

## Introduction

In the month of September, a quick search of University homepages around the country will reveal many boasting their new national ranking from *US News and World Report* or *Business Week*. Every year publications like these release college “guides” containing articles relating to SAT’s, scholarships or “which MBA program is right for you”. But the highlights of each issue are the national rankings, which are eagerly accepted by students, faculty and the universities themselves. There are all kinds of useful facts and figures to peruse, and then of course the final ranking placement. But how are these rankings calculated? Does anyone ever look at the methodology or do they simply accept the rankings as being correct? And most importantly, what do these rankings say?

*US News and World Report* has the most thorough and popular college guide published by a major magazine. They provide many articles relating to undergraduate, graduate and doctoral education. They also provide many rankings. These rankings are broken down into regions, tiers, programs, missions and specialties. The commonality between each ranking is usually the “indicators of academic excellence” (Morse and Flanigan 80). These include retention rates, peer assessment scores, student to faculty ratios, class sizes, graduation rates and acceptance rates. Each factor is then given a weight to reflect its importance.

For this project, *US News and World Report’s* 2003 MBA program rankings will be examined. Each year the top 50 MBA programs are ranked by looking at indicators such as starting salary, GMAT scores, employment rates, undergraduate GPA, and acceptance rates. The distribution of the data is examined and made into a normal curve. The values are then standardized around the mean and rescaled to give the highest performer a score of 100 (Garret 34). One of the downfalls of this method is the importance given to outputs and the disregard for

efficiency. Of course Stanford and Harvard are the top schools, but what does it mean when they score 100 and Rice University scores 60? How much worse is Rice than Stanford?

We propose to use a new approach known as Data Envelopment Analysis, or DEA, to rank colleges and universities. This analysis uses weighted inputs and outputs to maximize efficiency. This method effectively allows one to compare “apples and oranges” because it measures efficiency, not output. Every school is given a chance to pick their own weights for the individual inputs and outputs in order to maximize their efficiency. Efficiency is defined as the ratio of weighted outputs to weighted inputs. At the same time, every other school calculates their efficiency in accordance with the chosen weights. Every school is given a chance to do their best, and in the end an average of all efficiency calculations is created for each school. This average is then used to rank the universities.

This thesis project will create an efficiency analysis of the top 50 MBA programs and the Pac-10 undergraduate business schools using Data Envelopment Analysis. The first objective is to compare *US News and World Report's* ranking, which is based on outputs, to a DEA ranking using the same data and interpret those results. Secondly, exploratory research will be conducted to examine which undergraduate business school in the Pac-10 is achieving the most output with their given input. Unlike the MBA rankings, this more specific and unique ranking has never been done and poses many challenges.

## **Data Envelopment Analysis**

Data Envelopment Analysis (DEA) first appeared in 1978, making it relatively new in the realm of mathematics. DEA was first used by a Ph.D. student named Edwardo Rhodes and his mentor, W.W. Cooper, at Carnegie Mellon University's School of Urban and Public Affairs (Charries et al. 1997). Rhodes was completing a dissertation comparing school districts using inputs and outputs (Charries et al. 1997). Rhodes, Charries and Cooper formally introduced DEA to the world in a paper published in the *European Journal of Operations Research* (Charries et al. 1997). DEA quickly became a new tool in Management Science for technical efficiency analyses.

DEA calculates relative efficiency using a ratio of weighted sum of outputs to weighted sum of inputs (Charries et al. 1997). Weights are selected for each Decision-Making unit (DMU) under a constraint limiting efficiency to be no greater than the unity (Charries et al. 1997). The strength of DEA is its ability to optimize each DMU in place of using averages of a single optimization. Charries, Cooper, Lewin, and Seiford list the features of DEA in their book,

### Data Envelopment Analysis:

1. focus on individual observations in contrast to population averages;
2. produce a single aggregate measure for each DMU in terms of its utilization of input factors (independent variables) to produce desired outputs (dependent variables);
3. can simultaneously utilize multiple outputs and multiple inputs with each being stated in different units of measure;
4. can adjust for exogenous variables;
5. can incorporate categorical (dummy) variables;
6. are value free and do not require specification or knowledge of a priori weights or prices for the inputs or outputs;
7. place no restriction on the functional form of the production relationship;
8. can accommodate judgment when desired
9. satisfy strict equity criteria in the relative evaluation of each DMU.

DEA has been recognized as a reliable tool to determine effective and inefficient behavior. Most organizations have several inputs, such as salaries, staff size and hours of

operation, and several outputs, like profit, market share and growth rate (Zhu). DEA is a tool used to compare these organizations that are of different size and scope, such as hospitals or schools. DEA has been applied to the fields of banking, sports, mining, health care, education, agriculture, transportation and retail outlets (Charries et al. 1997).

It is important to note the realm of possibilities for DEA is still expanding and its ultimate potential remains unknown. A mathematical process dating back to 1978 is extremely new in its field, considering mathematical principles were of great importance to societies dating back to the Egyptians.

## DEA Mathematical Breakdown

The DEA analyses used for this project were carried out using Excel, but it is also important to understand the math behind the operation. Excel makes computing large amounts of data easy, but it must be set up in the proper fashion to produce correct results. The mathematical principles behind DEA must be transferred to an Excel spreadsheet. The following example will use variables and general mathematical notation to show how DEA calculates relative efficiencies.

The first definitions are for the Decision Making Units, (DMU's), and the inputs and outputs. There are K Decision Making Units with N outputs and M inputs for each DMU.

Data (inputs and outputs for all DMU's)

- K DMU's:  $k= 1, \dots, K$
- N outputs for each DMU:  $i= 1, \dots, N$
- M inputs for each DMU:  $j= 1, \dots, M$
- $O_{ik} = i^{\text{th}}$  output of DMU k;  $i= 1, \dots, N$ ;  $k= 1, \dots, K$
- $I_{jk} = j^{\text{th}}$  input of DMU k;  $j= 1, \dots, M$ ;  $k= 1, \dots, K$

For example,  $O_{25}$  is the second output of DMU five.

The next step is to define the Decision Variables, or weights. This section is very important to understand because this principle is what sets DEA apart from other efficiency analyses. Each DMU will choose weights for its inputs and outputs that will maximize its efficiency relative to its peer DMU's.

