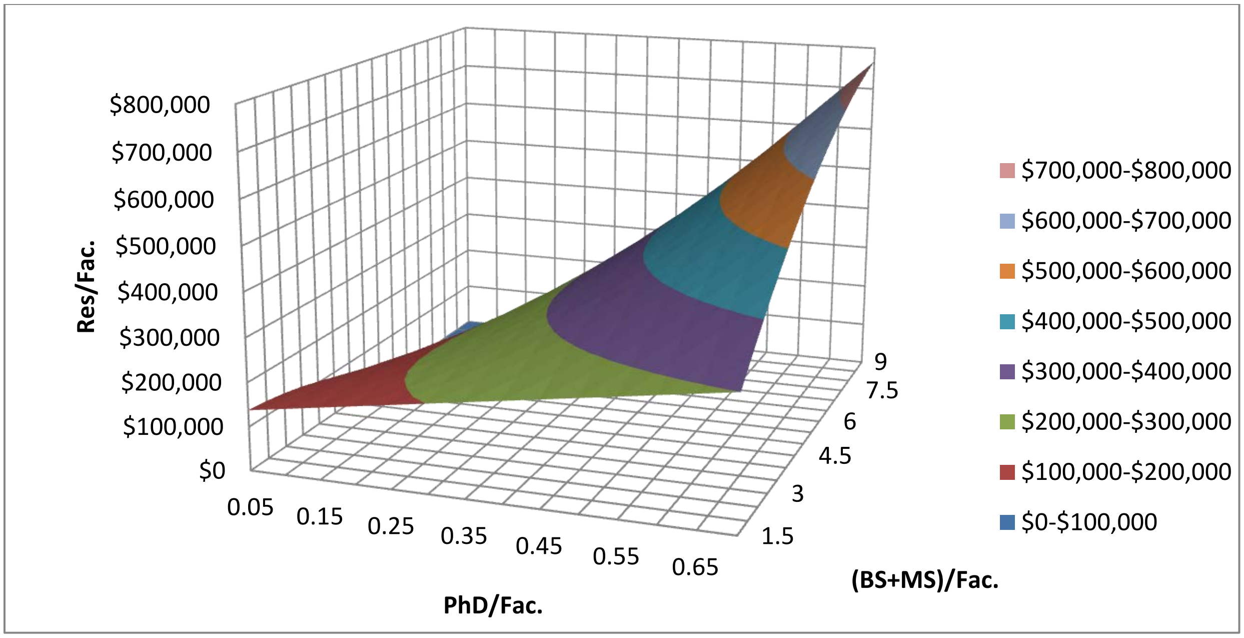

Figure 13. A surface fit though the set of efficient programs with high acceptance rate

4.4 Tuition as an Input

4.4.1 Tuition Low

Same as acceptance rate, considering tuition as an input, a separate DEA model has been built for universities with different levels of tuition (low or high). Using that information, then each university could be compared to the group they belong, and set goals more accurately. Table 11 is a list of all efficient universities that have low tuition.

As shown in Figure 14, a surface fit though the set of efficient programs with low tuition. The surface could reaveal important information about how programs with such characteristics would behave in different levels of inputs. Universities with low tuition seem to be more sensitive to PhD than BS+MS. As the number of PhD students increase, they are able to produce more research dollars.

TABLE 13

EFFICIENT PROGRAMS WITH LOW TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
Texas A&M University	High	Low	Cleveland State University	High	Low
University of Central Florida	High	Low	Brigham Young University	High	Low
North Carolina State University	High	Low	University of Puerto Rico-Mayaguez Campus	High	Low
The University of Alabama in Huntsville	High	Low	University of Maryland-College Park	Low	Low
University of Colorado Colorado Springs	High	Low	Lawrence Technological University	Low	Low
Texas A&M University - Kingsville	High	Low	University of Minnesota -Twin Cities	Low	Low
Idaho State University	High	Low	California State University-Long Beach	Low	Low
State University of New York at Buffalo	High	Low	Stony Brook University	Low	Low
The University of Texas at Arlington	High	Low	New Mexico Institute of Mining & Technology	Low	Low
The State University of New York at Binghamton	High	Low	City College of the City University of New York	Low	Low
University of New Orleans	High	Low	University of Wisconsin-Madison	Low	Low

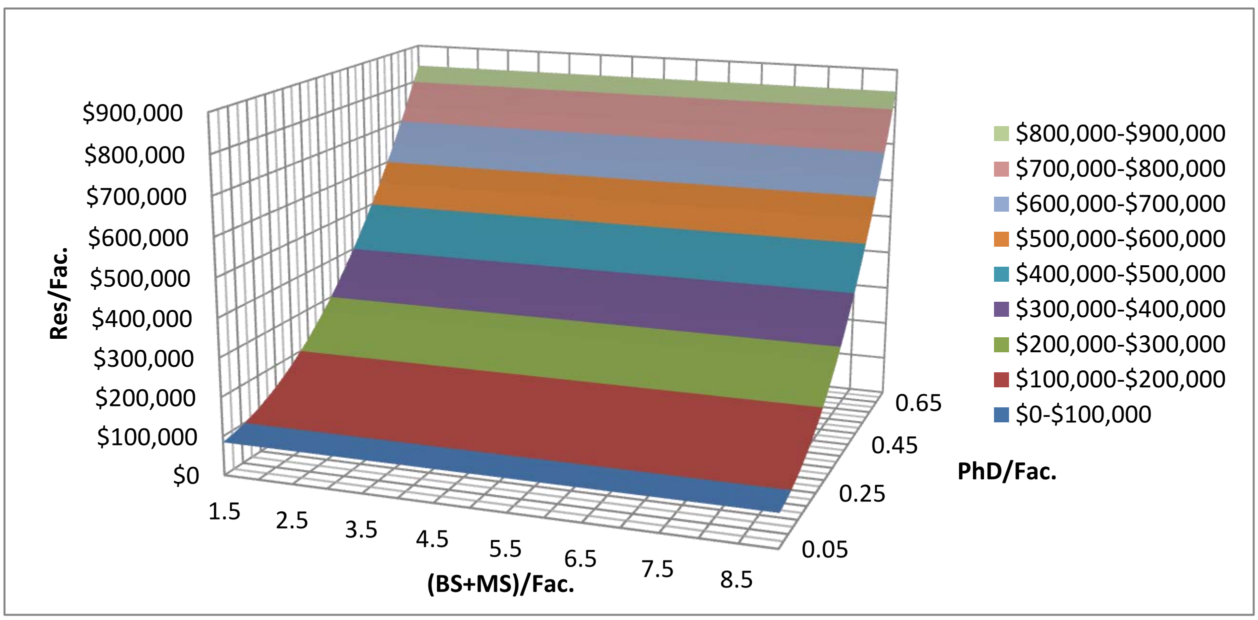

Figure 14. A surface fit though the set of efficient programs with low tuition

4.4.2 Tuition High

Same methodology applied to programs with high tuition. Table 12 is a list of all efficient universities that have high acceptance rate and their inputs and outputs. These universities are relatively more expensive than others.

TABLE 14.

EFFICIENT PROGRAMS WITH HIGH TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
Worcester Polytechnic Institute	High	High	Washington University in St. Louis	Low	High
Southern Methodist University	High	High	Duke University	Low	High
University of California-Irvine	High	High	Northwestern University	Low	High
University of Illinois at Urbana-Champaign	High	High	Stevens Institute of Technology	Low	High
Georgia Institute of Technology	High	High	Cornell University	Low	High
Purdue University	High	High	Yale University	Low	High
Alfred University-NY State College of Ceramics	High	High	Princeton University	Low	High
The George Washington University	Low	High	University of Michigan	Low	High
Rensselaer Polytechnic Institute	Low	High	University of California-San Diego	Low	High
Dartmouth College	Low	High	University of California-Riverside	Low	High
The Johns Hopkins University	Low	High	The University of Texas at Austin	Low	High
Brown University	Low	High	William Marsh Rice University	Low	High
University of Pennsylvania	Low	High			

As shown in Figure 15, a surface fit though the set of efficient programs with high tuition. The surface could reveal important information about how programs with such characteristics would behave in different levels of inputs.

Universities with high tuition have similar behavior with we had prior to adding tuition and acceptance rate. The maximum amount of research can produce 5.5 BS+MS per faculty, and

0.55 PhD per faculty. PhD students seems to have a positive impact on research, meaning that by rescuing the number of PhD students, the amount of research dollars that can be produce in a university will reduce.

