RANKING CHEMICAL ENGINEERING DEPARTMENTS

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THIRTY YEARS AGO it was a relatively simple task for those in industry, government, and education to rank or rate chemical engineering graduate programs. At that time, programs were few in number and could be easily evaluated by knowledgeable observers. The trends of the intervening years, namely, the rapid proliferation of graduate programs and the general rise in quality have clouded the situation. In the complexities of today's academic world, the simplistic insights of the past no longer work. It is essential, therefore, to have realistic, objective techniques for graduate program evaluation.

Others have grappled with this problem [1], [2], [5]. For example, in 1966 the American Council on Education (ACE) published the

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Cartter Report "An Assessment of Quality in Graduate Education" [1]. Again, in 1969 the same organization completed a follow-up study "A Rating of Graduate Programs" by Roose and Andersen [2]. Basically these studies consisted of polling selected faculty members in universities and asking them to rank departments both on "quality of Graduate Faculty" and "Effectiveness of Doctoral Program." The initial study by Cartter found a high degree of correlation between these rankings. This was in essence replicated in the 1970 study. The results of these studies for chemical engineering departments are given in Table I.

TABLE I
American Council of Education Ratings

1966	1970	School
1	1	Wisconsin
4	2	Minnesota
4	3	Cal., Berkeley
1	4	M. I. T.
10	4	Stanford
8	6	Illinois
3	6	Princeton
6	8	Michigan
9	9	Cal. Tech.
6	10	Delaware
10	11	Northwestern
14	11	Rice
12	13	Carnegie-Mellon
12	14	Texas
—	15	Pennsylvania
15	16	Wash. (Seattle)
—	17	Purdue

2.5 – 2.9 range:

Brooklyn Polytech.	Louisiana State
Cal., Davis	Maryland
Case Western Res.	N. Y. U.
Colorado	Notre Dame
Columbia	Ohio State
Cornell	Oregon State
Florida	Penn. State
Houston	Rensselaer
Ill. Inst. of Tech.	Tennessee
Iowa State (Ames)	Washington (St.L.)
Lehigh	

2.0 – 2.4 range:

Buffalo	Oklahoma State
Cal., L.A.	Pittsburgh
Cincinnati	Rochester
Georgia Tech.	Syracuse
Kansas	Texas A & M
Kansas State	Tulane
Michigan State	Utah
Missouri	Virginia
N. C. State	Va. Polytech.
Oklahoma	Yale

The ACE studies, while valuable, depended to a large extent on opinion. As such, there was always the question of personal subjectivity or in some cases the danger of lack of knowledgeability.

For example, lesser known departments, although capable, could be ignored because they do not have the national exposure of better known units. The present paper develops a system whereby objectivity can be maximized and the potential problems of the earlier studies can be avoided.

INDICES OF PERFORMANCE

THE METHODOLOGY USED in this study is simple, direct, and effective since it is based on published statistical data. Fundamentally, rankings on four indices of performance are used to generate an overall index of performance that ranks chemical engineering departments by effectiveness or productivity. Unlike the earlier

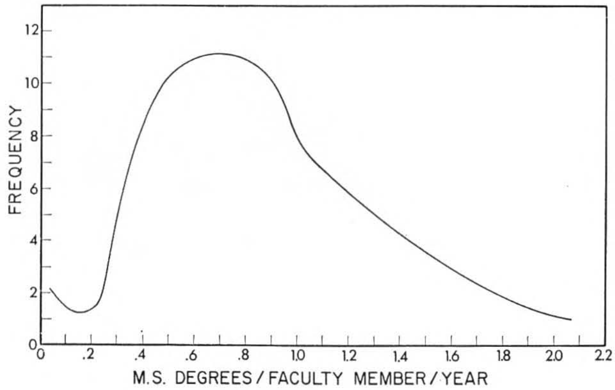


FIGURE 1: Frequency Distribution for M.S. Degrees per Faculty Member per Year.

studies, this ranking reflects overall graduate and research productivity and not just doctoral program effectiveness. The four indices of performance are: Master's Degrees Awarded per Faculty Member per Year, Doctoral Degrees Awarded per Faculty Member per Year, Thousands of Dollars of Extramural Research Funds Expended per Faculty Member per Year and Refereed Publications per Faculty Member per Year.