### Decision Variables (weights)

- $X_{ik}$  = weight of output  $i$  chosen by DMU  $k$
- $Y_{jk}$  = weight of input  $j$  chosen by DMU  $k$
- All  $X, Y \geq 0$

At the same time, the exact same weights are applied to all other DMU's to calculate efficiency. This process is done  $K$  times, once for each DMU, with each DMU getting a chance to choose their best weights. The final efficiency score for each DMU is obtained by averaging its  $K$  efficiency scores.

We now formulate the DEA as a linear program. Efficiency is defined as the weighted sum of outputs divided by the weighted sum of inputs. The object is to maximize the efficiency of the DMU under consideration, relative to all other DMU's, by choosing input and output weights. All other DMU's are indexed by letter " $l$ ".

### Optimization Formulation for DMU $k$

$$\text{Max} \left[ \text{Min} \left\{ \frac{\sum X_{ik} \times O_{ik}}{\sum Y_{jk} \times I_{jk}} \middle/ \frac{\sum X_{il} \times O_{il}}{\sum Y_{jl} \times I_{jl}} \right\} \right] \text{ with respect to } X_{ik} \text{ and } Y_{jk} \quad (1)$$

In the above optimization formulation, the numerator is the efficiency of DMU  $k$ . The denominator is the efficiency of other DMU's using the weights selected by DMU  $k$ . DMU  $k$  tries to choose its input and output weights so its efficiency, relative to its strongest competitor, is maximized.

The above optimization formulation is difficult to solve as directed. Next, we reduce the formulation to a linear program, which can be solved efficiently by Excel. First, we limit all DMU's efficiency to be no more than 1. The original optimization formulation (1) reduces to:

$$\text{Max } \frac{\sum X_{ik} \times O_{ik}}{\sum Y_{jk} \times I_{jk}} \quad \text{with respect to } X_{ik} \text{ and } Y_{jk}$$

$$\text{Subject to } \frac{\sum X_{ik} \times O_{il}}{\sum Y_{jk} \times I_{jl}} \leq 1 \text{ for all } l \text{ and } k \quad (2)$$

To ensure all the expressions involved in the optimization problem are linear, we set the input of DMU  $k$  to 1 and rewrite constraint (2).

$$\frac{\sum X_{ik} \times O_{il}}{\sum Y_{jk} \times I_{jl}} \leq 1 \text{ for all } l \text{ is equivalent to } \sum X_{ik} \times O_{il} \leq \sum Y_{jk} \times I_{jl} \text{ for all } l$$

This leads to a linear program formulation of the DEA problem:

$$\text{Maximize } \sum X_{ik} \times O_{ik} \quad \text{with respect to } X_{ik} \text{ and } Y_{jk}$$

$$\text{Subject to } \sum Y_{jk} \times I_{jk} = 1$$

$$\sum X_{ik} \times O_{il} \leq \sum Y_{jk} \times I_{jl} \text{ for all } l$$

$$X, Y \geq 0$$

The last constraint in the linear program formulation ensures the weights for all inputs and outputs are greater than or equal to zero.

## Excel Model

### I. Data Section

Microsoft Excel is an excellent tool to perform the DEA analysis because it makes manipulating large amounts of data easy. In this case, the data consists of inputs and outputs for an efficiency analysis from fifty colleges and universities. Due to the nature of the DEA process previously discussed, there will be 2,500 different efficiency calculations. Microsoft Excel allows these calculations to be done automatically, simply by clicking and dragging the mouse. Excel also allows for easy editing and manipulating, meaning new data can be added without having to re-design the entire set-up. The following example will contain excerpts from the DEA analysis of the Pac-10 schools.

The first section of the spreadsheet is designated for the input and output data. A table is constructed that separates the data by category and school. This table contains no formulas, just raw data to be used in the calculations. All inputs and outputs are properly scaled so the larger input value indicates a larger output. For example, it is assumed the school with the highest faculty salaries will attract the best teachers and therefore provide the best instruction. In the case of the faculty to student ratio, the larger value indicates more faculty per student and corresponds to more teacher access.

Assume there are ten faculty members and five students. This would produce a ratio of 2, 10/5. Now assume the faculty figure stays the same, but the number of students drops down to 1. The ratio now becomes 10, 10/1. The higher ratio, 10, indicates there are 10 faculty members for each student, compared to 2 faculty members for every student. The school with the highest faculty to student ratio should indicate more student-faculty interaction and should therefore provide a higher level of education.

Selected Unit		Inputs			Outputs	
School	Tuition	Faculty Salary	Scholarships	Fac/Stud	Starting Salary	Giving
Arizona	2490	97776	185000	0.0327	39787	10%
Cal	4200	97770	0	0.0871	53942	17%
Oregon	4155	94000	101000	0.0313	36000	12%
OSU	3654	76200	150000	0.05	35,000	15%
WSU	4864	88727	400000	0.0485	36799	23%
UW	5016	115782	300000	0.0442	43050	14%
Weights	0	1.12705E-05	0	0	1.35659E-05	2.1773434

The upper left-hand corner of the spreadsheet is designated “Selected Unit”. This refers to which DMU is choosing weights that will maximize its efficiency while minimizing that of all other DMU’s. In this case, WSU is selecting the weights that are applied to each input and output for every school.

The highlighted line is designated for the Decision Variables, or weights. The weights are applied to the data figures in their respective columns. The weights will change for each DMU. By the end of the calculation there will have been six different sets of weights chosen.

## II. Mathematical Model Section

The second section of the Excel spreadsheet contains the mathematical model. This area contains the formulas, tables and constraints used to calculate efficiency. This section will be presented with examples from the mathematical representation previously discussed. This is done so the formulas and constraints can be seen at work, since it can be difficult to visually transfer mathematical models to a spreadsheet.

### Efficiency ratio constraint

	Weighted Inputs		Weighted Outputs
Arizona	1.101987	>=	0.75748022
Cal	1.1019194	>=	1.10191937
Oregon	1.0594295	>=	0.74965308
OSU	0.8588141	>=	0.8014075
WSU	1	>=	1
UW	1.3049241	>=	0.88883944

### Constraints that the selected unit has weighted inputs=1 (one unit at a time)

Selected unit	Weighted inputs		
WSU	1	=	1

### Maximize the weighted outputs for the selected unit (one at a time)

Selected unit	Weighted outputs
WSU	1

### Resulting efficiency under preferred weights of the selected unit

	Efficiency
Arizona	0.6873767
Cal	1
Oregon	0.7076007
OSU	0.9331559
WSU	1
UW	0.6811426

The first set of calculations serves two purposes. First, it satisfies the constraint that the weighted inputs must be greater than or equal to the weighted outputs. This constraint is seen in the mathematical model in this form:  $\sum X_{ik} * O_{il} \leq \sum Y_{jk} * I_{jl}$ . This constraint keeps every school's efficiency less than or equal to 1. Notice the weighted inputs and outputs for WSU are equal to 1 because WSU is the DMU currently maximizing its efficiency.