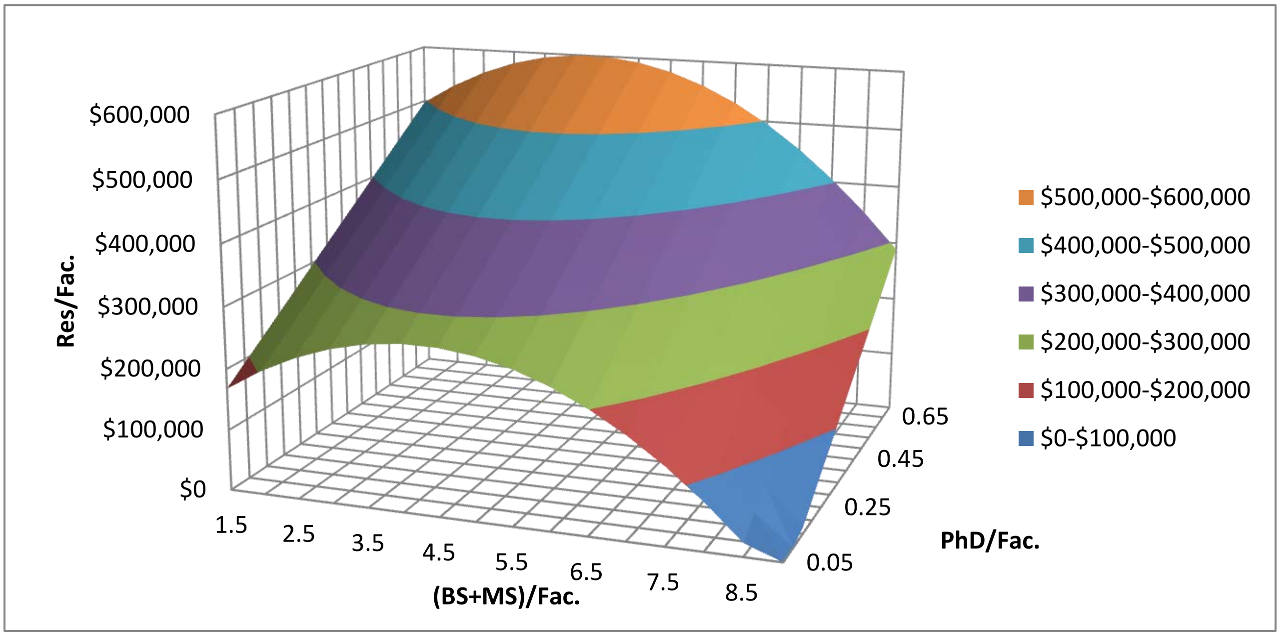

Figure 15. A surface fit though the set of efficient programs with high tuition

4.5 Conclusion

Using acceptance rate and tuition as additional inputs would increase the accuracy of this study. As it could be seen from the efficient surfaces, efficient programs have different behavior with different levels of inputs and outputs. Clustering colleges based on their level of inputs and analyzing them, have many benefits. The most important advantage of this approach is that, programs only compared to the ones with similar characteristics. That would eliminate the fact that universities with more resources dominate other. In that case, each college could look at its position to the surface and find a practical way to enhance its efficiency. For the next step, a further analysis performed to determine the interaction of different inputs.

CHAPTER 5

INTERACTION OF DIFFERENT INPUTS

5.1 Introduction

To strengthen this study, for the next step, an analysis performed based on the interaction of each input. To do so, colleges clustered based on their level different inputs, and a model was built for programs with similar characteristics. That would help to have a more robust model for each set of programs, so that programs that are not in the efficient frontier could find their path easier.

5.2 Tuition - Acceptance Rate Relation

Looking at the relationship of the contributing factors revealed that, there is a good correlation between tuition – fee and the acceptance rate. Figure 16 represents the relationship between the tuition and acceptance rate. As the acceptance rate is smaller- this indicates more quality in the inputs - the tuition become bigger. That can be explained from an economic perspective, since apparently the demand is higher for universities with lower acceptance rate, they demand to have a higher tuition. This correlation is significant with R^2=0.55, in the efficient set. This means that universities that have a lower acceptance rate in the efficient set usually are more expensive because they are producing a higher service.

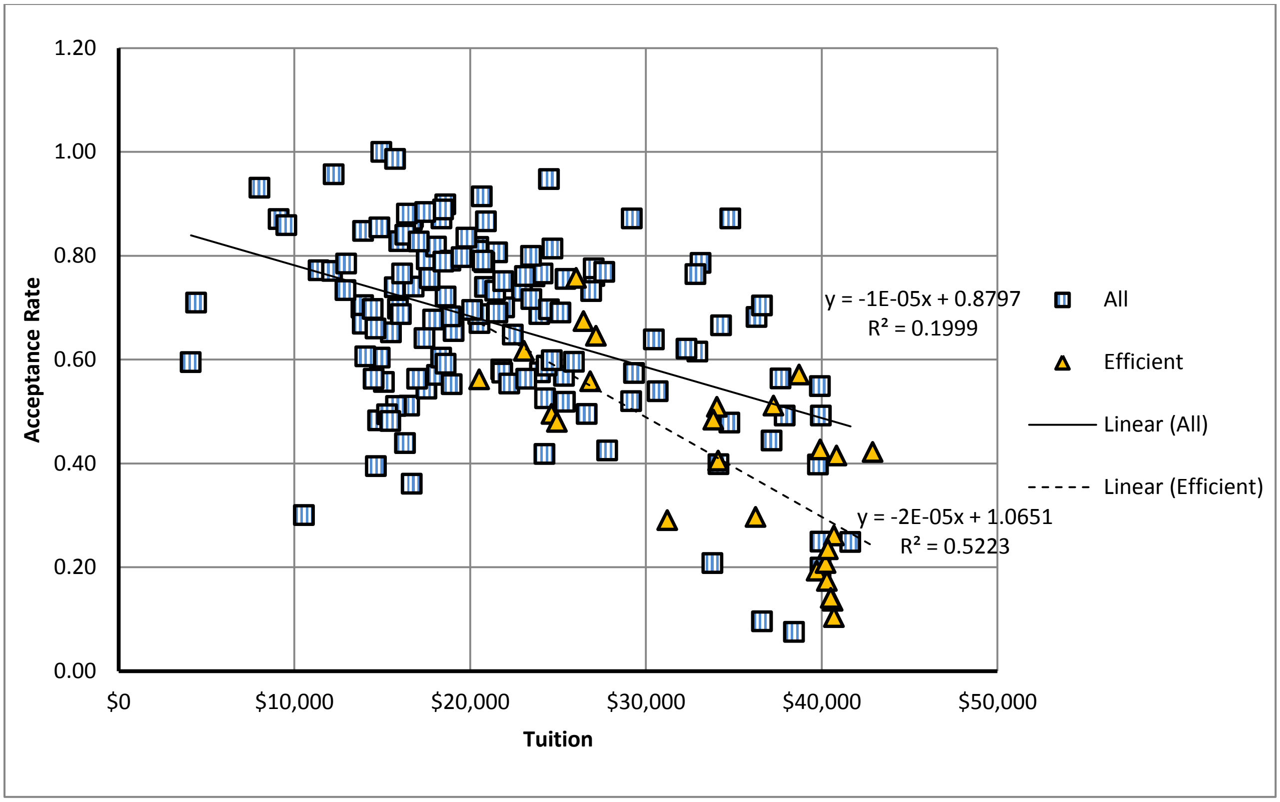

Figure 16. Tuition-Acceptance Rate correlation

After analyzing each category separately, the next step is to study efficient universities considering both tuition and acceptance rate. Four categories identified: universities with low tuition and high acceptance, low tuition and low acceptance, high tuition and low acceptance and high tuition and high acceptance. Figure 17 are the results of each category of colleges. A surface was fit through efficient universities in each category. As it could be seen in Figure 17, efficient universities may have different behavior in different levels of inputs.

