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ABSTRACT

Twelve articles that are designed to provide ideas to engineering department heads are presented. Articles and authors are as follows: "Estimating Undergraduate Student Capacity for an Engineering Department," (T. W. F. Russell, R. L. Daughtery, A. F. Graziano); "Financial Evaluation of Education Programs," (George DePuy and Ralph Swalm); "The Department Head in Facsimile," (Paul E. Torgersen and Robert E. Taylor); "Resource Allocation for a College of Engineering," (M. R. Reddy, M. B. Pashazadeh and P. H. Randolph); "An Algorithm for Forecasting University Population," (R. A. Wysk and R. P. Sadowski); "Cost and Organization in Engineering Colleges," (P. G. Kirmser, L. E. Grosh, and R. G. Nevins); "How Do Academic Administrators Spend--and Think They Spend--Their Time?" (A. E. Magana and B. W. Neibel); "Administering Engineering and Technology Programs on the Same Campus," (Victor Richley); "Planning Factors Study for Technology Education (Including Faculty Salaries)," (R. Bruce Renda); "Methods of Faculty Evaluation and Development," (Otis E. Lancaster); "A Plan to Increase and Improve Scholarship," (Arnold Allentuch); and "Almost Everything You've Ever Wanted to Know About Electrical Energy Management," (Wayne L. Stebbins). Topics include the determination of faculty course capacity and the maximum undergraduate student spaces in a department; an annual cost comparison for five methods of instructional development; an academic department head game designed for orientation and training; a survey of the administrative structures of institutions offering baccalaureate programs in engineering technology; and a method of resource allocation for a college of engineering that recognizes the need for quality and diversity of faculty. (SW)

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FOREWORD

The American Society for Engineering Education is publishing this monograph to help the engineering department heads in the Society better understand some of the facets of their jobs. It is not a "how to run your department" monograph, but rather some ideas that various people in the society have found useful in their jobs. Hopefully this initial effort will stimulate others to share their ideas with colleagues.

ASEE
Publications Committee

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ESTIMATING UNDERGRADUATE STUDENT CAPACITY FOR AN ENGINEERING DEPARTMENT

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INTRODUCTION

For several years academic institutions have experienced budgetary constraints that require more thorough analyses of their programs. Most institutions have data collection processes that include the determination of faculty workload, course and department student enrollment, class size, etc.; but little has been done to determine capacity from this data. To make the necessary decisions resulting from budget constraints, administrators need to better understand the requirements and objectives of the academic programs. Forthermore, there is a need to account for differences in disciplinary characteristics which must be a part of any evaluation process.

The purpose of the present paper is to set forth a procedure that determines undergraduate student capacity for an existing or contemplated engineering department. The procedure accounts for overall departmental objectives before examining the other factors which affect the department's ability to adequately service its undergraduate students. Although undergraduate student capacity is a necessary final result of the analysis, an understanding of the factors affecting this number is also important and the procedure can be used to determine the consequences of:

(i) changes in the way the faculty divides its time between teaching, research and service.

(ii) changes in class size

(iii) changes in supporting staff

(iv) changes in funding for supplies and equipment

(v) changes in facilities

When applied to an existing situation the method identifies problem areas and potential problem areas. The typical response to a university budget crisis is a "temporary" campus-wide reduction or reallocation of specific funds deemed to be least critical to the institution taken as a whole. Very often these decisions prove to be unworkable or at the very least inconvenient for an individual department. The procedure advanced in this paper provides an easily applied methodology to compare possible alternatives in the deployment of resources as well as to eliminate from consideration those changes which are not acceptable. The method can also provide to internal and external evaluation and review committees a basis upon which judgements can be made. ECPA accreditation review teams are presently provided with the necessary data to complete the proposed analysis. Using it should give the evaluation committee a better understanding of the strengths and weaknesses of the department under review.

Any method used to estimate student capacity must provide for certain value judgements. These judgements must be based on averages for the department as a whole to eliminate the wide variety of roles played by individual faculty members. Those judgements concerning the faculty and their overall workload as a whole are the most important; and it is impreative that department and college attitudes and policies be incorporated into the calculation. The analysis allows for this by providing guidelines for the quantification of faculty effort based on commonly accepted broad definitions of faculty activities. Starting with this initial step the maximum number of undergraduate student spaces that can be handled by the department is calculated for a set of stated conditions. Modification of the maximum student spaces due to inadequate instructional laboratory space, staff support, and/or funding is the second step of the procedure. The value judgements associated with the standards used to calculate these inadequacies can be based either on previous studies of engineering curricula [1, 2,3,4,5] or modified values that are appropriate for the given department. In this paper the standards, as well as ranges for some of them, are explicitly stated for each inadequacy so that the procedure can be easily modified.

DETERMINATION OF FACULTY COURSE CAPACITY FACTOR

By far the most important component of any method of determining a department's undergraduate student capacity is the faculty's capability for effectively teaching students. This key parameter is included in the analysis as a faculty course capacity factor which can be estimated by persons knowledgeable about the faculty's activities.