The second purpose of the set is to act as a table. Once the table is set up, it will be highlighted and given a name, such as table 1. The table includes the columns listing school names, weighted inputs, the greater than or equal to sign, and weighted outputs.

The numbers in the Weighted Inputs and Outputs columns are calculated the "sumproduct" command. This command takes the chosen weights and applies them to each school individually. The weights are applied to the input and output data found in the table of

the first section of the spreadsheet. A command for this procedure would be as follows:

`sumproduct($B$13:$E$13,B6:E6)`. The cell numbers with the dollar signs are weights. Dollar signs are used to anchor those cells into the formula. The other two cells listed, B6 through E6, represent data from the table. This formula can be typed once and then copied by dragging down the column. The anchored cells, B13 through E13, will stay the same in each copy, while the last two cell numbers will change. This change makes sure the weighted inputs and outputs for each school will be calculated using its input and output data and no another.

The next section down is a constraint to keep the weighted sum of inputs for the target DMU equal to 1. This is also seen in the mathematical model:  $\sum Y_{jk} * I_{jk} = 1$ . The highlighted cell indicates the DMU, or school, which is currently picking the weights.

**Constraints that the selected units has weighted inputs=1  
(one unit at a time)**

Selected unit	Weighted input
WSU	1 = 1

The number in the Weighted Input column is derived using a command called “vlookup”. This command tells the cell to display a number from the table previously created. An example of the formula used to achieve this would be `vlookup(A27,table4,2)`. The A27 refers to the highlighted Selected Unit cell containing “WSU” to the direct left. This tells the program to find the “WSU” row in the table. In this case, the table is given the name table4. The last number in the formula, 2, tells the program to choose the number in the second column of the designated row. Looking at the table, it can be seen the second column in the WSU row contains a 1. The two numbers match.

The next portion is titled “Maximize the weighted outputs for the selected unit”. This portion of the spreadsheet contains the target cell to be maximized. This represents the first part of the mathematical linear model. As mentioned, the model is given as

$$\text{Max } \sum X_{ik} * O_{ik} .$$

$X_{ik}, Y_{jk}$

The formula set up for this portion of the DEA analysis is very similar to that of the previous formulation involving the constraint for weighted inputs.

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted Outputs
WSU	1

The similarities lie in the columns titled Selected Unit and Weighted Outputs. The highlighted cell has been made to equal all other Selected Unit cells. The cell under Weighted Outputs uses the same vlookup formula used for inputs, with one modification. An example of the formula is vlookup(A31,table4,4). The last figure, 4, refers to the fourth column of table 4. The program is taking the value in the fourth column of the WSU row in table4.

The cell under “Weighted Outputs” containing the number 1 is considered the target cell because it is the only cell in the spreadsheet Excel will maximize. The number appearing in this cell represents the best efficiency of the target DMU. In this case, WSU has chosen weights that produce an efficiency of 1 for itself. This is the greatest level of efficiency WSU can achieve.

The last portion of the mathematical section contains the relative efficiencies calculated for every school using the weights chosen by WSU.

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Arizona	0.6873767
Cal	1
Oregon	.7076007
OSU	.9331559
WSU	1
UW	0.6811426

Efficiency has been defined as weighted output divided by weighted input. Given this fact, the calculation for efficiency is simple division. The weighted outputs and inputs for every school can be found in table4, or the first portion of the Mathematical Model Section. Creating a simple formula to divide output by input is the only requirement.

### III. Results Section

The final spreadsheet set up is a table to list the different efficiency calculations for each DMU. Each column contains the individual school's maximum efficiency and their efficiency with alternating weights. For example, the first column shows the efficiency of every school under the preferred weights of Arizona.

#### Rank all the units by cross efficiency matrix

Under preferred weights of

	Arizona	Cal	Oregon	OSU	WSU	UW	Average
Arizona	1	1	1	0.978761	0.687377	1	0.8933
Cal	1	1	1	1	1	0.734946541	1
Oregon	0.681429	0.68142866	1	0.682191	0.707601	1	0.83973
OSU	0.995748	0.995748451	1	1	0.933156	1	0.88733
WSU	0.638145	0.638144835	0.571557313	0.644079	1	0.957626537	0.83665
UW	0.670254	0.670254491	0.736292346	0.670477	0.681143	0.892425221	0.74000

The final column is the average efficiency for each school. In this case, Cal has the most efficient undergraduate business school.

### IV. Excel Commands

The formulas used in this Excel setup have already been given, but the method in which Excel performs the DEA calculations has not. Excel has a linear programming tool called Solver, which enables the user to choose the target cell, the decision variables, and constraints.

The decision variables are the weights, which change every time solver is run. The target cell and constraints remain the same throughout. Solver also has many options, but the only two that pertain to this case are making the program a linear model and assuming all non-negative numbers. The Solver function is then run six times, once for every school, and the DEA analysis is complete.

## Evaluation of Top 50 MBA Programs

### I. Existing Methods and DEA as the Solution

University rankings have become commonplace in the media, with such publications as *Business Week*, *U.S. News and World Report* and *The Wall Street Journal* all producing their own rankings. There are ways to rank universities by discipline, size, and geographic location, but the most widespread rankings are those for MBA programs. *U.S. News and World Report* includes MBA rankings in their annual edition of “America’s Best Graduate Schools.” One of the goals of this thesis is to investigate the methods used by *U.S. News and World Report* in their ranking calculations, discuss the problems associated with such methods, and propose an alternative manner using Data Envelopment Analysis.

*U.S. News and World Report* formulates their MBA rankings based on numerous “indicators of academic excellence”, which they determine (Morse and Flanigan 80). These factors include a peer and recruiter assessment score, average undergraduate GPA, average GMAT score, acceptance rate, average starting salary and bonus, employment rates and tuition. Weights are then applied to each indicator at the discretion of *U.S. News*. A score is determined for each school and rescaled so the highest-scoring school receives a 100 (Morse and Flanigan 81). The remaining forty-nine schools are listed in descending order, with ties being a possibility.