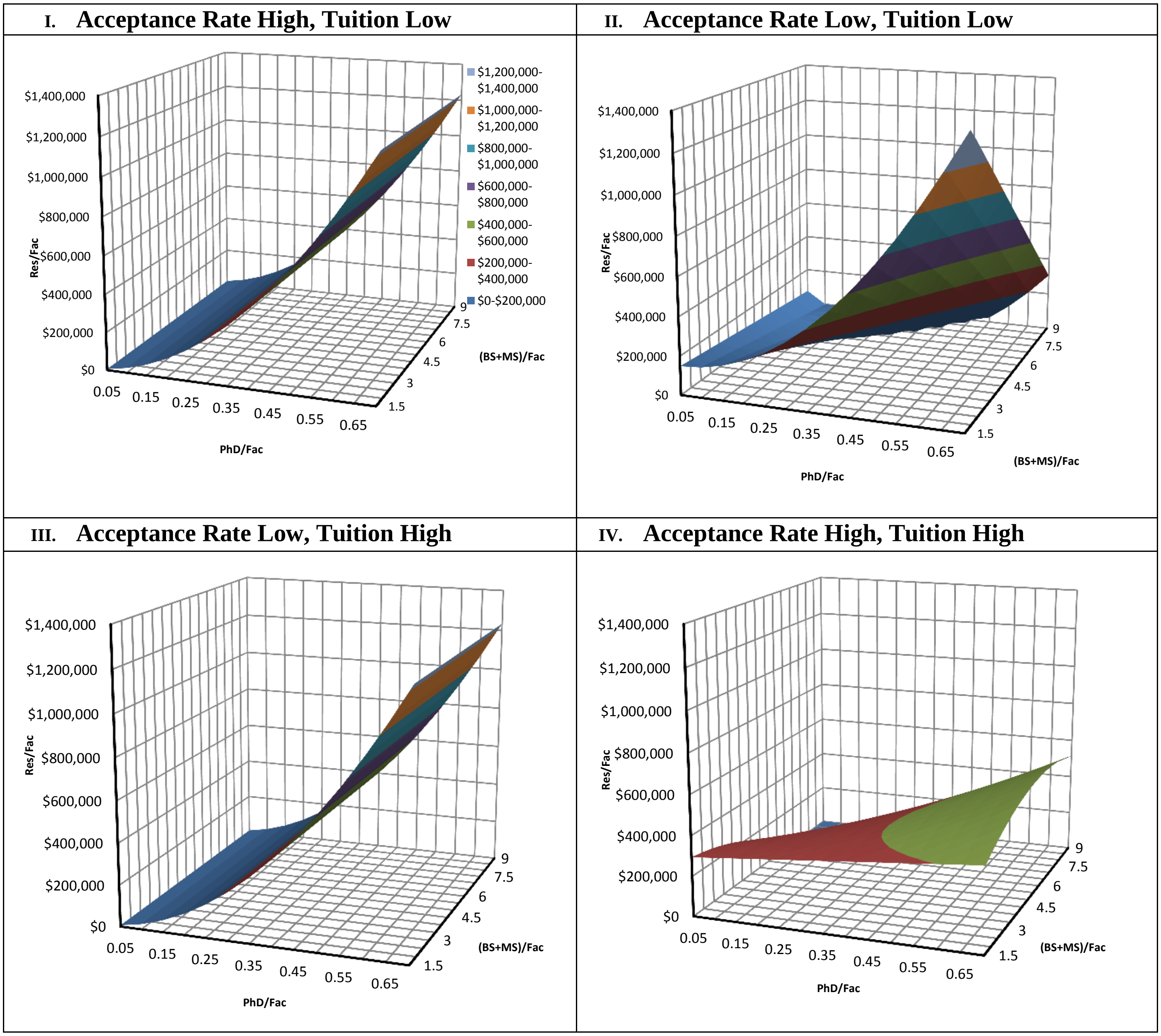

Figure 17. Efficient surfaces for universities in different levels of tuition and acceptance rate

5.3 Acceptance High, Tuition Low

To enhance the accuracy of this study, an analysis performed for different groups of universities based on different levels of tuition and acceptance rate. That could be very helpful in revealing important information about efficient programs with same characteristics. Table 15 is a list of all efficient universities with such characteristics.

TABLE 15

EFFICIENT PROGRAMS WITH HIGH ACCEPTANCE RATE AND LOW TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
Texas A&M University	High	Low	State University of New York at Buffalo	High	Low
University of Central Florida	High	Low	The University of Texas at Arlington	High	Low
North Carolina State University	High	Low	The State University of New York at Binghamton	High	Low
The University of Alabama in Huntsville	High	Low	University of New Orleans	High	Low
University of Colorado Colorado Springs	High	Low	Cleveland State University	High	Low
Texas A&M University - Kingsville	High	Low	Brigham Young University	High	Low
Idaho State University	High	Low	University of Puerto Rico-Mayaguez Campus	High	Low

As shown in Figure 17(I), a surface was fit though the set of efficient programs with high tuition and low acceptance rate. The surface could reveal important information about how programs with such characteristics would behave in different levels of inputs. These universities are the one that accepts a lot of students and they are relatively cheaper to go to. Looking at the efficient schools with these characteristics reveal that their efficient frontier is only correlated to the number of PhD students that they have. This means that these universities can produce more research dollars only if they have more PhD per faculty members, and number of BS and MS students per faculty is not contributing in their frontier.

5.4 Acceptance Rate Low, Tuition Low

Furthermore a different analysis performed on universities with low acceptance rate and low tuition. Table 16 represents the results of the analysis.

TABLE 16

EFFICIENT PROGRAMS WITH LOW ACCEPTANCE RATE AND LOW TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
University of Maryland-College Park	Low	Low	Stony Brook University	Low	Low
Lawrence Technological University	Low	Low	New Mexico Institute of Mining & Technology	Low	Low
University of Minnesota -Twin Cities	Low	Low	City College of the City University of New York	Low	Low
California State University-Long Beach	Low	Low	University of Wisconsin-Madison	Low	Low

Figure 17(II), is a surface fit though the set of efficient programs with high tuition. Schools with these characteristics do not accept a lot of students; this means that their quality of students is relatively higher. However they are relatively cheaper to go in comparing to other schools. According to their efficient surface, the amount of producible research dollars is related to their higher PhD and lower BS+MS students per faculty members. That means universities which have these characteristics with a lot of PhD, and few BS+MS should provide a higher research to stay efficient.

5.5 Acceptance Rate Low, Tuition High

An analysis performed on universities with low acceptance rate and high tuition. Table 17 is a list of all efficient universities with low acceptance rate and high tuition. Universities in this category are typically more expensive, and they are accepting relatively less applicants.

TABLE 17

EFFICIENT PROGRAMS WITH LOW ACCEPTANCE RATE AND HIGH TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
The George Washington University	Low	High	Stevens Institute of Technology	Low	High
Rensselaer Polytechnic Institute	Low	High	Cornell University	Low	High
Dartmouth College	Low	High	Yale University	Low	High
The Johns Hopkins University	Low	High	Princeton University	Low	High
Brown University	Low	High	University of Michigan	Low	High
University of Pennsylvania	Low	High	University of California-San Diego	Low	High
Washington University in St. Louis	Low	High	University of California-Riverside	Low	High
Duke University	Low	High	The University of Texas at Austin	Low	High
Northwestern University	Low	High	William Marsh Rice University	Low	High

In Figure 17(III), a surface fit though the set of efficient programs with high tuition. The surface is really similar to the efficient surface for universities with high acceptance rate and low tuition. Universities with these characteristics have a higher quality of inputs, and they have more resources. Looking at the efficient schools with these characteristics reveal that their efficient frontier is only correlated to the amount of PhD students that they have. This means that these universities can produce more research dollars only if they have more PhD per faculty members, and number of BS and MS students per faculty is not contributing in their frontier.

5.6 Acceptance Rate High, Tuition High

A separate analysis performed on universities with low acceptance rate and high tuition. Table 18 is a list of all efficient universities with high acceptance rate and tuition. These universities are expensive, but they accept more applicants than universities with low acceptance rate.

TABLE 18

EFFICIENT PROGRAMS WITH HIGH ACCEPTANCE RATE AND TUITION

School	Acceptance Rate	Tuition	School	Acceptance Rate	Tuition
Worcester Polytechnic Institute	High	High	Georgia Institute of Technology	High	High
Southern Methodist University	High	High	Purdue University	High	High
University of California-Irvine	High	High	Alfred University-NY State College of Ceramics	High	High
University of Illinois at Urbana-Champaign	High	High			

In Figure 17(IV), a surface fit though the set of efficient programs with high tuition. These universities are the one that accepts a lot of students and they are relatively more expensive to go in. the efficient frontier reveals that, maximum amount of research dollars can produce when they have a lot of PhD students and BS+MS students per faculty ration is 4.5. PhD students seem to have more impact when BS+MS are high.

5.7 Relationships

It could be beneficial to take a look at programs with different characteristics all in the same graph to reveal similar behaviors and patterns. To do so, different graphs provided in Fig 18-19, with different levels of BS+MS, PhD students, tuition and acceptance rate predicting the amount of research dollars per faculty members. Looking at the behavior of universities in different clusters provide important information. Below few notes provided from these graphs.

Non-dominated universities with high levels of BS+MS (Fig. 18), have very similar behavior, except when programs have low tuition and low acceptance rate. As the number of PhD students increase the amount of research dollars that they should produce would increase significantly. That means if a university in this class wants to stay in the efficient frontier it should be able to produce a significant amount of research dollars with more PhD students.

According to this model, programs should be able to generate nearly $500,000 per faculty if the ratio of the PhD students per faculty members is 0.5; this number would be double if the ratio increases to 0.7. However, if a program has low tuition and low acceptance rate, this rate of increase would drop significantly. Efficient universities with low BS+MS students (Fig. 19), have a very similar behavior to programs with high BS+MS students.

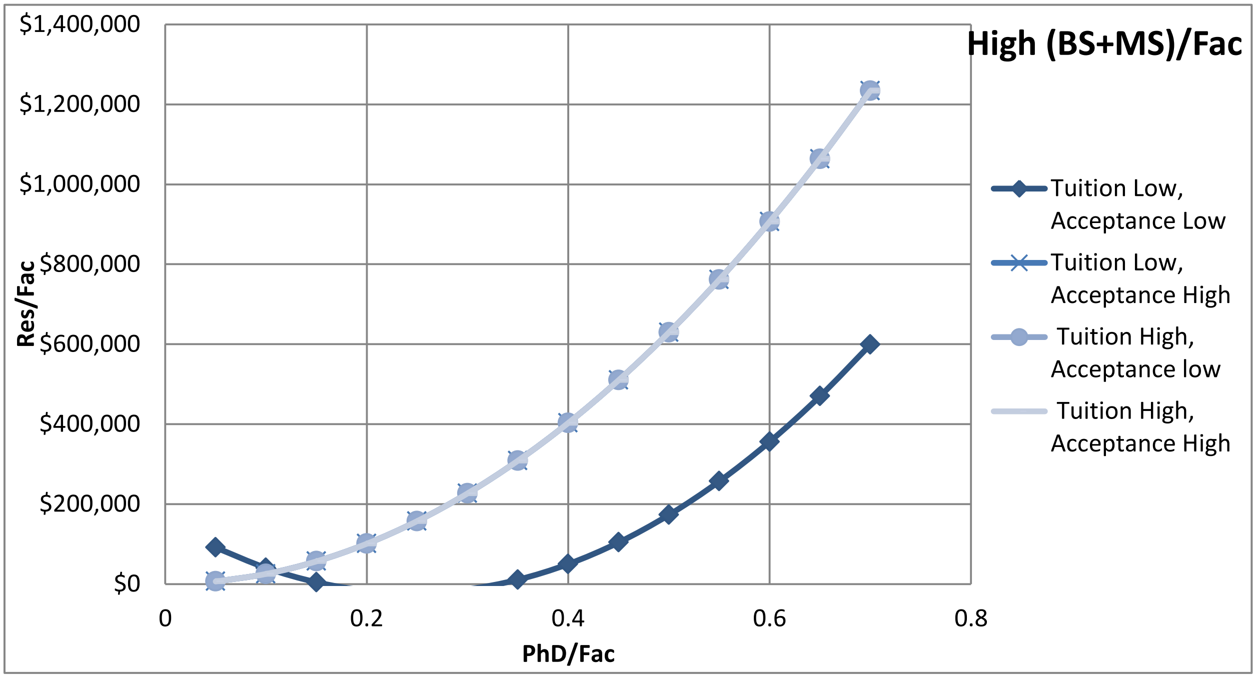

Figure 18. Efficient programs with high level of BS+MS students vs. Predicted amount of research dollars per faculty with different levels of input for efficient programs