The development of indices based on units of performance per faculty member was purposeful. First, it was felt that gross data such as numbers of M.S., Doctorates, or publications for a given department could be quite misleading. For example, a small department (of say five faculty) could turn out five doctorates and appear not as productive as a large department (of say twenty faculty) that turned out ten doctorates. Yet, if these data were reduced to the basis of per faculty member, the smaller department would have an index of 1.0 while the larger department would

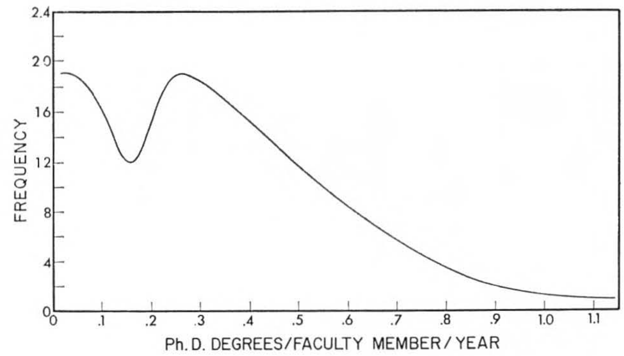
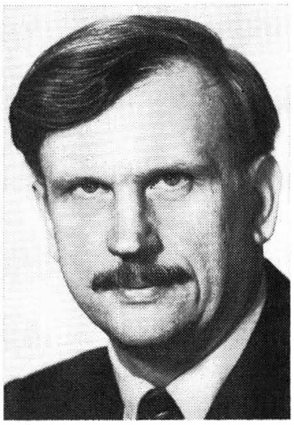


FIGURE 2: Frequency Distribution for Doctorates per Faculty Member per Year.

be only 0.5. Thus, a clearer, more objective picture could be obtained.

Two sources of information were used for the statistical data to compute the indices. The first was the annual supplement of *Engineering Education* titled, *Engineering College Research and Graduate Study* [3]. This volume gave the numbers of Master's and Doctor's degrees awarded and the amount of extramural funds expended. The American Chemical Society publication [4], *Directory of Graduate Research,* furnished listings of refereed publications. The former source [3] gives annual data while the latter is on a biennial basis.



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. . . in this study . . . rankings on four indices of performance are used to generate an overall index of performance that ranks chemical engineering departments by effectiveness or productivity. Unlike earlier studies, this ranking reflects overall graduate and research productivity and not just doctoral program effectiveness.

Frequency distribution plots of index values for all four categories are given in Figures 1, 2, 3, and 4. These data give a valuable insight into the performance of chemical engineering departments. If the most frequent index is taken for all four areas, the performance of an "average" department could be computed regardless of size of faculty. For example, such a ten member department would generate 7 M.S. degrees per year, 3 doctorates per year, $170,000 in total extramural research funds per year and 14 total refereed publications per year. On the other hand, a twenty member department would double those figures for "average" performance.

DECIMAL SCALE APPROACH

ALTHOUGH SUCH DATA as Figures 1-4 are useful, they do not answer the question of overall effectiveness or productivity. In order to satisfy the need, a different approach was taken. This approach involved the reduction of the indices in each area to a decimal scale. For example, consider the situation for Master's degrees per faculty member per year. The top value determined for any institution was 2.08. This figure was then divided into each index value to give a reduced decimal score (i.e. $\frac{2.08}{2.08} = 1.00; \frac{1.04}{2.08} = 0.5$, etc.). The same process was repeated for the other three areas (of course, using the appropriate top index value). The result was that each area now could be described on a decimal scale ranging from low values to unity. The top index values for all four areas are given in Table II.

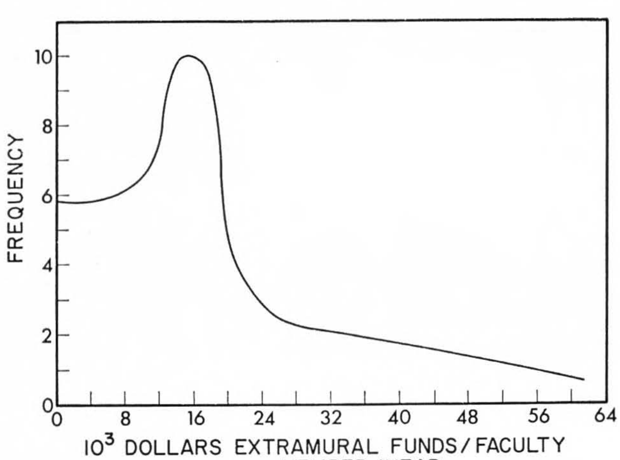

FIGURE 3: Frequency Distribution for Thousands of Dollars of Extramural Funds per Faculty Member per Year.