There are several problems with this existing method, the first being there is no definition given for the “best school”. Comparing institutions of higher learning is very difficult because each institution can have a different focus or mission. The score itself is also ambiguous,

meaning an interpretation could be a school with a score of 50 is half as good as the first place school with a score of 100.

The audience for this type of ranking is very narrow. The people that can most benefit from this type of ranking are prospective students. These rankings are of very little use to schools because the ranking method is not shown. There is simply a sheet of paper with numbers and an overall score. This system does not allow the option to investigate how one could improve their overall score. It is difficult to decipher how the scores are calculated when many of the indicators are close for every school. For example, the average undergraduate GPA for the top school, Stanford, and the thirty-fourth school, Arizona, differ by .08.

The last glaring problem is the fact this ranking is focused solely on outputs and fails to consider a MBA program's potential. No one should need a publication like *U.S. News* to know Ivy League universities have excellent MBA programs. It is a given these graduates will have higher starting salaries than other students around the country. Perhaps a better view would be to look at how well graduates are doing compared to their abilities before they entered their MBA program. The top ranked MBA programs may not have a better program based on the output produced with the given inputs. These schools may be extremely successful and inefficient, but that could not be realized with the *U.S. News* rankings.

The answers to these problems can be solved using Data Envelopment Analysis to calculate efficiencies. As discussed, DEA uses weighted inputs and outputs to calculate efficiency. A way to compare the ranking from *U.S. News* and that produced by DEA would be to use the data from *U.S. News* in the DEA analysis. This can be done by separating the indicators of academic excellence into inputs and outputs and running a DEA analysis with Excel. This would provide a comparison of the schools *U.S. News* indicates being the best with

those that are achieving the greatest efficiency. In a sense it decides which schools are getting the most bang for their buck.

Data Envelopment Analysis can address the problem of providing a definition of the ranking because it is by classification an efficiency analysis. Each school would have fifty different efficiency analyses to calculate their average efficiency. The efficiency scores would all range from 1.00 to 0, with little possibility of a tie. The highest ranking school would then be deemed as having the most efficient MBA program, or in other words, they are achieving the most output with their given input.

A DEA analysis ranking MBA programs would be useful to several audiences. The first would be the administrators of these programs. Budget constraints are always a concern for colleges and universities. A DEA analysis would indicate how well a school is using its resources. Administrators would have an idea if their students should be achieving more after they graduate, based on their performance before entering graduate school.

Another audience that would benefit from this DEA analysis would be prospective students. Not everyone can attend Stanford or Yale, but that doesn't mean they don't have the ability to get a return on their investment. Graduate school is very expensive and students expect to receive an elevated salary with their MBA degree. A DEA analysis would indicate which schools are likely to have the best return on investment. A student could attend a school that would save them \$10,000 a year and still command a starting salary comparable to that of a graduate from a top 10 MBA program.

One of the problems facing *U.S. News'* MBA rankings is the focus on outputs. DEA alleviates this problem because the method considers inputs and outputs in the efficiency

calculations. Weights are applied to the inputs and outputs to arrive at the efficiency calculation. DEA puts and equal importance on inputs and outputs, unlike *U.S. News and World Report*.

## II. The MBA DEA Analyses

The purpose of the following two DEA analyses is to use already existing data to calculate efficiencies for graduate schools. The first calculation will rely on the 2003 input and output data used by *U.S. News and World Report* to determine efficiencies for each of the top fifty schools. These results will then be compared to those of *U.S. News*. The second DEA analysis will examine some of the same schools, but will include added inputs from another source. The purpose of this analysis is to see how the added data will affect each school's efficiency.

The column titled "DEA Results" is the ranking produced by the efficiency calculation. These results are paired with those from *U.S. News* to allow an easy comparison of the results of the two rankings. One difference to note is the DEA calculations have no ties, unlike the *U.S. News* rankings. For example, the University of California Berkeley, Michigan and Virginia are all tied for tenth, listed in alphabetical order, in *U.S. News* (Garret 40).

<b>DEA Results</b>	<b>Efficiency</b>	<b>US News</b>
1 Carnegie Mellon	0.985	Stanford
2 Iowa	0.976	Harvard
3 Dartmouth	0.973	Penn
4 Rice	0.972	MIT
5 Cornell	0.967	Northwestern
6 Chicago	0.964	Duke
7 Duke	0.964	Chicago
8 Virginia	0.963	Columbia
9 Rochester	0.962	Dartmouth
10 Georgia Tech	0.960	UC Berkeley
11 Penn State	0.958	Michigan
12 Harvard	0.951	Virginia
13 N Carolina	0.950	New York
14 Yale	0.950	Yale
15 Michigan	0.949	UCLA
16 Texas	0.949	Cornell Mellon
17 Stanford	0.948	N Carolina
18 Emory	0.948	Carnegie
19 Vanderbilt	0.944	Texas
20 Michigan St	0.942	USC
21 Minnesota	0.942	Indiana
22 Purdue	0.941	Emory
23 Cal Berkeley	0.941	Rochester
24 Columbia	0.939	Georgetown
25 Ohio St	0.938	Michigan State
26 Penn	0.935	Ohio State
27 New York Univ.	0.929	Minnesota
28 BYU	0.927	Purdue
29 ASU	0.926	BYU
30 Indiana	0.925	Vanderbilt
31 MIT	0.924	ASU
32 Wake Forest	0.924	Rice
33 Texas A&M	0.919	Washington Univ.
34 Northwestern	0.904	Southern Methodist
35 Tulane	0.899	Arizona
36 Southern Methodist	0.893	Georgia
37 Washington Univ.	0.892	Iowa
38 Illinois	0.888	Notre Dame
39 Arizona	0.887	Boston College
40 UCLA	0.881	Georgia Tech
41 USC	0.879	Tulane
42 Boston College	0.876	UC- Davis
43 Georgia	0.875	Penn State
44 Notre Dame	0.867	Florida
45 Maryland	0.854	Maryland
46 Wisconsin	0.850	Illinois
47 Georgetown	0.849	Wisconsin
48 Florida	0.828	Wake Forest
49 Univ. Washington	0.821	Texas A&M
50 Cal- Davis	0.806	Univ. Washington

The second DEA analysis includes the data from *U.S. News* and the added inputs of annual income missed, length of program and average work experience. These added data sets were obtained from Business Week Online. Unfortunately, the data could not be found for all fifty schools, meaning only twenty-eight schools could be included in this particular ranking. The annual income data represents the average income students give up by attending graduate school. The length of each MBA program and the average work experience of students before entering the MBA program are given in months.