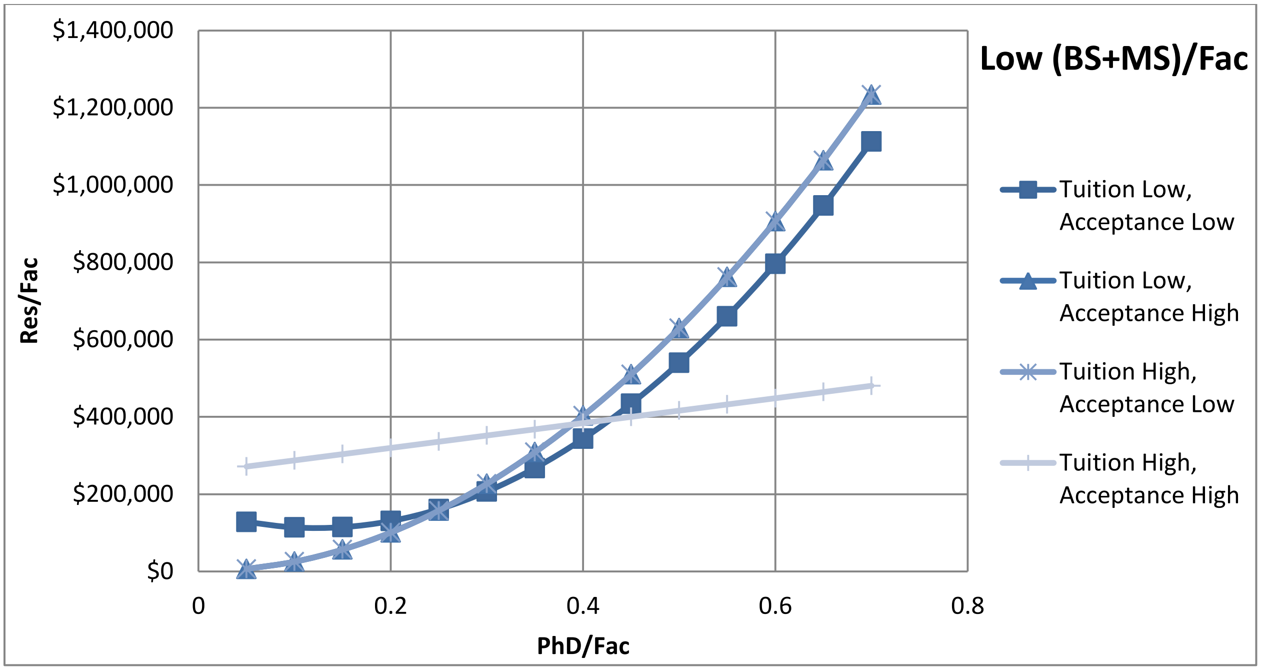

Figure 19. Efficient programs with high level of BS+MS students vs. Predicted amount of research dollars per faculty with different levels of input for efficient programs

In another look, universities clustered based on their level of PhD students (Fig. 20-21). Programs with these characteristics show different behaviors in different levels of inputs. Efficient programs with high number of PhD students (Fig. 20) reveal different behavior when they have different levels of inputs. Looking at Fig. 21, it could be understood that if a program has high level of PhD, with low tuition and high acceptance rate, or with high acceptance rate and low tuition, regardless of its undergraduate students it should produce nearly $800,000 to stay in the efficient frontier. In the other hand, if a program has low level of PhD (Fig. 21), with low tuition and high acceptance rate, or with high acceptance rate and low tuition, with any level of undergraduate students, it should generate nearly $100,000 to stay in the efficient frontier.

The amount of research dollars for programs with high number of PhD students and low tuition and acceptance rate would decrease as their undergraduate students increase. This behavior is the same for programs with low PhD students with high tuition and high acceptance rate. In general, universities with low PhD students (Fig. 21) should relatively generate less research to stay in the efficient frontier. Programs that have low tuition and low acceptance rate to stay competitive, should generate a significant amount of research dollars per faculty when they have low BS+MS.

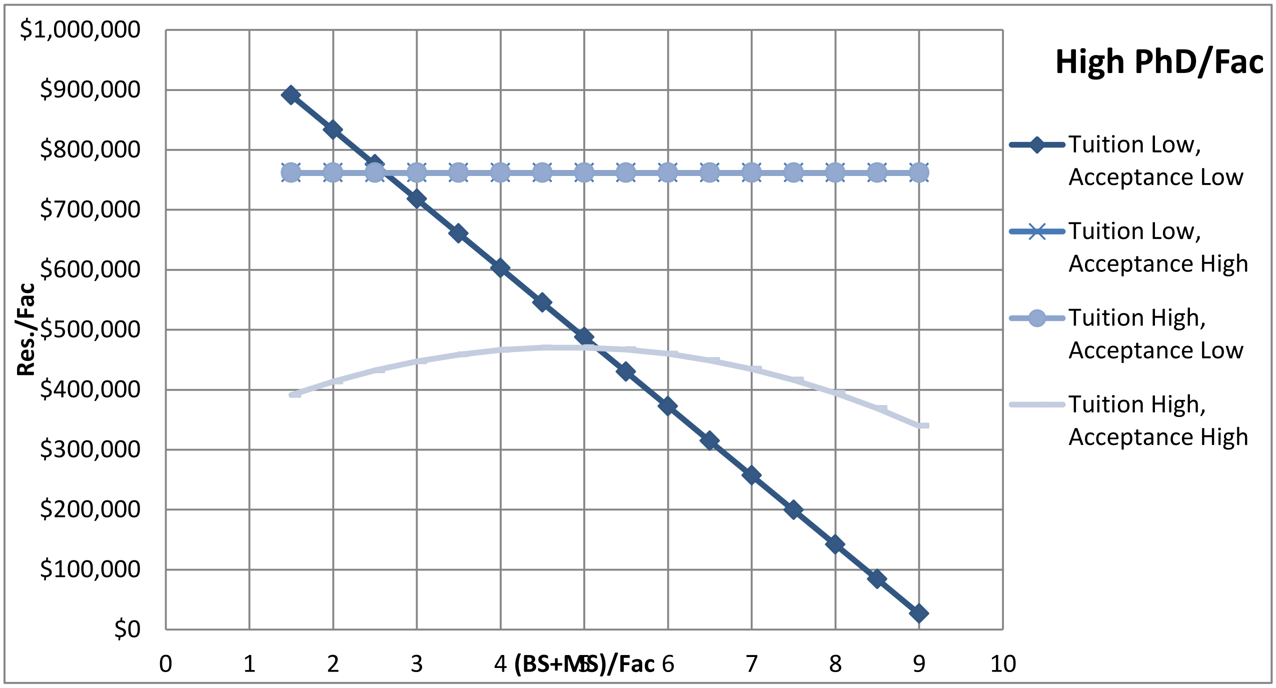

Figure 20. Efficient programs with high level of PhD students vs. Predicted amount of research dollars per faculty with different levels of input for efficient programs