There are basically five major activities to which faculty devote their time:

(1) teaching
(2) course and curriculum development
(3) research
(4) professional service
(5) institutional service

Consulting activity, although important in judging the quality of the department's program, is considered to be a private professional activity pursued by the faculty on their own time. Each of the last four activities listed above can be quantified for a department considered as a whole and Tables I to IV provide the means to do this for an engineering department. Since the procedure is designed for a department with an undergraduate program, Tables I to IV are defined to assure that, on the average, at least 30% of the faculty's time is devoted to teaching. Once a rating has been established for each of the activities in the tables, the difference between their sum and 100 provides a measure of faculty time allotted to teaching activities. The faculty course capacity factor (FCCF) is defined as this differenced divided by 100; Table V summarizes the calculation. The FCCF is the fraction of the time the faculty as a whole is able to devote to both graduate and undergraduate in-class instruction.

DETERMINATION OF MAXIMUM UNDERGRADUATE STUDENT SPACES IN A DEPARTMENT

Although undergraduate student capacity of a department is the quantity most college administrators would like to refer to, it is an ill-defined phrase that has many varied connotations. We have chosen to calculate an easily defined quantity: the department capacity of undergraduate student spaces, DSS. This is the number of adequately supported spaces available in undergraduate courses taught by the department.

Many colleges and universities have data in terms of student credit hours taught by the faculty per academic session. Although this quantity is closely associated with the department student spaces, DSS, it varies greatly between universities because of the number of credits assigned to courses; and, thus, student credit hours is not as useful a number for comparison purposes.

The first step toward estimating the adequately supported department student spaces, DSS, is the maximum number of undergraduate student spaces available in a department, MSS. The MSS is a number dependent only upon faculty availability to teach courses; it ignores other resource requirements. Inadequacies in supporting staff, laboratory instructional space, and/or funding for supplies and equipment - quantities which restrict the faculty's ability to devote their time effectively to teaching - are calculated based on the MSS. The department undergraduate student space capacity (DSS) is obtained from the MSS by taking these inadequacies into account.

The maximum undergraduate student capacity for a department (MSS) depends on:

(a) the number of full-time equivalent faculty in the department (FF)
(b) the fraction of faculty time available to teach courses (FCCF)
(c) the administered workload of the faculty (AWL)
(d) the fraction of faculty time devoted to teaching graduate courses (GCF)
(e) the number of students that can be effectively taught in an engineering class section (SPC)

Tables I to V are used to compute the FCCF. The number of full-time faculty, FF, must be a known for any analysis. FF includes all department faculty supported by unrestricted funds ("hard dollars") allocated by the college or university to the department. Department heads and others in the department with assigned administrative duties may be counted as fractional positions when calculating the FF. If an existing department is being reviewed, FF is a known; if possible alternatives are under review or an envisioned department is being evaluated, FF can be assigned a value. The number of students that can be effectively taught in an engineering class, SPC, is a controversial quantity. It is our strong contention that a quality program requires this number to be between 20 and 30, depending to some extent on course level. In order to calculate the MSS, the administered workload (AWL) is a number with dimensions of class sections per faculty member and, for many colleges and universities, it is the quivalent of about four three-hour class sections per faculty member per academic session.

The maximum undergraduate student spaces for a department (MSS) is:

$$MSS = (FF)\ (FCCF)\ (CWL)\ (SPC) \qquad (1)$$

where:

FCCF = faculty course capacity factor already determined (see Table V)

FF = number of full-time equivalent faculty in the department

CWL = undergraduate course workload, class sections per faculty member per academic session

$$CWL = AWL\ (1-GCF), \text{ where} \qquad (2)$$

AWL = administered workload, class sections per faculty member per session

GCF = fraction of the AWL which is devoted to teaching graduate courses

SPC = number of undergraduate students that can be effectively taught in an engineering class section

The product of CWL and FCCF represents the average course load of the faculty which many institutions refer to as accepted practice.

The MSS is the maximum number of undergraduate student spaces available in courses taught by the department. In order for a department to meet its minimum requirements, the MSS must equal or exceed the product of the number of undergraduate sections that must be taught per academic session times the SPC. If this is not true, the fundamental teaching resource (i.e. faculty) is in short supply and it is not possible for the department to meet its instructional responsibility to the undergraduate students.

An example of the calculation of the MSS and all other pertinent quantities is given later in the paper.

MODIFICATIONS IN STUDENT SPACES

If the department under review does not have the necessary supporting staff and funding or if the facilities do not meet minimum standards, the maximum student space capacity (MSS) should be decreased accordingly. There are five factors which influence the teaching effectiveness of the faculty that can be quantitatively evaluated:

(1) graduate teaching assistants
(2) instructional laboratory space
(3) non-academic support personnel
(4) capital equipment expenditures
(5) appropriations for expendibles

Each of these will be discussed separately. Their combined effect on the department student space capacity will be analyzed through an interative scheme.

The first factor, graduate teaching assistants, can be evaluated simply by treating this resource as a partial extension of the teaching faculty. The model provides for certain assumptions about the nature of the teaching assigned to graduate teaching assistants and converts this directly into student spa-e equivalents. A Cobb-Douglas production function [6] will be used to relate the loss or gain in student spaces to the inadequacy or surplus associated with each of the other four given above. The model assumes that the availability of faculty time is the single most important factor in determining the instructional "product," i.e., the maximum number of student spaces, MSS. But supporting resources are required. The Cobb-Douglas production function gives a quantitative assessment of the relative dependence of faculty time on instructional laboratory space, support personnel, and expenditures for equipment and expendibles. Let $\bar{R}$ designate the ratio of the available support resources to that required (the standard) for each of these. The ideal production capacity possible with adequate personnel and funding is simply the maximum number of student spaces, MSS. Any deficiency, D, is related to $\bar{R}$ and MSS through the Cobb-Douglas formula:

$$\frac{D}{MSS} = 1 - \bar{R}^{b}$$

where b is an empirically assigned number and varies between 0.3 and 1.0. The relationship for different values of $\bar{R}$ and b is given in Fig. 1; larger values of b indicate a more profound effect of the deficiency on output.