The figures for missed income are added to the data set because it is a measure of a student's abilities. It is assumed someone who commands a higher salary would be more knowledgeable and therefore a better student. Also, one of the main reasons people choose to get a MBA degree is to command a higher salary in the marketplace. This DEA analysis provides an excellent measure of how much a MBA degree increases one's value because the salary data represents pre-MBA and post-MBA benchmarks.

This reasoning is also applied to the added inputs of length of program and average work experience. It is assumed a longer program provides a better education and students with more work experience should do better in school. The whole idea is a higher input should lead to a higher output. DEA is a great tool because it measures the ratio of output to input, not allowing output to be the sole determinant of a school's value.

The results for this second DEA analysis are given on the following page. Each school's ranking in *U.S. News* is given in the last column.

DEA Results		U.S. News
1 Iowa	1.000	34
2 Michigan	0.978	10
3 Cornell	0.977	16
4 Rice	0.971	31
5 Emory	0.967	22
6 Texas A&M	0.965	49
7 BYU	0.964	29
8 Virginia	0.962	10
9 Purdue	0.958	28
10 North Carolina	0.956	17
11 Michigan St	0.954	24
12 New York Univ.	0.951	13
13 Ohio State	0.943	24
14 Vanderbilt	0.942	29
15 Wake Forest	0.932	46
16 Indiana	0.929	21
17 Cal Berkeley	0.924	10
18 ASU	0.923	31
19 Georgia	0.919	34
20 Tulane	0.908	39
21 Notre Dame	0.895	34
22 Boston College	0.894	39
23 Washington Univ.	0.892	31
24 Southern Methodist	0.887	34
25 Maryland	0.866	43
26 Georgetown	0.865	24
27 Florida	0.841	43
28 UC- Davis	0.802	39

### III. Conclusions

The conclusion from the DEA analyses using the data from *U.S. News* is the two systems produce different rankings and it should therefore be clear *U.S. News* does not provide an indication of the most efficient MBA program. Carnegie Mellon jumped from #18 in *U.S. News* to #1 in DEA. Iowa made a huge leap from #34 in *U.S. News* to #2 in DEA.

Programs with excellent reputations are not always the most efficient, but there were some schools that performed well in both rankings. Duke, Dartmouth, and Chicago placed in the top 10 in each ranking. These are examples of excellent MBA programs that are close to achieving their best possible results. Stanford, on the other had, is underachieving. Given their resources and students' abilities, they need to be achieving higher starting salaries and employment placement.

The results from the second DEA analysis involving added inputs are the most interesting to prospective students because the data includes salary information. It can be reasoned the University of Iowa adds the most value to their students. They are going to have the largest change in salary as a result of their MBA degree. These graduates may not have the highest starting salaries of all MBA graduates around the country, but they improved the most from what they were making before entering graduate school.

Iowa graduates, on average, will make over \$54,000 more than they were making before they entered graduate school and will pay less than \$16,000 a year in tuition. Cornell students will make just over \$56,000 more than before entering graduate school, but pay over \$30,000 a year in tuition. They will pay twice as much for tuition and will improve their salary only

slightly more than Iowa graduates. In the short run students at Iowa are better off than those at Cornell, yet Iowa is ranked 18 places below #16 Cornell by *U.S. News*.

Looking at these results, DEA is a better method for ranking MBA programs than the method used by *U.S. News*. The comparison between Cornell and Iowa shows the flaws of the *U.S. News* rankings. This is the type of comparison only a DEA analysis can provide.

Comparisons like this can be done repeatedly with any two schools using DEA. A comparison of Michigan and Iowa would produce the same result. These types of conclusions show what a valuable tool DEA is for calculating efficiency and ranking MBA programs. Anyone can make their own rankings, but it has been shown here all rankings are not necessarily worthwhile.

## Evaluation of Pac-10

### I. The Goal

The heart of this thesis project is the efficiency analysis of the undergraduate business schools in the Pac-10 using DEA. This portion of the project involves new research and findings that can contribute to the academic community. As the project progressed, it became clear nothing like this has ever been attempted. This revelation added many obstacles and difficulties, but it also made the process that much more rewarding.

The exploratory research is broken down into three sections; deciding on inputs and outputs, data collection, and the DEA calculations. Each section had to be done in the given order because it would have been futile to proceed without the necessary information. For example, there is no way to run a DEA analysis without the relevant data.

### II. Deciding on Inputs and Outputs

The very first step of any DEA analysis is deciding on plausible and relevant inputs and outputs. This case, involving universities, made the process more complicated than one would think. This DEA analysis requires inputs and outputs that will be good representations of productivity and at the same time be feasible.

Using sources like *U.S. News and World Report* is a good way to get a reference for which inputs and outputs are most relevant. This DEA analysis is focused on undergraduate education, as opposed to research. This means the inputs and outputs, or indicators, can be broken down into four categories: facilities, student, financial and faculty. Some possible input indicators would include average faculty salary, the amount of state funding, total scholarship

money, budget, average undergraduate GPA, faculty to student ratio and acceptance rate. Some examples of potential outputs are employment rate, starting salary, GMAT scores, graduating GPA, retention, annual giving, and graduation efficiency.

The problem with every one of these indicators is they all lack a specific definition. For example, there are full-time and part-time students, major certified students and students who attend a branch campus or main campus. There are also several classifications of faculty, like tenured professor, associate professor, and lecturer. To obtain accurate data throughout the Pac-10, each indicator would have to be very specific.

Consulting someone who collects university related data solved this problem. At Washington State University, the Office of Institutional Research serves this purpose. Kathy Fulkerson assisted in arriving at specific definitions that would be feasible and excellent indicators of undergraduate education.

Once this was accomplished, the next step was to decide on the handful of indicators that would work best to determine a business school's efficiency, which was solved by surveying the deans of the undergraduate business schools in the Pac-10. A survey was mailed and e-mailed to each dean's office listing twelve inputs and eight outputs. Each dean was asked to rank six in each category that would be "most relevant in determining a business school's productivity, with a focus on undergraduate education." Seven of the eight deans responded to the survey (Stanford and UCLA do not have undergraduate business schools).