Next, the reduced decimal scores for the four areas (i.e. Master's Degrees per Faculty Member per Year, etc.) were summed for each

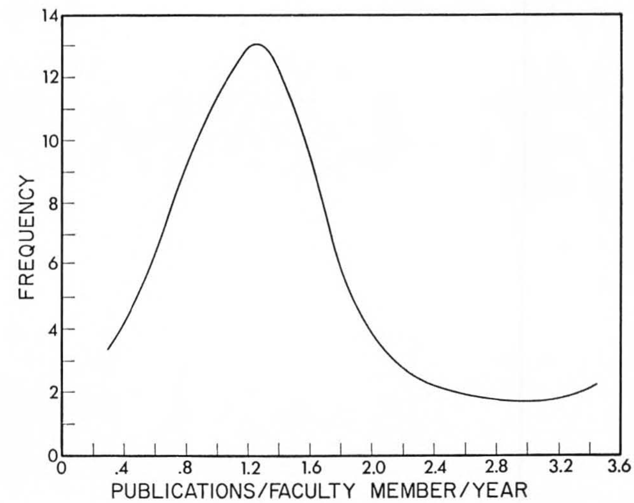

FIGURE 4: Frequency Distribution for Publications per Faculty Member per Year.

chemical engineering department **for which all four categories were available.** Theoretically, the top score would be 4.00. Actually, this value was found to be 2.75. This figure was then used to reduce all the data to a decimal score (i.e. $\frac{2.75}{2.75} = 1.0$). These decimal scores were designated as a Graduate and Research Productivity Index (GRPI). The final ranking of the institutions by means of GRPI is given in Table III.

Institutions that were used in the various phases but not in the final compilation (because of lack of certain data) are given in Table IV. Before commenting on the data of Table III, it is worthwhile to cite the fact that one of the institutions of Table IV had the top index in the area of publication. However, none of the others were at the top of the remaining categories.

Now, in regard to Table III, the rankings were listed as shown to match the system used by

TABLE II
Top Index Values for Categories

CATEGORY	TOP INDEX VALUE
M. S. Degrees Awarded/Faculty Member/Year	2.08
Doctorates Awarded/Faculty Member/Year	1.14
Thousands of Dollars in Extramural Funds /Faculty Member/Year	122.2
Refereed Publications/Faculty Member/Year	3.62

Cartter [1] and Roose and Andersen [2] in their earlier studies. In essence, first a ranking of schools by order in the higher category and second an alphabetical listing of the other institutions that ranked lower. As a first step, it was decided that correlation between each of the earlier studies and the present should be checked. It was found that the respective correlation coefficients between the present work and the earlier studies were 0.5 for the Cartter Report and 0.73 for the later study by Roose and Andersen. The probability levels for correlation were about 0.10 for the Cartter Report and between 0.01 and 0.001 for the later study. The greatly improved correlation with the Roose-Andersen study most likely reflects changes in departmental effectiveness with time. The interesting result of the correlation is that there is a strong relation between the perceptions of the faculty raters and the objective rating system used in this work for the top rated institutions.

As was indicated, the earlier studies only ranked numerically the top rated institutions. The groups following these were cited only alphabetically. This, of course, prevented a direct correlation study being made of all listed schools. However, it was possible to make an indirect check. This was done in the following manner: the names of the first 37 institutions in the present study were compared to those named in Cartter's work [1] (i.e. Cartter listed 39 departments, two of which no longer exist) and the names of the first 55 institutions in the present work were compared to the 55 listed by Roose-Andersen [2]. The number in common was then divided by either 39 or 55 as the case dictated. The result was about a 60% ratio. Furthermore, if the departments not included in the present study because of lack of complete data were dropped, the ratio ran up to the 90% level.

TABLE III
Institution by Ranking of
Graduate and Research Program Effectiveness*

1.	Stanford	12.	Notre Dame
2.	Rice	13.	Carnegie-Mellon
3.	M. I. T.	13.	West Virginia
4.	Illinois	15.	Minnesota
5.	Oklahoma	16.	PINY
6.	Pennsylvania	16.	Stevens Institute
7.	Illinois Institute of Technology	16.	SUNY (Buffalo)
		19.	UCLA
8.	Columbia	20.	Purdue
9.	University of Southern California	21.	Texas (Austin)
		22.	Clarkson
10.	Lehigh	23.	Iowa State
11.	Northwestern	23.	Ohio State