1. Graduate Teaching Assistants

Graduate teaching assistants in engineering departments normally perform the dual roles of servicing courses and laboratories while pursuing the necessary graduate course work and thesis research to complete their degree requirements. This makes it somewhat difficult to quantify their duties on the basis of hours worked per week. We propose to define a full-time graduate teaching assistant as one who devotes approximately 20 hours per week to helping the faculty in its teaching duties. Many engineering departments may wish to use a different definition and Eq. (3) contains a factor, EH, to accomodate this difference.

For a quality program in engineering it is necessary to provide one full-time graduate teaching assistant for about every four full-time equivalent faculty members and the equation for the factor R which compares the actual number of assistants (GTA) to the full-time faculty (FF) contains this factor:

$$R = 4 \ \frac{GTA}{FF} \ \frac{EH}{20} \tag{3}$$

where: GTA = actual number of graduate teaching assistants in department supported by instructional funds

FF = full-time equivalent faculty in department

EH = average number of hours per week each assistant is expected to devote to assisting the faculty in its teaching activities

If If R is less than unity, faculty must be employed in activities commonly handled by graduate teaching assistants. In such cases, the product of FF/4 and (1-R) gives the deficiency in the number of assistants. A graduate teaching assistant can be considered to handle the equivalent of either a course or a portion of a course per academic session; thus, there is a direct relationship between student spaces and any deficiency. Multiplying the deficiency in assistants by the product of the average number of student spaces in an engineering class section and the course load per graduate teaching assistant, ECL, gives the deficiency in student spaces due to inadequate graduate teaching assistant support (GAD):

$$\begin{aligned} &\text{If } R \geq 1,\ GAD = 0 \\ &\text{If } R < 1,\ GAD = (FF/4)\ (1-R)\ (SPC)\ (ECL) \end{aligned} \tag{4}$$

where: SPC = number of students that can be effectively taught in an engineering class section (20 to 30)

ECL = equivalent course load per graduate teaching assistant, a number normally between 0.0 and 1.0

and the maximum number of student spaces must be modified accordingly to obtain MSS_1:

$$MSS_1 = MSS - GAD \tag{5}$$

If R is greater than unity, there is an investment in GTA resources which could be transferred to other supporting resources which may be in short supply. In this case, the product of FF/4 and (R-1) gives the surplus in the number of assistants. Multiplying this product by the average budget outlay for an assistant (GAB) gives the amount of funds which can be allocated to other funding deficiencies, GAS:

$$\text{If } R \leq 1,\ GAS = 0$$

$$\text{If } R > 1,\ GAS = (FF/4)\ (R-1)\ (GAB)$$

where: GAB = average budget outlay for a graduate teaching assistant, dollars.

2. <u>Instructional Laboratory Space</u>

Each engineering curriculum must include a laboratory portion which requires adequate space. To determine if present laboratory space is sufficient, the space required to handle the maximum student load, MSS_1, needs to be calculated. To perform this calculation, an estimate of the laboratory course load of the department is needed. Since courses taken by departmental majors are indicative of the types of courses offered by a department, the curriculum taken by such students will be used to estimate this load. Let LP be the ratio of the number of hours department majors spend in department laboratories during their tenure in the department to the total number of contact hours these students spend in all department courses. This latter number is to include both required courses and technical elective courses taken within the department. For an engineering department, LP is usually between 0.25 and 0.50.

Assuming that such space will be occupied 20 hours per week with 80% station utilization, Bareither and Schillinger (4) have estimated the net assignable square feet of instructional laboratory space required per weekly student hour for many fields of study. If the average engineering laboratory session meets three hours per week, these numbers can be modified to give net assignable square feet per student, DSF. These factors are presented for several engineering departments in Table VI.

The required instructional laboratory space, in sq. ft., (RLS), is then:

$$RLS = (LP)\ (MSS_1)\ (DSF) \tag{6}$$

Comparing this to the present instructional laboratory space (PLS) gives a ratio, R1:

$$R1 = \frac{PLS}{RLS} \quad (7)$$

Obviously, if R1 is equal to or greater than unity, there is sufficient instructional laboratory space in the department. If R1 is less than unity, there is a student space deficiency due to inadequate laboratory space and MSS_1 must be modified. For instructional laboratory space, there is almost a linear relationship between an inadequacy and a loss of student spaces. Therefore, the Cobb-Douglas function relating the student space deficiency due to inadequate laboratory space (LSD) is:

$$\text{If } R1 \geq 1, \; LSD = 0$$
$$\text{If } R1 < 1, \; LSD = MSS_1 \,(1 - R1^{b_1}) \quad (8)$$

where b_1 is expected to range between 0.7 and 1.0.