Once all the surveys were received, a simple mathematical process was used to determine the top six inputs and outputs. A score was attached to each ranking, so each #1 ranking received six points, each #2 ranking received five points, and so on. The indicators with the highest point total were then determined to be the most relevant.

		<b>Inputs (1 high 6 low)</b>								
<b>School Dean</b>		Avg Faculty Salary	State Funding	Scholarship Money	Budget	GPA	SAT	Acceptance Rate	Faculty to Student ratio	Financial Aid
ASU	Penley	3	2	5	1		4		6	
Cal	Annie Lai	6	2		1	3	4		5	
Oregon	Romero	3		4	2	5	1		6	
OSU	Carlson	6		4	5	2		3	1	
WSU	Paxson	1	2	6	4	3		5		
UW	Gupta			2		4	1	4	6	3
Idaho	Dangerfield	6	5		4	2	3		1	
<b>Total Score</b>		<b>16</b>	<b>12</b>	<b>14</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>8</b>	<b>15</b>	<b>4</b>

		<b>Outputs (1 high 6 low)</b>							
<b>School Dean</b>		Graduates employed	Starting salary	GMAT scores	GPA	Giving	Retention	Percent attending Grad school	Graduation efficiency
ASU	Penley	2	3	6		4	5		1
Cal	Annie Lai	3	1				4		2
Oregon	Romero	1	2	3	4	5	6		
OSU	Carlson	5	3			2	4	1	6
WSU	Paxson	1	4		3	5		2	6
UW	Gupta	5	4	3	6		1		2
Idaho	Dangerfield	2	1	3	5			4	6
<b>Total Score</b>		<b>22</b>	<b>22</b>	<b>9</b>	<b>8</b>	<b>12</b>	<b>18</b>	<b>11</b>	<b>18</b>

Unfortunately, relevance does not always equate to feasibility. The biggest problem associated with any DEA analysis is data collection. The first decision was to exclude USC from the project because the resources of a private institution cannot be compared to those of a public, state-funded university. The second step was to determine what data could actually be found. After some researching, the decision was made to exclude graduation efficiency, retention, state funding, acceptance rate and average GPA. This sort of data was unavailable at most schools, or in some cases, not available at all.

In the end, there were six inputs and four outputs. The inputs were tuition, average tenured faculty salary, annual scholarship money exclusive to undergraduate school of business, total budget, tenured faculty to certified students, and average GPA of certified students. The

outputs were graduate's starting salary, percent employed within three months, percent alumni giving (entire university), and the percent going on to graduate school.

### III. Data Collection

Data collection is the hardest and most important aspect of the DEA process. The information needed for an efficiency analysis of undergraduate business schools comes from all areas, like the dean's office, career services and alumni centers. A wide range of resources is needed to find a wide range of information.

The first, easiest, and most accessible place to start looking was the Internet. Business school websites usually contain many of the input data. Spending a few minutes searching usually revealed tuition expenses, scholarships available and the number of faculty and students. In some cases, these sites offered information related to each department in the business school. This was a good place to locate starting salary data for each major, which can then be used to find an average for the entire business school.

Several schools in the Pac-10 have offices that survey students, collect university data, and produce annual reports. These offices have websites that contain much of this information in reports, but differ from school to school due to different state requirements. These types of sources were good for finding faculty salary and budget information. The staff members of such offices proved to be good sources to talk to directly, to find out exactly what is and isn't available.

Once the information that could be pulled off the Internet was exhausted, it was time to contact individuals. This was accomplished by e-mail and phone.

The greatest two difficulties in the data collection proved to be the wide range of sources needed to gain the data and the fact that these types of questions are rarely asked. In most cases, departments would refer calls to other departments, which would then recommend contacting the original department. This circular process became very frustrating. Once the right individual was found there remained the problem of obtaining the right numbers. The data needed had to be specific to the business school, as opposed to a specific department of the entire university. This often meant individuals did not have the data in front of them, but had to search for or calculate it. It became clear this type of information is not commonly used.

In some cases the data wasn't available at all, like at the University of Idaho and Arizona State University. These two schools did not have any of the output data required for the DEA analysis. The result was the removal of these two schools from the project when it became clear it was impossible to obtain the necessary data. In other cases, only one or two indicators from a particular school were unavailable. This did not result in a removal because more than one DEA analysis could be run pairing different combinations of indicators. Excel makes using DEA quick and easy, which allowed for many different combinations of schools, inputs and outputs.

#### IV. DEA Calculations

Once the data collection was complete it became obvious one or two DEA analyses would not be sufficient. The first problem arose when the data collection did not produce results for every input and output indicator. For example, Arizona and Oregon State did not have data available for their graduates' three-month employment rate. In addition, the percentage of graduates going on to graduate school was only available for Oregon and California.

The second problem involved the budget information. There are several different ways to examine budget figures, but this project focused on two. Half of the schools only had their operational budget figure available and the other half only had their total budget available. This explains why some budget figures are in the millions and others are expressed in hundreds of thousands of dollars. One of the main differences between the two figures is the absence of faculty salaries from the operational budget, which accounts for a large portion of the total budget.

## Inputs

	Tuition	Faculty Salary	Scholarships	Budget	Fac/Stud
<b>Arizona</b>	2490	97,776	185,000	17,016,850	0.0327
<b>Cal</b>	4200	97,770	0	429,574	0.0871
<b>Oregon</b>	4155	94,000	101,000	512,000	0.0313
<b>OSU</b>	3654	76,200	150,000	5,509,852	0.05
<b>WSU</b>	4864	88,727	400,000	16,25,3818	0.0485
<b>UW</b>	5016	115,782	300,000	862,000	0.0442

## Outputs

	Starting Salary	% Employed	Alumni Giving
<b>Arizona</b>	39,787		10%
<b>Cal</b>	53,942	86%	17%
<b>Oregon</b>	36,000	44.80%	12%
<b>OSU</b>	35,000/45,000		15%
<b>WSU</b>	36,799	71%	23%
<b>UW</b>	43,050	83%	14%

The solution for overcoming these discrepancies was to complete a number of DEA calculations with different combinations of schools, inputs and outputs. An average was then taken from all the calculations to arrive at each school's mean efficiency. The averages were taken from five separate DEA calculations.