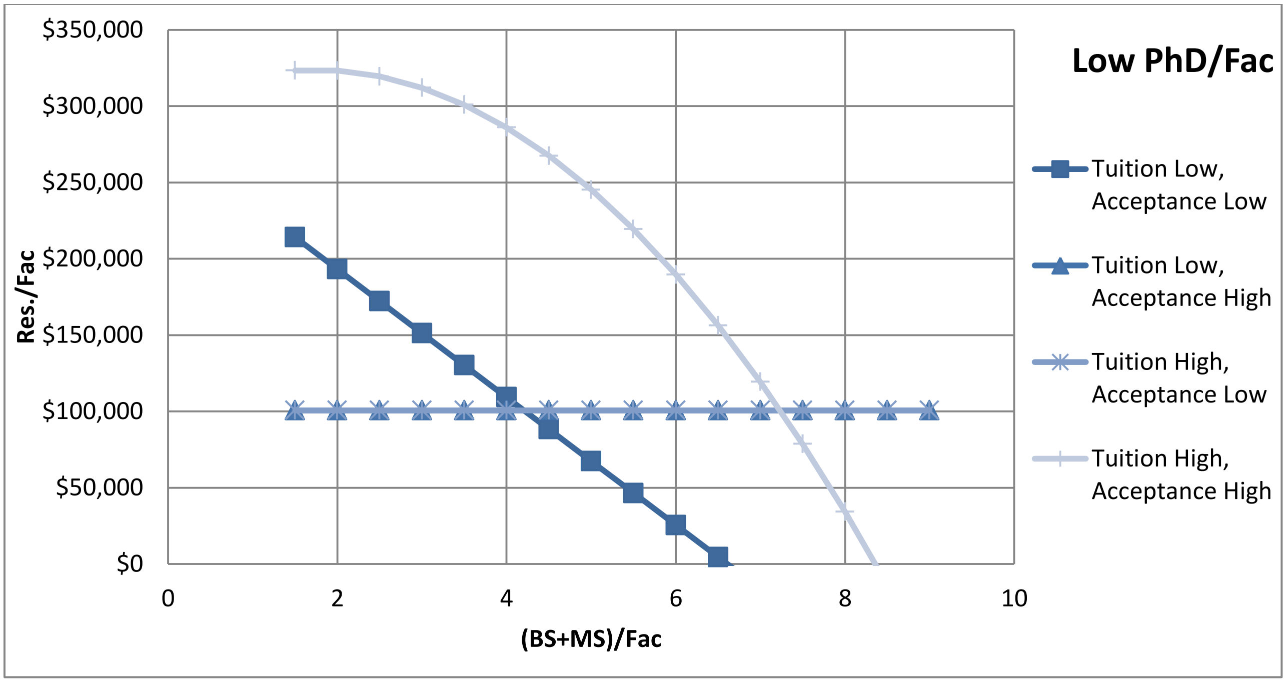

Figure 21. Efficient programs with low level of PhD students vs. Predicted amount of research dollars per faculty with different levels of input for efficient programs

5.8 Conclusion and Discussion

This work has provided at least the initial characteristics of the most efficient engineering colleges independent of their unique objectives. The underlying premise is that any program can then identify the most direct path from its position to the efficient surface. This path then can be interpreted in terms of specific strategies with the accompanying measures of improvement. The few "elite" schools as general models for emulation may not address the unique nature of each institution.

There are numerous issues with this approach, the first being the relative accuracy of the data. Although attempts are made for standardization in the ASEE database, the self-report process raises concerns. There is no assessment of the "quality" inputs or outputs. Are all faculty equivalents or are all degrees of the same value? Obviously there are more inputs into the system of higher education than number of faculty and there are likely other outputs. This is a very simple structural model.

Future studies to enhance the current research should consider adding more outputs to the DEA models. Outputs should be a measure of quality of outcome for each college. Factors like the salary of alumni of each college may be a good start.

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REFERENCES

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APPENDIXES

APPENDIX 1

DATA FOR ENGINEERING COLLEGES GATHERED FROM ASEE WEBSITE FOR THIS RESEARCH

	Ave. Degree			Ave. Students				
School	**Total Bachelor's**	**Total Master's**	**Total Doctoral**	**Total BS (Stds)**	**Total MS (Stds)**	**Total Phd(stds)**	**Total Fac.**	**Total Res.**
Alfred University-NY State College of Ceramics	62.67	10.33	4.67	285.00	32.67	21.67	18.33	$4,611,811
Arizona State University	682.00	537.67	118.67	5015.00	1610.67	813.67	225.00	$74,946,845
Auburn University	500.67	165.33	58.33	4021.67	441.33	393.67	161.33	$57,631,667
Boise State University	168.33	46.67	1.67	1662.33	141.00	22.67	55.33	$7,163,066
Boston University	266.33	156.67	56.33	1356.33	329.67	388.00	110.00	$73,401,058
Brigham Young University	356.67	96.33	21.67	2408.00	220.00	94.67	76.00	$9,615,157
Brown University	93.67	25.00	20.33	569.33	44.67	113.67	42.67	$16,156,427
California Institute of Technology	127.00	79.33	75.00	453.33	29.33	544.00	93.33	$87,254,468
California State University-Long Beach	356.00	186.00	1.00	2451.00	683.00	36.00	88.00	$4,148,000
Carnegie Mellon University	372.33	590.67	110.00	1716.33	1011.67	759.67	179.33	$188,993,343
Case Western Reserve University	325.67	122.33	63.00	1088.67	225.33	402.67	113.67	$39,060,667
City College of the City University of New York	247.00	141.67	29.00	2074.33	461.00	205.33	153.00	$29,595,638
Clarkson University	286.67	45.67	21.00	1580.33	124.67	85.67	70.67	$10,805,281

Clemson University	622.33	270.00	80.00	4051.67	695.00	569.00	225.00	$28,652,446
Cleveland State University	105.67	121.00	10.33	960.00	369.00	66.33	43.67	$2,909,355
Colorado School of Mines	685.33	320.00	49.00	3893.00	798.33	508.00	202.67	$49,306,602
Colorado State University	256.00	102.67	40.33	1886.67	349.67	283.00	104.33	$61,335,487
Cornell University	746.00	735.33	133.00	3125.00	805.00	907.67	258.00	$130,759,321
Dartmouth College	146.67	57.00	13.00	436.00	113.00	88.00	51.33	$17,199,559
Drexel University	570.33	299.00	63.33	3819.33	663.33	479.00	163.67	$37,678,667
Duke University	262.00	239.00	49.00	1236.00	401.33	405.67	105.00	$74,392,134
FAMU-FSU College of Engineering	294.67	61.67	18.67	2213.00	146.67	134.00	84.33	$20,665,055
Florida Atlantic University	215.33	92.67	11.00	2006.33	214.67	82.33	70.00	$7,195,307
Florida Institute of Technology	260.33	194.33	11.00	1433.33	471.00	115.00	74.33	$4,500,102
Florida International University	546.33	273.00	36.00	4146.67	572.67	276.67	124.00	$20,554,619
George Mason University	439.67	455.33	26.33	2713.67	1215.33	389.00	131.67	$18,650,855
Georgia Institute of Technology	1674.33	992.33	284.33	8480.67	1805.33	2078.33	428.00	$207,424,291
Harvard University	133.67	54.33	46.00	599.00	26.00	369.67	80.00	$49,064,310
Howard University	53.00	24.50	1.50	445.50	49.50	18.00	46.00	$5,980,855
Idaho State University	38.00	19.00	5.00	533.00	48.00	34.00	33.00	$1,773,158
Illinois Institute of Technology	256.67	387.00	35.33	1201.67	880.67	247.33	95.67	$18,768,627
Indiana University Purdue University Indianapolis	162.00	51.50	2.50	1002.00	190.00	18.00	43.50	$8,539,660

Iowa State University	860.00	221.67	91.33	6085.00	503.00	533.67	254.67	$78,908,667
Kansas State University	439.00	128.33	20.33	3058.67	371.67	156.00	129.00	$22,273,667
Lamar University	127.00	201.33	7.67	1145.67	265.33	68.33	79.00	$4,862,283
Lawrence Technological University	128.00	133.00	4.00	578.00	337.00	22.00	37.33	$2,155,104
Lehigh University	370.00	194.67	44.00	1849.67	170.33	570.00	129.33	$23,843,542
Louisiana State University	578.33	109.00	36.67	4029.33	237.33	338.33	128.67	$18,168,496
Louisiana Tech University	174.00	110.00	20.67	1409.00	223.00	152.67	91.67	$16,012,964
Marquette University	200.33	52.67	8.67	1082.67	148.33	66.33	52.67	$5,461,649
Massachusetts Institute of Technology	619.67	740.67	296.33	2058.00	1042.67	1843.33	374.33	$333,776,667
Michigan State University	489.00	89.33	71.00	3283.33	282.33	540.33	175.00	$49,776,667
Michigan Technological University	630.67	163.33	33.67	3322.00	452.33	301.00	148.67	$26,789,506
Mississippi State University	355.67	99.67	44.33	2551.67	280.67	331.67	119.00	$52,480,000
Missouri University of Science and Technology	758.33	395.33	42.00	4206.00	700.33	336.00	175.67	$33,286,617
Montana State University	216.00	52.00	7.33	1904.00	118.33	53.00	67.33	$18,359,838
New Jersey Institute of Technology	361.33	502.00	36.67	2358.00	1120.00	226.00	157.00	$43,166,999
New Mexico Institute of Mining & Technology	126.33	51.33	4.00	934.00	139.33	33.33	47.00	$7,703,300
New Mexico State University	194.33	121.00	12.33	1567.00	293.33	138.67	87.00	$11,328,608