3. Non-Academic Personnel in Department

Peters (1) has established the following ratios of full-time equivalent faculty (FF) to the number of full-time equivalent non-academic personnel (FS) for engineering departments:

Types of Teaching Load	FF/FS-Ratio
Lower-division undergraduate	5
Upper-division undergraduate	3
Master's Program	1.5
Doctoral Program	1

A ratio of 4:1 is taken as the minimum acceptable standard in an undergraduate engineering department. Since the faculty course capacity factor (FCCF) is a measure of the instructional activities of the departmental faculty, four times the FCCF approximates the ratios suggested by Peters. By defining a ratio R2:

$$R2 = 4\,(FCCF)\,\frac{FS}{FF} \quad (9)$$

where:

FS = full-time equivalent non-academic personnel supported by instructional funds allocated by the college or university to the department

an inadequacy in non-academic personnel can be quantified. As before, if the ratio is less than unity, a modification in MSS_1 must be made since there are insufficient non-academic personnel to provide the support required by the faculty. The student space deficiency due to inadequate non-academic support personnel (DSD) is:

$$\text{If } R2 \geq 1, \ DSD = 0$$
$$\text{If } R2 < 1, \ DSD = MSS_1 \ (1-R2^{b_2}) \qquad (10)$$

with b_2 having a range of 0.5 to 1.0. We believe that b_2 should be in the upper range for most engineering departments.

If R2 is greater than unity, there is an investment in non-academic personnel which can be reallocated to other support resources that may be in short supply. The funds available for reallocation due to an excessive number of non-academic personnel, FSS, is:

$$\text{If } R2 \leq 1, \ FSS = 0$$
$$\text{If } R2 > 1, \ FSS = (R2-1) \ \left(\frac{FF}{4}\right) \ \left(\frac{1}{FCCF}\right) \ (FSB)$$

where: FSB = average budgeted salary for a full-time equivalent staff position, dollars.

4. Capital Equipment Expenditures

Laboratory equipment is a necessary part of any engineering curriculum; Peters (1) and the ECPD (5) have given some indication of the magnitude of the equipment inventory required for the undergraduate program of an engineering department. To maintain a minimum current, workable laboratory, we estimate an expenditure requirement of approximately $1,000 per year per full-time equivalent faculty member (based on 1975 dollars). If equipment is not replaced at this rate, laboratory experiments will become outdated and there will be an increase in necessary equipment maintenance and repair.

Because the purchase of large pieces of equipment can result in uneven expenditures of funds over the years, the capital equipment expenditures for the last five years (EE5) is used to define the ratio of the actual expenditures to the minimum standard:

$$R3 = \frac{EE5}{FF\ (5000)}\ \frac{164}{CPI} \qquad (11)$$

where: EE5 = actual capital equipment expenditures for the last five years purchased from instructional funds for undergraduate laboratories allocated by the college or university to the department, dollars

CPI = consumer price index, CPI = 100 in 1967 and 164 in 1975

An R4 of less than unity indicates that faculty time must be devoted to servicing laboratory sections to make up for obsolete and inadequate equipment. This results in a student space deficiency due to inadequate capital equipment expenditure (EED):

$$\text{If } R3 \geq 1,\ EED = 0$$
$$\text{If } R3 < 1,\ EED = MSS_1\ (1-R3^{b_3}) \qquad (12)$$

b_3 is expected to range between 0.4 and 0.6.

If the ratio R3 is greater than unity, there are funds allocated to equipment purchases that could be reallocated to other support resources without decreasing the departmental student space capacity. The funds available for reallocation due to an excessive appropriation to equipment, EES, is:

$$\text{If } R3 \leq 1,\ EES = 0$$
$$\text{If } R3 > 1,\ EES = (R3-1)\ (FF)\ (1000)\ \left(\frac{CPI}{164}\right)$$

where: EES = funds available for reallocation from yearly appropriation for equipment averaged over the last five years, dollars.

5. Appropriations for Expenditures

For the faculty to effectively devote their time to teaching, sufficient supplies and expense funds must also be available. Although Peters [1] has presented data giving adequate levels for such expenditures in 1967, they do not represent the drastic increases in telephone and copying expenses that have occurred since then. ECPD [5] published some 1975 data for this item which should include these enlarged expenditures. Using these data, $1,000 (1975 dollars) per full-time equivalent faculty is estimated as a reasonable standard.

To account for yearly fluctuations in the departmental budget, this standard is compared with the existing yearly expendibles appropriations averaged over the last two years (YEA):

$$R4 = \frac{YEA}{1,000\ (FF)}\ \frac{164}{CPI} \qquad (13)$$

where: YEA = yearly expendible appropriations (averaged over the last two years) from instructional funds for the undergraduate program allocated by the college or university to the department, dollars.

If R4 is less than unity, a decrease in the maximum number of student spaces results. The student space deficiency due to inadequate expendibles appropriations (ESD) is:

$$\text{If } R4 \geq 1,\ ESD = 0$$

$$\text{If } R4 < 1,\ ESD = MSS_1\ (1-R4^{b_4}) \qquad (14)$$

As was the case for capital equipment expenditures, the deficiency and faculty productivity relation is not linear and b_4 is taken to be between 0.6 and 0.8.