The combinations were created to group matching data sets. The first DEA calculation included California, Oregon and Washington. These schools were grouped together because their budget figures are for the operational budget. The second DEA calculation included Arizona, Oregon State and Washington State because their budget figures are for the total undergraduate business school budget.

Pac- 10 DEA 1

Selected Unit **UW**

College	Inputs					Outputs		
	Tuition	Faculty Salary	Scholarships	Budget	Fac/Stud	Starting Salary	% Employed	Alumni Giving
Cal	4200	97770	0	429574	0.0871	53942	86%	17%
Oregon	4155	94000	101000	512000	0.0313	36000	44.80%	12%
UW	5016	115782	300000	862000	0.0442	43050	83%	14%
Weights	0	7.1666E-06	0	0	3.8515019	0	1.20481928	0

**Efficiency ratio constraint**

	Weighted Inputs	Weighted Outputs
Cal	1.036144578 >=	1.03614458
Oregon	0.794212681 >=	0.53975904
UW	1 >=	1

**Constraints that the selected unit has weighted inputs=1 (one unit at a time)**

Selected unit	Weighted inputs
<b>UW</b>	1 =

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted outputs
<b>UW</b>	1

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Cal	1
Oregon	0.679615232
UW	1

**Rank all the units by cross efficiency matrix**

Efficiency of	Under preferred weights of			Average
	Cal	Oregon	UW	
Cal	1	1	1	1
Oregon	0.694149824	1	0.67961523	0.791255019
UW	0.673923622	0.934851135	1	0.869591586

Pac-10 DEA 2

Selected Unit **WSU**

School	Inputs					Outputs		
	Tuition	Faculty Salary	Scholarships	Budget	Fac/Stud	Starting Salary	Giving	
Arizona	2490	97776	185000	17,016,850	0.0327	39787	10%	
OSU	3654	76200	150000	5,509,852	0.05	35000	15%	
WSU	4864	88727	400000	16253818	0.0485	36799	23%	
<b>Weights</b>	<b>0</b>	<b>1.12705E-05</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1.87844E-05</b>	<b>1.3424</b>	

**Efficiency ratio constraint**

	Weighted Inputs	Weighted Outputs
Arizona	1.101987 >=	0.88161433
OSU	0.858814 >=	0.85881412
WSU	1 >=	1

**Constraints that the selected unit has weighted inputs=1 (one at a time)**

Selected unit	Weighted inputs	
<b>WSU</b>	1 =	1

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted outputs
<b>WSU</b>	1

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Arizona	0.800022
OSU	1
WSU	1

**Rank all the units by cross efficiency matrix**

Efficiency of	Under preferred weights of			Average
	Arizona	OSU	WSU	
Arizona	1	1	0.80002244	0.933340815
OSU	1	1	1	1
WSU	0.432142	0.872559046	1	0.768233769

The third and fourth DEA calculations included all six Pac-10 schools in the study.

These calculations included inputs and outputs that were common between all six schools. For this reason the budget input and employment rate output were not included in the data table.

During the data collection process the starting salary for Oregon State graduates could only be determined to be between \$35,000 and \$45,000. To combat this problem, two DEA calculations

were run, one with the low-end data and one with the high-end data. This is the only difference between spreadsheet 3 and 4.

Pac-10 DEA 3

Selected Unit **Arizona**

School	Inputs				Outputs	
	Tuition	Faculty Salary	Scholarships	Fac/Stud	Starting Salary	Giving
Arizona	2490	97776	185000	0.0327	39787	10%
Cal	4200	97770	0	0.0871	53942	17%
Oregon	4155	94000	101000	0.0313	36000	12%
OSU	3654	76200	150000	0.05	35,000	15%
WSU	4864	88727	400000	0.0485	36799	23%
UW	5016	115782	300000	0.0442	43050	14%
Weights	0	6.42888E-06	0	5.7839625	1.88231E-05	1

**Efficiency ratio constraint**

	Weighted Inputs	Weighted Outputs
Arizona	0.817726 >=	0.81772598
Cal	1.132335 >=	1.13233496
Oregon	0.785353 >=	0.76020524
OSU	0.779079 >=	0.76202562
WSU	0.8509376 >=	0.85093763
UW	1 >=	0.90667036

**Constraints that the selected unit has weighted inputs=1 (one unit at a time)**

Selected unit	Weighted inputs	
<b>Arizona</b>	0.817726 =	1

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted outputs
<b>Arizona</b>	0.817726

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Arizona	1
Cal	1
Oregon	0.9679791
OSU	0.9781109
WSU	1
UW	0.9066704

**Rank all the units by cross efficiency matrix**

Efficiency of	Under preferred weights of						Average
	Arizona	Cal	Oregon	OSU	WSU	UW	
Arizona	1	1	1	0.6725289	0.687377	1	0.89332
Cal	1	1	1	1	1	1	1
Oregon	0.6814287	0.68142866	1	1	0.707601	0.967979073	0.83974
OSU	0.774471	0.774471017	0.87627336	0.9875115	0.933156	0.978110895	0.88733
WSU	0.6381448	0.638144835	0.74361601	1	1	1	0.83665
UW	0.6702545	0.670254491	0.83768987	0.6740401	0.681143	0.906670359	0.74001

Pac-10 DEA 4

Selected Unit **Arizona**

School	Inputs				Outputs	
	Tuition	Faculty Salary	Scholarships	Fac/Stud	Starting Salary	Giving
Arizona	2490	97776	185000	0.0327	39787	10%
Cal	4200	97770	0	0.0871	53942	17%
Oregon	4155	94000	101000	0.0313	36000	12%
OSU	3654	76200	150000	0.05	45000	15%
WSU	4864	88727	400000	0.0485	36799	23%
UW	5016	115782	300000	0.0442	43050	14%
Weights	0.0002	4.92868E-06	0	0	2.51338E-05	0

**Efficiency ratio constraint**

	Weighted Inputs	Weighted Outputs
Arizona	1 >=	1
Cal	1.3558 >=	1.35576947
Oregon	1.3278 >=	0.90481816
OSU	1.1359 >=	1.1310227
WSU	1.4494 >=	0.92490009
UW	1.6143 >=	1.08201171

**Constraints that the selected unit has weighted inputs=1 (one unit at a time)**

Selected unit	Weighted inputs	
<b>Arizona</b>	1 =	1

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted outputs
<b>Arizona</b>	1

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Arizona	1
Cal	1
Oregon	0.6814
OSU	0.9957
WSU	0.6381
UW	0.6703

**Rank all the units by cross efficiency matrix**

Efficiency of	Under preferred weights of						Average	
	Arizona	Cal	Oregon	OSU	WSU	UW		
Arizona	1		1	1	0.97876	0.60694	1	0.931
Cal		1	1	1	1	0.90957	0.734946541	0.9408
Oregon	0.6814	0.68142866	1	1	0.68219	0.64851	1	0.7823
OSU	0.9957	0.995748451		1	1	1	1	0.9986
WSU	0.6381	0.638144835	0.57155731	0.64408		1	0.957626537	0.7416
UW	0.6703	0.670254491	0.73629235	0.67048	0.62218	0.892425221	0.7103	

The fifth DEA calculation included schools that produced employment rate data. The budget figures are the only data sets that are excluded from this calculation.