North Carolina A&T State University	197.67	71.33	13.00	1324.33	193.33	114.00	94.00	$10,758,197
North Carolina State University	1205.33	682.00	142.00	6305.00	1699.00	1102.00	373.33	$143,955,000
North Dakota State University	337.00	48.50	17.00	1983.00	125.00	81.00	77.00	$3,406,881
Northeastern University	386.33	375.33	37.00	2510.67	1062.67	416.67	138.00	$25,663,084
Northwestern University	331.00	373.00	119.33	1546.00	725.67	820.67	182.67	$112,091,338
Oakland University	140.33	109.67	11.33	1053.00	286.67	151.00	50.67	$2,176,085
Ohio University	163.00	58.00	9.00	1132.00	245.33	116.00	77.33	$15,890,439
Oklahoma State University	347.67	225.00	21.33	2537.67	584.67	241.67	130.33	$28,062,730
Old Dominion University	159.33	188.00	37.00	1334.67	559.67	198.67	81.67	$6,487,687
Oregon State University	599.67	183.67	42.00	4510.67	466.67	344.33	144.00	$31,838,764
Philadelphia University	7.00	3.00	2.00	90.00	11.00	0.00	6.00	$7,090,000
Polytechnic Institute of New York University	236.33	696.00	20.67	1252.00	1723.67	198.67	88.00	$13,198,986
Portland State University	252.00	217.00	10.00	1892.00	509.00	145.00	78.00	$8,369,684
Prairie View A&M University	106.00	23.50	2.50	973.50	108.00	16.50	53.00	$7,384,341
Princeton University	210.33	19.00	82.00	1057.33	38.00	527.67	137.33	$77,441,289
Purdue University	1359.33	472.67	214.00	7387.33	1170.33	1558.00	328.33	$202,752,123
Rensselaer Polytechnic Institute	731.67	228.00	74.00	3056.00	259.67	484.33	146.67	$48,452,394
Rochester Institute of Technology	367.33	243.33	5.67	2612.00	571.33	38.33	99.00	$29,069,000
Rutgers-The State University of New Jersey	572.67	151.33	58.00	3182.33	387.33	370.00	138.33	$51,640,665

Santa Clara University	152.00	281.33	7.67	844.67	667.67	59.33	46.33	$1,765,160
South Dakota School of Mines and Technology	207.67	57.33	6.33	1544.67	169.33	71.67	76.67	$7,781,270
South Dakota State University	147.00	55.00	4.33	1143.67	185.00	39.33	98.33	$8,824,196
Southern Illinois University Carbondale	140.33	134.67	13.00	750.33	244.33	100.00	56.00	$2,737,020
Southern Methodist University	148.00	346.00	23.00	1004.00	680.00	171.00	58.00	$5,635,967
Stanford University	423.33	1039.00	277.33	2717.33	1819.33	1742.00	223.33	$194,779,609
State University of New York at Buffalo	555.00	396.00	52.00	2701.67	820.67	460.00	148.33	$60,157,667
Stevens Institute of Technology	328.00	755.50	31.00	1867.00	1523.50	277.00	127.00	$25,786,293
Stony Brook University	441.00	346.00	62.50	1885.50	693.00	543.50	135.50	$29,282,836
Syracuse University	228.00	260.00	31.00	1445.00	618.00	220.67	75.33	$13,483,667
Temple University	131.67	41.33	5.33	967.33	67.67	52.33	57.67	$4,087,525
Tennessee State University	52.67	17.33	2.33	605.67	57.67	16.67	37.67	$3,542,000
Tennessee Technological University	247.67	37.67	11.00	1988.33	102.33	51.00	70.67	$5,202,234
Texas A&M University	1238.00	638.00	197.33	7563.00	1587.33	1327.00	364.00	$274,680,333
Texas A&M University - Kingsville	169.00	205.00	2.33	765.67	406.33	26.00	49.33	$1,939,628
Texas Tech University	521.00	207.00	41.00	3557.00	406.33	340.00	133.33	$22,280,821
The George Washington University	95.50	530.00	46.50	670.00	1025.50	351.50	87.50	$13,966,120

The Johns Hopkins University	325.00	836.33	79.33	1577.67	2609.00	690.33	167.00	$73,477,000
The Ohio State University	999.67	380.00	129.00	6648.67	767.67	961.33	293.00	$121,366,667
The Pennsylvania State University	1440.00	381.00	177.33	8827.67	745.67	1172.00	374.67	$138,262,299
The State University of New York at Binghamton	335.33	205.33	26.67	1887.67	458.67	228.33	78.33	$13,938,369
The University of Akron	202.67	56.00	19.00	2438.33	195.33	173.33	84.67	$11,146,969
The University of Alabama	335.00	87.33	20.33	3125.00	170.67	179.33	125.67	$16,777,947
The University of Alabama in Huntsville	266.33	125.33	22.00	1753.00	420.67	214.67	71.67	$45,114,738
The University of Iowa	274.33	79.33	39.33	1691.33	130.00	247.00	86.67	$47,531,524
The University of Memphis	59.67	32.00	7.00	636.00	82.67	68.67	38.67	$6,725,788
The University of Mississippi	115.33	35.33	9.67	964.00	84.00	73.67	49.33	$10,230,327
The University of New Mexico	191.67	117.67	38.67	1200.33	307.67	365.33	103.67	$31,409,000
The University of Texas at Arlington	296.33	438.67	58.33	2549.00	1114.00	371.33	156.33	$37,173,667
The University of Texas at Austin	1029.00	457.00	191.33	5585.00	700.33	1509.00	278.00	$161,379,281
The University of Texas at Dallas	289.33	375.33	66.67	2055.00	1140.33	391.33	143.00	$41,865,890
The University of Texas at El Paso	305.33	156.67	23.00	2541.00	390.67	199.00	82.33	$18,990,477
The University of Texas at San Antonio	201.00	92.33	13.67	2197.00	271.33	119.67	71.00	$7,337,599
The University of Toledo	261.00	82.33	17.67	1808.00	233.33	121.33	71.00	$9,829,398

Tufts University	176.33	123.67	24.33	747.00	376.33	193.00	84.33	$18,135,545
Tulane University	37.00	9.33	3.33	266.33	11.33	58.67	31.33	$5,263,059
University of Alabama at Birmingham	111.33	127.00	10.67	801.00	273.67	105.00	52.67	$7,165,569
University of Alaska Fairbanks	94.33	34.67	3.00	737.33	95.00	35.33	51.33	$15,621,233
University of Arizona	456.33	167.33	87.00	2189.00	344.00	497.67	160.00	$52,944,025
University of Arkansas	292.00	77.33	23.67	2372.67	200.00	185.00	115.33	$20,125,695
University of Bridgeport	5.50	351.00	2.00	51.50	536.00	71.00	39.00	$120,068
University of California-Berkeley	885.00	395.67	226.00	3473.33	342.00	1483.67	232.33	$187,563,667
University of California-Davis	532.67	173.33	111.33	3197.67	384.33	815.33	205.00	$80,239,970
University of California-Irvine	515.33	156.33	72.67	2852.67	276.67	514.67	115.33	$68,701,000
University of California-Los Angeles	706.33	469.33	150.00	3281.33	879.33	922.00	156.33	$95,491,824
University of California-Riverside	214.00	60.67	57.33	2040.00	102.00	421.00	86.67	$35,865,784
University of California-San Diego	807.00	341.67	135.33	4980.00	578.33	936.67	195.00	$151,155,031
University of California-Santa Cruz	183.67	59.33	34.33	1448.00	77.67	279.00	82.00	$31,970,091
University of Central Florida	735.67	325.00	65.00	6200.33	766.67	517.67	141.00	$66,951,404
University of Cincinnati	347.33	152.67	59.33	2550.33	523.67	403.67	123.00	$25,515,640
University of Colorado Boulder	610.67	436.00	88.00	3162.67	929.67	672.33	193.00	$78,474,970

University of Colorado Colorado Springs	86.00	42.00	3.00	487.00	192.00	51.00	34.00	$1,934,613
University of Colorado Denver	122.00	98.00	8.00	633.00	366.00	63.00	46.00	$1,751,700
University of Connecticut	391.33	109.67	53.00	2076.67	290.67	443.00	137.67	$41,941,333
University of Dayton	216.33	164.33	14.67	1388.00	515.00	109.00	68.33	$85,182,333
University of Delaware	329.67	102.67	72.33	2035.33	236.00	582.67	141.00	$50,509,204
University of Denver	28.00	57.50	4.50	277.00	135.50	53.00	31.00	$2,694,941
University of Florida	994.67	908.00	223.00	5470.00	1772.67	1146.67	281.67	$78,595,333
University of Georgia	43.00	16.00	4.33	456.67	28.33	29.67	35.00	$5,221,097
University of Hawaii at Manoa	137.00	47.67	11.33	808.33	154.00	70.33	55.67	$8,796,609
University of Houston	255.00	207.67	43.00	2843.33	469.67	306.33	119.00	$21,236,726
University of Idaho	183.33	107.67	6.33	1272.00	310.33	101.67	86.33	$13,904,270
University of Illinois at Chicago	363.33	241.67	63.67	2187.33	572.00	439.67	117.33	$27,653,970
University of Illinois at Urbana-Champaign	1361.33	536.67	285.67	7169.33	1112.33	1707.33	414.67	$223,340,012
University of Kansas	309.67	138.67	25.33	1951.33	426.67	195.33	105.67	$18,624,735
University of Kentucky	387.67	93.00	33.00	2474.33	205.67	303.00	156.33	$40,900,595
University of Louisiana at Lafayette	120.00	73.00	4.50	1355.50	157.00	32.00	49.00	$10,166,246
University of Louisville	267.00	238.67	23.67	1473.00	370.67	209.67	98.33	$12,690,820
University of Maine	180.67	29.67	8.00	1091.33	79.67	62.00	67.67	$23,990,508