Again, if R4 is greater than unity, funds can be reallocated without decreasing the departmental student space capacity. The funds available for reallocation due to excessive appropriations to expendibles, ESS, is:

$$\text{If } R4 \leq 1,\ ESS = 0$$

$$\text{If } R4 > 1,\ ESS = (R4-1)\ \ (FF)\ \ (1000)\ \ (\frac{CPI}{164})$$

where: ESS = funds available for reallocation from yearly expendibles appropriation, dollars.

COMBINED EFFECT OF MODIFICATIONS IN STUDENT SPACES

The combined effect of the inadequacies calculated above is not the summation of the independent deficiencies. The total effect is obtained through an iterative process.

By subtracting the greatest of the four deficiencies LSD, DSD, EED, and ESD from MSS_1, a new MSS can be calculated. This completely eliminates this one factor's affect on the MSS. The new MSS obtained is used in recalculating the remaining deficiencies; and the process is continued until all four factors have been used to modify MSS. The result is the department undergraduate student space capacity (DSS). The DSS is only an estimate which should be considered accurate to within ± 10%. The example will help to illustrate the procedure.

It must be remembered that if R1, R2, R3, and/or R4 are greater than unity, reallocation of funds from one support resource to another is possible. Such changes in funding affect the department undergraduate student spaces and should be seriously unvestigated.

DEPARTMENT STUDENT CAPACITY

To use the department student space capacity (DSS) in evaluating an existing or envisioned department, it is necessary to know:

1. the distribution of student (majors and non-majors) requiring instruction at each level (freshman, sophomore, junior, senior).

2. the number of required and technical elective courses to be taught at each level to each group per academic session

Multiplying the appropriate quantities at each level and summing the results gives the number of department undergraduate student space requests (RSS) anticipated for the academic session.

Required courses and technical elective courses need to be handled separately in this summation. The student spaces for required courses are obtained by multiplying the number of courses at each level by the student population which must take these courses. For technical elective courses, the summation includes the product of the number of different sections that may be taught and the SPC. The number of different technical elective course sections is a function of both curriculum requirements and the diversity of technical elective courses to be offered. The technical elective portion of the RSS must at least equal the number of required technical elective courses per academic session multiplied by the student population taking such courses. The example will help to clarify the calculation.

If the requested student spaces, RSS is less than or equal to the department student spaces, DSS, the department can manage the undergraduate course load. If RSS is greater than DSS, the department is operating at greater than the maximum capacity implying that the resources of the department are inadequate.

EXAMPLE

To understand the calculation of the department undergraduate student space capacity, consider a chemical engineering department of fifteen (15) full-time equivalent faculty (because of administrative duties, the chairperson is included as 0.5 FTE) with an administered workload of twelve credit hours per semester in a university using the semester system. A normal course, which meets three hours per week, is assigned three credit hours. Thus, the administered workload (AWL) is four class sections per faculty member per academic session. The average number of students capable of being taught in any class section (SPC) is assumed to be 25.

Tables I-V are employed to determine that the FCCF for this department is 0.5 (50% of the faculty's time is devoted to graduate and undergraduate in-class instruction). If approximately 25% of the department faculty's time is devoted to teaching graduate courses, Eq. (2) gives:

$$\begin{aligned} CWL &= AWL\ (1\text{-}GCF) \\ &= 4\ (1\text{-}0.25) = 3.00 \end{aligned}$$

The MSS is calculated using Eq. (1):

$$\begin{aligned} MSS &= (FF)\ (FCCF)\ (CWL)\ (SPC) \\ &= (15)\ (0.5)\ (3.00)\ (25) \\ &= 563 \text{ student spaces} \end{aligned}$$

To calculate the student space deficiencies resulting from inadequate instructional laboratory space, support staff, and/or funding, the department must supply the additional data listed in Table VII. The student space deficiency due to inadequate graduate assistant support for such a department is:

$$\begin{aligned} \text{Eq. (3):}\quad R &= 4\ \frac{GTA}{FF} \cdot \frac{EH}{20} \\ &= 4\ \frac{3}{15}\ \frac{20}{20} \\ &= 0.80 \end{aligned}$$

$$\begin{aligned} \text{Eq. (4):}\quad GAD &= \frac{(FF)}{4}\ (1\text{-}R)\ (SPC)\ (ECL) \\ &= \frac{15}{4}\ (1\text{-}0.80)\ (25)\ (1.0) \\ &= 19 \text{ student spaces} \end{aligned}$$

and, using Eq. (5):

$$\begin{aligned} MSS_T &= MSS - GAD \\ &= 563 - 19 \\ &= 544 \text{ student spaces} \end{aligned}$$

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The other deficiencies can be calculated using MSS_1:

(1) Eq. (6) gives the required instructional laboratory space (RLS):

$$RLS = (LP)\ (MSS_1)\ (DSF)$$

$$= (0.40)\ (544)\ (30.00)$$

$$= 6,528\ ft.^2$$

Eq. (7) gives the ratio of required laboratory space to present space (R1):

$$R1 = \frac{PLS}{RLS}$$

$$R1 = \frac{5380}{6528}$$

$$R1 = 0.824$$

and the student space deficiency due to inadequate laboratory space (LSD) is found using Eq. (8):

since R1 < 1,

$$LSD = MSS_1\ (1-R1^{b_1})$$

$$LSD = 544\ (1-0.824^{1.0})$$

$$LSD = 36 \text{ student spaces}$$

(2) Use of Eq. (9) and (10) gives the deficiency due to inadequate non-academic support personnel:

$$R2 = 4\ (FCCF)\ \frac{FS}{FF}$$

$$R2 = 4\ (0.5)\ \frac{8}{15}$$

$$R2 = 1.07$$

Since $R2 \geq 1$, DSD = 0; but funds may be reallocated from this resource to one of the other areas. If the average budgeted amount per staff position is $6,000, the funds available are:

$$FSS = (R2-1)\ (\frac{FF}{4})\ (\frac{1}{FCCF})\ (FSB)$$

$$= (0.07)\ (\frac{15}{4})\ (\frac{1}{.5})\ (\$6,000)$$

$$= \$3,150$$

(3) Eq. (11) and (12) are used to calculate the student space deficiency due to inadequate capital equipment expenditures:

$$R3 = \frac{EE5}{FF\ (5000)} \quad \frac{164}{CPI}$$

$$= \frac{65{,}000}{(15)\ (5{,}000)} \quad \frac{164}{172}$$

$$= 0.826$$

Since R3 < 1:

$$EED = (MSS_1)\ (1 - R3^{b_3})$$

$$= (544)\ (1 - .826^{.5})$$

$$= 49 \text{ student spaces}$$

(4) To calculate the deficiency due to inadequate appropriations for expendibles, use Eq. (13) and (14)

$$R4 = \frac{YEA}{(1000)\ (FF)} \quad \frac{164}{CPI}$$

$$= \frac{9{,}000}{(1000)\ (15)} \quad \frac{164}{172}$$

$$= 0.572$$

Since R4 < 1:

$$ESD = MSS_1\ (1 - R4^{b_4})$$

$$= (544)\ (1 - .572^{.7})$$

$$= 176 \text{ student spaces}$$

Thus, the deficiencies are:

Graduate Teaching Assistants	GAD	19.
Instructional Laboratory Space	LSD	96.
Non-Academic Personnel	DSD	0.
Capital Equipment Expenditures	EED	49.
Appropriations	ESD	176.

The largest of the last four is used to obtain a new MSS. For this example, ESD is the largest deficiency and is 176 student spaces. Subtracting this deficiency from MSS_1 gives MSS_2

$$MSS_2 = 544 - 176 = 368$$

Recalculating the remaining deficiencies using MSS_2 gives

(1) DSD = 0 (obvious from previous calculations)

(2) RLS = (14) (368) (30) = 4416

R1 > 0

LSD = 0

(3) $EED = (MSS_2) (1-R3^{b_3})$

$= (368) (1-8.26^{.5})$

= 33 student spaces

The iteration process is completed when only one deficiency remains. The department space capacity (DSS) is obtained by subtracting this remaining deficiency from the last used value of MSS; in our example:

$$DSS = MSS_2 - EED = 368 - 33$$

DSS = 335 ± 34 student spaces

The DSS calculated above must be compared with the requested undergraduate student spaces to complete the departmental evaluation. For our example, the department teaches only courses taken by ChE Majors (it does not teach any "service" courses). Within the department there are the following course and student loads:

	No. of courses taught by dept.						No. of students taught by dept.
	Fall Semester			Spring Semester			
	No. of Req'd Courses	No. of Elective Course Sections	No. of Req'd Elective Courses	No. of Req'd Courses	No. of Elective Course Sections	No. of Req'd Elective Courses	
Freshmen	1	0	0	0	0	0	70
Sophomore	1	0	0	1	0	0	60
Junior	2	0	0	3	1	0	50
Senior	2	6	3	1	4	3	45

Thus, the requested undergraduate student spaces per semester are:

(a) Fall Semester

For required courses:

RSS = 1 (70) + 1 (60) + 2 (50) + 2 (45) = 320

For elective courses:

RSS = 6 (25) = 150

or: RSS = 3 (45) = 135

The total is:

RSS = 320 + 150 = 470 student spaces

(b) Spring Semester

For required courses:

RSS = 0 (70) + 1 (60) + 3 (50) + 1 (45) = 225

For elective courses:

RSS = 1 (25) + 4 (25) = 125

or: RSS = 3 (45) = 135

The total is:

RSS = 255 + 135 = 390 student spaces

The RSS for the department is 470 student spaces. But the department student space capacity is only 335. Since the maximum student space capacity is 563, department capacity may be increased to the required 470 student spaces by eliminating one or more deficiencies.

Reallocating funds, such as increasing the expendibles appropriation (YEA), is one possibility. Another way is to redefine the faculty's activities to allocate more time to in-class instruction. However, this would require a new departmental, college, and university attitude toward education and research.

CONCLUSIONS

A general method has been developed for determining the number of adequately supported undergraduate student spaces available in classes taught by an engineering department. The calculation is sensitive to department and college attitudes and policies, and yields a result which has the proper characteristics for the department under study. The method has been developed so that the effect of inadequacies of support staff, funding and/or facilities are readily calculated. Thus, decisions on possible or needed changes can be more fully based upon facts rather than intuition.

The mathematical model developed in this paper was devised to describe a most complex situation. The model is helpful but not in itself adequate for purposes of analyzing a department's operations. Temper the use of this model with judgment and understand that its principle contribution can be made through reiterative use and testing of alternatives.