Pac-10 DEA 5

Selected Unit **Cal**

School	Inputs				Outputs		
	Tuition	Fac Salary	Scholarships	Fac/Stud	Starting Salary	% employed	Giving
Cal	4200	97700	0	0.0871	53942	86%	17%
Oregon	4155	94000	101000	0.0313	36000	44.80%	12%
WSU	4864	88727	400000	0.0485	36799	71%	23%
UW	5016	115782	300000	0.0442	43050	83%	14%
Weights	0	1.02E-05	0	0	1.85384E-05	0	0

**Efficiency ratio constraint**

	Weighted Inputs	Weighted Outputs
Cal	1 >=	1
Oregon	0.962129 >=	0.66738349
WSU	0.9081576 >=	0.68219569
UW	1.1850768 >=	0.79807942

**Constraints that the selected unit has weighted inputs=1 (one unit at a time)**

Selected unit	Weighted inputs	
<b>Cal</b>	1 =	1

**Maximize the weighted outputs for the selected unit (one at a time)**

Selected unit	Weighted outputs
<b>Cal</b>	1

**Resulting efficiency under preferred weights of the selected unit**

	Efficiency
Cal	1.0000
Oregon	0.6937
WSU	0.7512
UW	0.6734

**Rank all the units by cross efficiency matrix**

Efficiency of	Under preferred weights of				Average
	Cal	Oregon	WSU	UW	
Cal	1	1	1	1	1
Oregon	0.6936528	1	0.57153546	0.69913	0.741079619
WSU	0.7511864	0.926437	1	1	0.919405881
UW	0.6734411	0.93481	0.79568348	1	0.850983556

## V. Conclusions

The main results are the efficiency rankings, which are given in the following table. The rankings are based on each school's average efficiency score. An average was calculated from the five DEA analyses to find the most efficiency school overall.

<b>Results</b>	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5	<b>Average</b>
1 <b>Cal</b>	1		1	0.940753	1	0.985188
2 <b>OSU</b>		1	0.887332292	0.998583		0.961972
3 <b>Arizona</b>		0.933340815	0.893317611	0.930951		0.919203
4 <b>WSU</b>		0.768233769	0.836650947	0.7415921	0.919406	0.816471
5 <b>UW</b>	0.869591586		0.740008664	0.7103132	0.850984	0.792724
6 <b>Oregon</b>	0.791255019		0.839739522	0.7822598	0.74108	0.788583

Based on this DEA analysis, California-Berkeley is achieving more output based on less input, relative to its peers. Washington and Oregon have the lowest efficiency scores, but this does not indicate a lack of academic excellence. It indicates these schools should be achieving a higher output given their input.

There are also many other individual conclusions that can be drawn by comparing the results of all five DEA calculations. For instance, Oregon is lagging behind its peers in the areas of graduate job placement, starting salaries and alumni giving. The University of Washington is paying its professors very well, but do not seem to carry this advantage into producing high output. The UW again has the highest tuition rates, but its graduates do not have the highest starting salaries or employment rates. Those honors belong to California-Berkeley graduates.

These conclusions show that some schools are failing to reach their whole potential. These DEA calculations should be used by Oregon and Washington to determine how they can better use their resources. These schools should examine their operations to find any inefficiency that may be causing them to lag behind in the Pac-10. Oregon and Washington need

to examine how they can better convert their input resources into higher output. They should strive for higher outputs or maintain their outputs while reducing their inputs.

## **Final Conclusions**

Data Envelopment Analysis is an excellent tool to calculate efficiency among university academic programs and a viable way to rank these programs. First, DEA has an advantage over existing ranking systems because it is based on the mathematical definition of efficiency, not the discretions of publicists. Secondly, DEA is a fair model because each DMU is given the opportunity to choose its preferred weights for the efficiency evaluation. The final efficiency score is then determined by taking an average of all the efficiency evaluations. Lastly, using Microsoft Excel makes DEA relatively easy, quick and understandable. Excel spreadsheets are easily manipulated and provide a visual display of the entire process. Inputs and outputs can be effortlessly added and deleted. The calculations can be seen every time the Excel Solver function is utilized and the basic set ups of all the spreadsheets are the same.

The one condition of DEA is the strength of the data used. Every DEA calculation is only as useful and correct as the data that is used in the calculation, meaning garbage in will produce garbage out. This implies if data had been collected differently for the Pac-10 DEA analysis the results would have been different. For example, if different indicators (inputs and outputs) would have been used it is most likely the results would be different.

There are several assumptions that cause potential biases for DEA when interpreting the results and drawing conclusions. The DEA model assumes a linear model can measure university performance, when in fact performance may not be linearly related. It is also assumed the inputs and outputs used in this analysis are good representations of efficiency. There also could be other factors, such as economic disparities, that were assumed to be negligible. For example, graduate's starting salaries could be higher in California than Arizona

due to a higher cost of living. These are all assumptions that made this project feasible but also affect the conclusions.

The larger ramifications of this work involve the economics and politics of any university. A balanced budget at any university is never an easy task. There are tough decisions that need to be made regarding cutting programs, faculty salaries, tuition and state funding. State governments want to see results with the allotted budget they provide. A DEA analysis can help these governing bodies hold state universities accountable for how money is spent. Efficiency comparisons can be done between peer institutions to see if improvements need to be made.

Individual universities can perform DEA analyses to identify inefficient departments and programs. This will help them locate areas of concern and also identify possible areas of improvement. With the DEA tool, these institutions would have greater ease in locating problem areas, instituting solutions and thus using money and resources more efficiently.

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