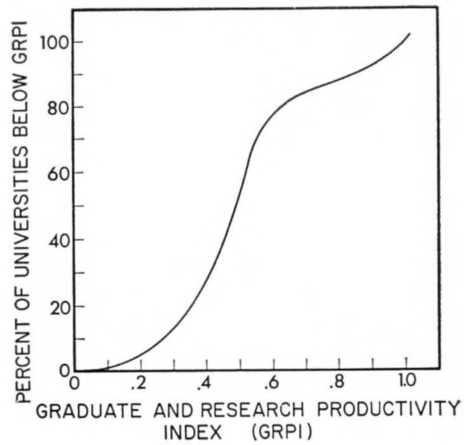

FIGURE 5: Ranking Versus Graduate and Research Productivity Index (GRPI).

As a result of the direct correlation and the indirect approach it can be seen that the results from the faculty panels used earlier compare quite favorably with the present objective technique. This shows that the perceptions of knowledgeable faculty are a good guide to qualitatively ranking departmental effectiveness. However, it should also be apparent that the objective technique set forth in this paper gives a one to one quantitative ranking of departmental productivity or effectiveness which should be more meaningful.

It is interesting also to consider the findings of Bernier, Gill and Hunt [5]. These authors correlated a number of factors (citations, research expenditures, publications, etc.) for 21 ChE departments named in the Roose-Anderson study [2]. They found good correlation between various factors dealing with citations and research expenditures and the Roose-Anderson work [2].

TABLE IV
Institutions Not Rated But Used To Supply Certain Data

A. The following institutions were used to supply data for the evaluation of M. S. doctorate and extramural funding.

Akron	Maryland
Arizona State	Michigan Tech.
Arizona	Mississippi State
Arkansas	New Hampshire
Auburn	New Mexico State
Cal. Tech.	Northeastern
Case Western Reserve	Ohio U.
Catholic U.	Rutgers
Cincinnati	South Dakota Mines
Cooper Union	Texas Tech.
Delaware	Toledo
Georgia Tech.	Tulane
U. of Iowa	Tulsa
Kansas State	Washington State
Louisiana State	Washington (Seattle)
	Wyoming

B. The following institutions were used to supply data on doctorates and publications.

California (Berkeley)	Rochester
Detroit	Syracuse
Houston	Texas A & M*
Mississippi	Yale
Princeton*	

*Also involved in M. S. Evaluation

The question that naturally arises is what about those institutions in Table IV or others for which no data were available? This can be handled by first pointing out what was cited earlier, namely, that *all* available data were used to compile the decimal scores that were summed to get the GRPI. In fact, as was mentioned earlier, the 1.0 decimal score for publications was attained by one of the departments in Table IV. Actually there is no problem in any department finding where it ranks by this method. In Figure 5, the ranking is plotted as a function of GRPI. Hence, if a department can compute its GRPI, it can determine its rank. Consider an example to see how this can be done. Suppose a department had 1.04 M.S. degrees per faculty member per year, 0.57 doctorates granted per faculty member per year, 61.1 in thousands of dollars of extramural research funds per faculty member per year and 1.81 refereed publications per faculty member per year. By taking the top index values of Table II the decimal score for each category could be computed. In this example these decimal scores would be: $\frac{1.04}{2.08} = 0.5$; $\frac{0.57}{1.14} = 0.5$; $\frac{61.1}{122.2} = 0.5$; and $\frac{1.81}{3.62} = 0.5$. The sum of the decimal scores is found to be 2.00 and the resultant GRPI, $\frac{2.00}{2.75} = 0.73$. From Figure 5, the ranking corresponding to this GRPI shows that the institution ranks above 88% of the institutions or that only 12% of the institutions rank above it.

CONCLUSIONS

IT IS FELT THAT the method outlined in this paper offers an objective realistic way of evaluating chemical engineering department graduate and research productivity and effectiveness. In light of the excellent correlation between "Quality of Graduate Faculty" and "Effectiveness of Graduate Programs" found by both the Cartter and Roose-Andersen studies, it would also appear that the scale developed in this paper also is a strong indicator of quality of graduate faculty in chemical engineering departments. Beyond the apparent impact on rank, there is another important ancillary benefit. This is to provide chemical engineering departments a way of comparing their annual performance on a year by year basis. In other words, is the department standing still, declining or improving? In today's tight academic budget situation, the method presented in this paper could be extremely useful in showing reluctant university administrations that a given program is either worthwhile or on the upgrade. Regardless, however, of the ultimate use to which the present method is directed, it cannot but help to bring a more reasoned approach to an important area of consideration. □

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