In developing Eq. (3), (6), (9), (11) and (13), the following standards were used:

(i) Eq. (3) - One graduate teaching assistant for every four faculty.

(ii) Eq. (6) - The square feet per student required in a laboratory as given in Table VI.

(iii) Eq. (9) - One non-academic person for every four faculty.

(iv) Eq. (11) - Expenditure of $1,000 per faculty member per year for laboratory equipment.

(v) Eq. (13) - Expenditure of $1,000 per faculty member per year for expendibles.

Although we feel that these are reasonable standards, they may be changed to fit the particular situation under study.

Ranges for the values of the b parameters used in the inadequacy equations are given in the paper. The specific values used in the example were obtained from University of Delaware experience and might be expected to approximate situations elsewhere.

There are essentially two ways of using the model:

(i) using the standards suggested in the paper and the b values listed in the example allows a comparison of the department with one constructed to meet acceptable standards for engineering departments

(ii) modifying the standards and be values to fit a particular department. These modifications are made through comparison of the model with previous department data, resulting in a base case which can then be used to answer a series of "what if" type questions. Such questions could include:

(a) How many students could be effectively taught if the faculty were reduced in number or required to increase its research output?

(b) How are student spaces affected by increasing appropriations to expendibles and equipment?

(c) How are student spaces affected by adding GTA positions or a secretary?

(d) How are student spaces affected by reallocating funds?

It is hoped that the model presented will provide departments, colleges, and evaluation teams an additional tool for reviewing engineering educational programs, and that working with the model will provide a better understanding of the department when developing recommendations.

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TABLE I

MEASURE OF COURSE AND CURRICULUM DEVELOPMENT ACTIVITIES OF THE FACULTY

MAXIMUM RATING = 20

RATING	GENERAL DESCRIPTION OF ACTIVITY
15-20	Department must be very active in text writing, new approaches to engineering education, and/or preparation of audio and video material which are available on a national level. (At least two texts or equivalent which are rather widely used on a national level, are indicative of such activity). Department should be able to show how new advances in technology are being incorporated into its graduate and undergraduate programs.
10-15	A department at this level should be producing educational material which is starting to be used on a national level. Encouragement from the administration must be given to text writing, development of new courses and curriculum improvement. Use of this new material both within and outside the department should be evident.
5-10	Department is active on a local level in course development but work has not received national acceptance. Such activities include new course notes that have been developed, original homework problems, new laboratory procedures, special computer programs, etc.
1-5	Department uses readily available texts produced outside the department and relies on solution manuals prepared by others. However, some effort is being expended to develop additional problem demonstrations, computer programs and/or new laboratory procedures.
0	Department does little or no original work in either course or curriculum development.

TABLE II

MEASURE OF RESEARCH ACTIVITIES OF THE FACULTY

MAXIMUM RATING = 30

RATING	GENERAL DESCRIPTION OF ACTIVITY
25-30	A department with this rating needs to have a well established national reputation and be considered as one of the top ten departments in the country in some national evaluation.
20-25	Over 50% of the faculty should be well known and active in research on the national level. External funding needs to be at a high level. Over 50% of the graduate student support and equipment needs of the department are supplied by external research funding. The publications record must be outstanding and above any national average with respect to quality and impact. The faculty needs to be quite active in presenting work at other universities, at national meetings, and to the industrial and government sectors. Such a department is obviously staffed by a senior faculty with very few young members.
10-20	To achieve a rating in this range the department needs to have at least 20-40% of its faculty active and known through its research at a national level. Funding from external sources should provide for 20-50% of the graduate student support and equipment needs. There needs to be some activity by most of the faculty to present their work to others. A means of assuring that younger faculty receive students and support to start their programs must be evident. It is expected that a rating in this range should be achieved by those departments who are effectively building new programs.
0-10	Research effort is confined to a few individuals, there are few publications, and external funding is at a low level.

TABLE III

MEASURE OF PROFESSIONAL SERVICE ACTIVITIES OF THE FACULTY

MAXIMUM RATING = 10

RATING	GENERAL DESCRIPTION OF ACTIVITY
8-10	The majority of the faculty must be active in professional society work by holding office or serving on committees at the national level. The faculty should be actively involved in local professional societies.
5-8	20 to 50% of the faculty should be active at the national level and other members of the faculty should hold offices and serve on committees at the local level.
3-5	Faculty activity is mostly at the local level.
0-3	Faculty are generally inactive in local and national professional societies except to attend meetings and few if any take responsibility for professional activities.

TABLE IV

MEASURE OF INSTITUTIONAL SERVICE ACTIVITIES OF THE FACULTY

MAXIMUM RATING = 10

RATING	GENERAL DESCRIPTION OF ACTIVITY
7-10	A number of faculty must be very active in university faculty and engineering college committees. Departmental faculty should have responsibility for a number of key committees at either the college or university level.
4-7	A number of faculty have committee assignments in key committees in the college and university but no one has major responsibility for any committee operation.
2-4	Only a few faculty are active in college and university activities outside the teaching area.
0-2	Faculty makes almost no contribution to institutional service.

TABLE V

CALCULATION OF FACULTY COURSE CAPACITY FACTOR (FCCF)

This calculation will give the percentage time that an average faculty member can effectively devote to the undergraduate and graduate in-class instructional program. Note that the ratings for the course and curriculum development, research, and service activities of the faculty have been chosen so that the average faculty member devotes a minimum 30% of his time to the in-class instructional program.