University of Maryland-Baltimore County	225.00	86.67	22.00	1768.00	310.00	194.67	66.00	$10,414,275
University of Maryland-College Park	646.67	382.33	132.67	3034.67	1082.00	902.00	200.00	$150,514,179
University of Massachusetts Amherst	296.67	127.33	43.00	1666.00	279.33	337.00	114.00	$39,568,355
University of Massachusetts Dartmouth	149.33	55.67	2.33	988.67	180.67	57.67	56.67	$13,204,667
University of Massachusetts Lowell	223.67	157.33	13.00	1710.67	402.33	164.33	78.33	$9,834,827
University of Miami	163.00	54.00	22.00	895.00	85.00	130.00	65.67	$5,230,751
University of Michigan	1294.33	916.00	236.33	5624.33	1580.33	1543.67	377.67	$188,390,621
University of Minnesota -Twin Cities	869.33	413.00	133.67	3962.00	879.33	1056.33	226.00	$98,597,782
University of Missouri	446.00	106.67	39.67	2523.33	329.67	265.00	123.33	$31,986,300
University of Nebraska-Lincoln	475.33	160.33	39.33	2892.00	308.33	330.33	180.00	$36,472,617
University of Nevada-Las Vegas	166.33	64.67	12.33	1664.33	162.33	70.67	65.67	$5,340,440
University of Nevada-Reno	207.00	70.00	17.33	1678.67	159.33	127.67	61.00	$14,344,301
University of New Hampshire	260.00	55.67	7.33	1416.00	185.00	71.33	65.00	$8,277,008
University of New Orleans	109.00	50.00	10.00	932.67	99.00	81.33	37.33	$4,463,140
University of North Carolina at Charlotte	265.00	83.67	14.67	1683.00	225.00	161.00	88.67	$6,290,000
University of North Texas	123.00	96.50	13.00	1366.00	238.00	112.50	82.50	$7,065,271
University of Notre Dame	263.67	58.33	52.33	1002.00	23.67	450.33	118.67	$37,290,477

University of Oklahoma	368.33	163.00	38.00	2827.67	407.67	252.67	132.67	$28,341,706
University of Pennsylvania	365.33	436.33	61.00	1662.00	1149.67	457.67	123.00	$85,842,104
University of Pittsburgh	432.00	162.00	53.00	2329.33	474.67	396.33	128.00	$77,994,000
University of Puerto Rico-Mayaguez Campus	567.50	65.00	7.50	4414.50	298.50	86.50	181.50	$10,739,079
University of Rhode Island	204.00	61.67	11.00	1060.67	152.67	93.33	64.00	$6,485,205
University of Rochester	175.67	109.67	44.00	970.67	155.67	331.67	93.67	$87,319,667
University of South Carolina	269.33	73.67	34.00	1842.00	183.67	347.00	109.67	$25,257,282
University of South Florida	460.00	214.67	48.00	3056.33	421.00	387.00	119.00	$27,350,657
University of Southern California	462.00	1596.67	136.33	2147.67	3309.00	996.00	204.33	$175,078,681
University of Tennessee-Knoxville	407.00	177.00	56.33	2447.33	430.33	505.67	168.33	$54,517,667
University of Tulsa	127.00	83.00	12.50	824.00	131.00	77.50	55.50	$18,480,100
University of Utah	415.67	215.67	73.00	2977.00	475.67	567.00	169.33	$78,663,333
University of Vermont	141.50	15.50	5.50	813.50	71.50	66.50	42.00	$3,786,512
University of Virginia	508.00	144.33	76.33	2381.67	196.67	482.33	142.67	$65,903,657
University of Washington	807.33	417.00	110.00	4183.00	1011.00	861.00	276.33	$112,005,000
University of Wisconsin-Madison	644.33	424.33	120.67	3865.67	674.67	862.67	204.00	$130,111,726
University of Wisconsin-Milwaukee	231.00	66.50	16.50	1566.50	170.50	199.00	81.00	$8,196,320
University of Wyoming	174.00	48.00	11.00	1293.50	145.00	98.50	87.50	$12,453,547

Vanderbilt University	302.00	79.33	51.33	1283.33	63.33	376.33	106.00	$61,490,667
Villanova University	201.50	121.50	3.00	914.50	333.50	34.50	74.00	$3,787,069
Virginia Commonwealth University	209.33	50.00	20.00	1404.33	96.00	147.67	60.00	$4,608,082
Virginia Polytechnic Institute and State University	1244.33	458.67	160.00	6634.00	978.00	1296.00	343.33	$146,264,637
Washington State University	375.33	117.00	34.67	2649.33	304.67	353.00	128.67	$20,111,143
Washington University in St. Louis	256.67	181.00	43.33	1243.00	399.00	332.33	77.67	$24,216,450
Wayne State University	117.67	234.33	35.00	1115.67	578.00	260.00	107.00	$16,736,274
West Virginia University	475.67	164.67	31.67	3115.00	433.67	241.67	116.33	$28,482,064
Western Michigan University	245.67	102.33	11.67	1887.67	299.67	76.00	78.00	$3,397,848
Wichita State University	203.00	208.33	9.00	1533.00	540.67	104.33	43.67	$5,873,451
William Marsh Rice University	215.33	107.33	75.00	1174.33	128.33	541.67	123.00	$48,789,853
Worcester Polytechnic Institute	482.33	301.00	20.00	2500.67	719.00	139.67	94.33	$10,266,666
Wright State University	204.00	190.00	18.33	1742.67	379.67	139.67	76.00	$12,612,333
Yale University	64.33	70.33	21.67	132.33	19.00	177.67	61.33	$27,731,285

APPENDIX 2

SHORTEST DISTANCE TO THE EFFICIENT SURFACE, AND SET OF STRATEGIES FOR ALL IE PROGRAMS

	Current (per fac.)			Best (per fac.)				Vector to Surface (per fac.)		
School	**BS+MS**	**PhD**	**Res.* 1M**	**BS+MS**	**PhD**	**Res.*1M**	**Distnce**	**BS+MS**	**PhD**	**Res.**
Arizona State University	6.1	0.51	$0.12	6.1	0.21	$0.34	0.3702728	-0.01	-0.30	$215,199
Auburn University	7.9	0.57	$0.17	7.9	0.6	$0.20	0.060158	0.03	0.03	$37,373
Clemson University	7.5	0.67	$0.09	7.5	0.76	$0.15	0.1117496	0.02	0.09	$59,559
Cornell University	10.9	0.31	$0.08	9	0.31	$0.00	1.9095332	-1.91	0.00	-$83,797
FAMU-FSU College of Engineering	3.5	0.25	$0.33	3.5	0.36	$0.27	0.1250474	0.00	0.11	-$59,472
George Mason University	4.4	0.15	$0.14	4.4	0.18	$0.13	0.0365811	0.01	0.03	-$14,148
Georgia Institute of Technology	10.1	0.45	$0.20	9	0.45	$0.00	1.1013185	-1.08	0.00	-$198,215
Iowa State University	4.4	0.24	$0.07	4.3	0.18	$0.11	0.0877687	-0.05	-0.06	$36,405
Kansas State University	3.9	0.17	$0.31	3.9	0.29	$0.24	0.1422052	0.01	0.12	-$69,912
Lamar University	3.6	0.09	$0.01	3.6	0.09	$0.00	0.0206471	0.02	0.00	-$8,428
Lehigh University	6.2	0.30	$0.10	6.2	0.12	$0.20	0.208265	0.04	-0.18	$96,821
Mississippi State University	4.2	0.34	$0.39	4.2	0.35	$0.38	0.0419464	-0.04	0.01	-$4,527
New Mexico State University	8.1	0.20	$0.01	8.1	0.13	$0.07	0.1073691	0.05	-0.07	$64,250
North Carolina A&T State University	1.9	0.26	$0.05	3	0.3	$0.04	1.0533728	1.05	0.04	-$14,269
North Carolina State University	4.3	0.41	$0.28	4.3	0.31	$0.34	0.1201389	-0.04	-0.10	$62,446
North Dakota State University	5.2	0.22	$0.03	5.2	0.1	$0.08	0.1331914	-0.02	-0.12	$48,040
Northwestern University	4.9	0.39	$0.16	4.8	0.22	$0.27	0.2108276	-0.06	-0.17	$106,317
Ohio University	1.9	0.22	$0.12	3	0.32	$0.07	1.1163227	1.11	0.10	-$45,255

Oklahoma State University	5.7	0.20	$0.09	5.7	0.1	$0.13	0.1159164	-0.04	-0.10	$39,998
Oregon State University	5.4	0.33	$0.13	5.4	0.16	$0.22	0.1954451	-0.01	-0.17	$89,997
Purdue University	7.8	0.56	$0.17	7.8	0.61	$0.23	0.0793781	0.03	0.05	$55,833
Rutgers-The State University of New Jersey	3.7	0.43	$0.09	3.7	0.28	$0.18	0.1722275	0.01	-0.15	$85,935
Stanford University	9.0	0.58	$0.21	9	0.57	$0.00	0.2133149	0.01	-0.01	-$212,890
State University of New York at Buffalo	6.2	0.55	$0.64	6.2	0.55	$0.56	0.0878078	0.04	0.00	-$77,009
Texas A&M University	10.9	0.45	$0.54	9	0.45	$0.00	1.98814	-1.91	0.00	-$538,603
Texas Tech University	3.8	0.68	$0.07	3.7	0.34	$0.28	0.4029146	-0.07	-0.34	$210,927
The Ohio State University	5.4	0.43	$0.26	5.4	0.26	$0.39	0.2131813	-0.03	-0.17	$127,333
The Pennsylvania State University	7.9	0.62	$0.07	7.9	0.69	$0.12	0.0838996	0.02	0.07	$48,179
The State University of New York at Binghamton	6.8	0.58	$0.16	6.8	0.77	$0.32	0.2457057	-0.01	0.19	$159,675
The University of Alabama in Huntsville	5.2	0.67	$1.03	5.2	0.63	$0.62	0.4149875	0.03	-0.04	-$412,018
The University of Iowa	5.0	0.57	$0.60	5	0.57	$0.62	0.0234934	0.00	0.00	$23,450
The University of Texas at Arlington	7.6	0.84	$0.06	7.6	0.81	$0.04	0.0516466	0.04	-0.03	-$12,937
University of Arizona	5.5	0.84	$0.12	5.5	0.84	$0.47	0.3485974	0.02	0.00	$348,023
University of Arkansas	2.9	0.14	$0.12	3	0.14	$0.00	0.1354954	0.06	0.00	-$120,840
University of California-Berkeley	6.2	0.63	$0.10	6.2	0.84	$0.36	0.3416535	0.04	0.21	$265,253
University of Central Florida	6.7	0.51	$0.83	6.6	0.51	$0.52	0.3249015	-0.09	0.00	-$312,604
University of Florida	12.7	0.57	$0.14	9	0.57	$0.00	3.7384334	-3.74	0.00	-$138,925
University of Houston	6.6	0.45	$0.03	6.6	0.14	$0.23	0.3705257	-0.01	-0.31	$200,051
University of Illinois at Urbana-Champaign	2.4	0.24	$0.10	3	0.31	$0.06	0.6333153	0.63	0.07	-$42,574

University of Louisville	5.2	0.34	$0.09	5.1	0.16	$0.19	0.2164587	-0.06	-0.18	$99,631
University of Miami	4.4	0.34	$0.04	4.4	0.18	$0.13	0.1889949	0.02	-0.16	$90,127
University of Michigan	12.2	0.41	$0.16	9	0.41	$0.00	3.1612672	-3.16	0.00	-$161,372
University of Missouri	3.0	0.09	$0.05	3	0.09	$0.00	0.0539938	0.00	0.00	-$53,965
University of Nebraska-Lincoln	1.5	0.08	$0.07	3	0.08	$0.00	1.5401156	1.54	0.00	-$71,293
University of Oklahoma	3.6	0.34	$0.19	3.6	0.31	$0.21	0.0357648	-0.01	-0.03	$13,928
University of Pittsburgh	5.4	0.28	$0.32	5.4	0.24	$0.36	0.0557719	-0.01	-0.04	$33,539
University of South Florida	2.4	0.40	$0.06	3	0.33	$0.09	0.6298017	0.63	-0.07	$33,544
University of Southern California	8.0	0.29	$0.10	8	0.23	$0.19	0.1098802	0.02	-0.06	$87,052
University of Tennessee-Knoxville	4.7	0.52	$0.14	4.7	0.25	$0.30	0.3214197	-0.04	-0.27	$167,144
University of Washington	3.9	0.29	$0.05	3.9	0.21	$0.08	0.0925539	0.02	-0.08	$35,326
University of Wisconsin-Madison	8.0	0.50	$1.31	7.8	0.44	$0.30	1.0272616	-0.18	-0.06	-$1,009,587
Virginia Polytechnic Institute and State University	7.4	0.61	$0.21	7.4	0.68	$0.27	0.0878521	0.00	0.07	$58,306
Wayne State University	3.5	0.41	$0.19	3.5	0.34	$0.24	0.0900271	0.03	-0.07	$45,713
West Virginia University	7.8	0.18	$0.22	7.8	0.2	$0.20	0.031381	0.00	0.03	-$18,968
Western Michigan University	1.6	0.19	$0.02	3	0.19	$0.00	1.4043738	1.40	0.00	-$18,184
Wichita State University	**4.9**	**0.19**	**$0.14**	**4.9**	**0.16**	$0.17	**0.052690206**	**0.03**	**-0.03**	**$28,423**

APPENDIX 3

ALL UNIVERSITIES WITH THEIR INPUTS AND OUTPUTS AND THEIR RELATIVE EFFICIENCY SCORES

	Outputs				Inputs			
School	**Total Bachelor's**	**Total Master's**	**Total Doctoral**	**Total Res.**	**Total Fac.**	**Acceptance Rate**	**Tuition**	**Efficiency**
Worcester Polytechnic Institute	482.33	301.00	20.00	$10,266,666	94.33	0.57	38723	**100**
Southern Methodist University	148.00	346.00	23.00	$5,635,967	58.00	0.51	37273	**100**
University of California-Irvine	515.33	156.33	72.67	$68,701,000	115.33	0.51	34044	**100**
University of Illinois at Urbana-Champaign	1361.33	536.67	285.67	$223,340,012	414.67	0.65	27159	**100**
Georgia Institute of Technology	1674.33	992.33	284.33	$207,424,291	428.00	0.56	26835	**100**
Purdue University	1359.33	472.67	214.00	$202,752,123	328.33	0.67	26462	**100**
Alfred University-NY State College of Ceramics	62.67	10.33	4.67	$4,611,811	18.33	0.76	26035	**100**
Texas A&M University	1238.00	638.00	197.33	$274,680,333	364.00	0.62	23078	**100**
University of Central Florida	735.67	325.00	65.00	$66,951,404	141.00	0.56	20523	**100**
North Carolina State University	1205.33	682.00	142.00	$143,955,000	373.33	0.55	18959	**100**
The University of Alabama in Huntsville	266.33	125.33	22.00	$45,114,738	71.67	0.75	17679	**100**
University of Colorado Colorado Springs	86.00	42.00	3.00	$1,934,613	34.00	0.56	16987	**100**
Texas A&M University - Kingsville	169.00	205.00	2.33	$1,939,628	49.33	0.83	15979	**100**

Idaho State University	38.00	19.00	5.00	$1,773,158	33.00	0.70	15906	**100**
State University of New York at Buffalo	555.00	396.00	52.00	$60,157,667	148.33	0.51	15797	**100**
The University of Texas at Arlington	296.33	438.67	58.33	$37,173,667	156.33	0.74	15721	**100**
The State University of New York at Binghamton	335.33	205.33	26.67	$13,938,369	78.33	0.56	15093	**100**
University of New Orleans	109.00	50.00	10.00	$4,463,140	37.33	0.56	14520	**100**
Cleveland State University	105.67	121.00	10.33	$2,909,355	43.67	0.77	11391	**100**
Brigham Young University	356.67	96.33	21.67	$9,615,157	76.00	0.71	4423	**100**
University of Puerto Rico-Mayaguez Campus	567.50	65.00	7.50	$10,739,079	181.50	0.60	4119	**100**
The George Washington University	95.50	530.00	46.50	$13,966,120	87.50	0.42	42903	**100**
Rensselaer Polytechnic Institute	731.67	228.00	74.00	$48,452,394	146.67	0.41	40850	**100**
Dartmouth College	146.67	57.00	13.00	$17,199,559	51.33	0.10	40704	**100**
The Johns Hopkins University	325.00	836.33	79.33	$73,477,000	167.00	0.26	40703	**100**
Brown University	93.67	25.00	20.33	$16,156,427	42.67	0.14	40633	**100**
University of Pennsylvania	365.33	436.33	61.00	$85,842,104	123.00	0.14	40527	**100**
Washington University in St. Louis	256.67	181.00	43.33	$24,216,450	77.67	0.23	40363	**100**
Duke University	262.00	239.00	49.00	$74,392,134	105.00	0.17	40307	**100**
Northwestern University	331.00	373.00	119.33	$112,091,338	182.67	0.21	40223	**100**
Stevens Institute of Technology	328.00	755.50	31.00	$25,786,293	127.00	0.43	39926	**100**

Cornell University	746.00	735.33	133.00	$130,759,321	258.00	0.19	39720	**100**
Yale University	64.33	70.33	21.67	$27,731,285	61.33	0.08	38433	**100**
Princeton University	210.33	19.00	82.00	$77,441,289	137.33	0.10	36615	**100**
University of Michigan	1294.33	916.00	236.33	$188,390,621	377.67	0.30	36240	**100**
University of California-San Diego	807.00	341.67	135.33	$151,155,031	195.00	0.41	34119	**100**
University of California-Riverside	214.00	60.67	57.33	$35,865,784	86.67	0.48	33840	**100**
The University of Texas at Austin	1029.00	457.00	191.33	$161,379,281	278.00	0.29	31226	**100**
William Marsh Rice University	215.33	107.33	75.00	$48,789,853	123.00	0.21	33793	**99.83**
University of Maryland-College Park	646.67	382.33	132.67	$150,514,179	200.00	0.48	24949	**100**
Lawrence Technological University	128.00	133.00	4.00	$2,155,104	37.33	0.50	24640	**100**
University of Minnesota -Twin Cities	869.33	413.00	133.67	$98,597,782	226.00	0.36	16692	**100**
California State University-Long Beach	356.00	186.00	1.00	$4,148,000	88.00	0.44	16300	**100**
Stony Brook University	441.00	346.00	62.50	$29,282,836	135.50	0.49	15274	**100**
New Mexico Institute of Mining & Technology	126.33	51.33	4.00	$7,703,300	47.00	0.39	14647	**100**
City College of the City University of New York	247.00	141.67	29.00	$29,595,638	153.00	0.30	10550	**100**
University of Wisconsin-Madison	644.33	424.33	120.67	$130,111,726	204.00	0.42	24236	**99.57**