(a)	Using Table I, quantify faculty's activities in regard to course and curriculum development Maximum = 20	______
(b)	Using Table II, quantify faculty's activities in regard to research activities Maximum = 30	______
(c)	Using Table III, quantify faculty's activities in regard to professional service Maximum = 10	______
(d)	Using Table IV, quantify faculty's activities in regard to institutional service Maximum = 10	______
(e)	Total of (a) + (b) + (c) + (d) Maximum = 70	______
(f)	Subtract (e) from 100 Maximum = 100 Minimum = 30	______
(g)	Divide (f) by 100	______ = FCCF

TABLE VI

Engineering Department Laboratory Space

	Net Assignable Square Feet per Weekly Student Hour (4)	Net Assignable Square Feet per Student, DSF
Chemical Engineering	10.0	30.0
Mechanical Engineering	10.0	30.0
Civil Engineering (Engineering mechanics laboratories are assumed to be taught by this department)	8.13	24.39
Electrical Engineering	4.06	12.18

TABLE VII

DEPARTMENT INPUT DATA FOR MODIFICATION IN STUDENT SPACES USED IN EXAMPLE

GTA Analysis		
Standard Ratio of Faculty/Assistants	-	4.0
Graduate Teaching Assistants	GTA	3.0
Average Hours Per Week Per Assistant	EH	20.0
Equivalent Course Load/Graduate Student	ECL	1.0
Instructional Laboratory Space Analysis		
Laboratory Hours in Curriculum	-	24.
Lecture Hours in Curriculum	-	36.
Minimum Standard Lab Sq. Ft./Student	Tab. VI	30.00
Instructional Laboratory Space, Sq. Ft.	PLS	5380
Laboratory Space Exponent	B1	1.00
Non-Academic Personnel Analysis		
Standard Ratio of Faculty/Staff	-	4.0
Full-Time Equivalent Staff	FS	8.0
Staff Exponent	B2	0.90
Capital Equipment Expenditure Analysis		
Minimum Standard Annual Capital Expense	-	1000.
Actual 5-Year Capital Expense	EE5	65000.
Consumer Price Index	CPI	172.
Capital Expense Exponent	B3	0.50
Expenditures Analysis		
Minimum Standard for Yearly Expenses	-	1000.
Average Yearly Expenses	YEA	9000.
Yearly Expenses Exponent	B4	0.70

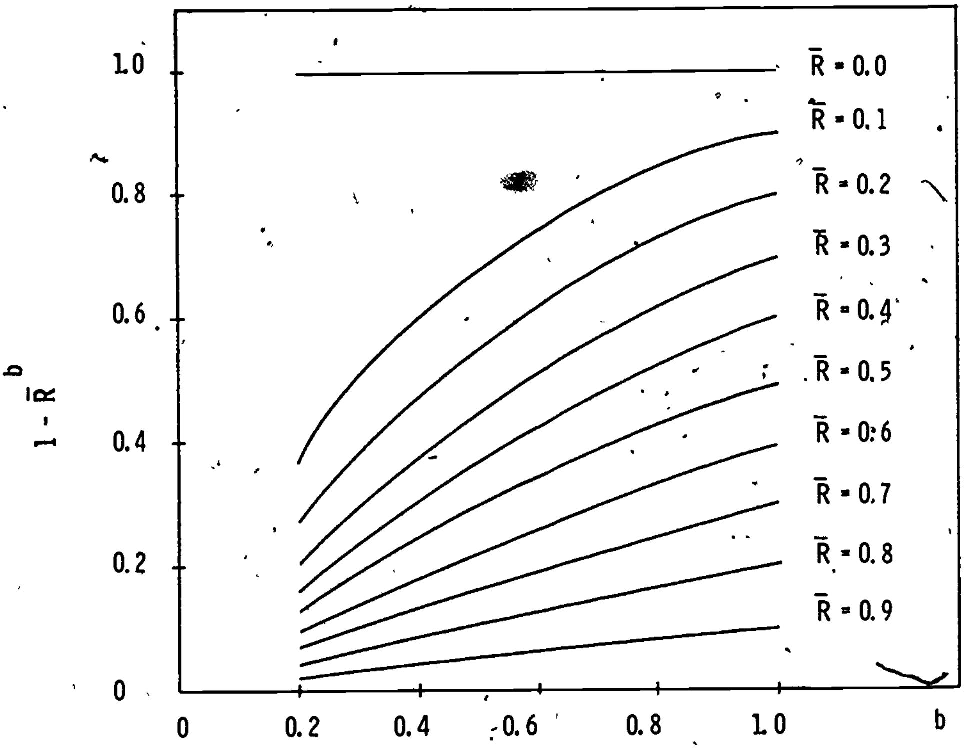

FIGURE 1. INADEQUACY - LOSS IN STUDENT SPACES PRODUCTION RELATION

2

FINANCIAL EVALUATION OF EDUCATION PROGRAMS

George DePuy
Ralph Swalm

Evaluation of education can be classified in three broad categories. They are:

1. Behavioral - how well does the program in question meet behavioral objectives.
2. Financial - how does the cost of the program compare to that of similar programs.
3. Political - interpretation of results to suit parochial interests.

Political evaluation deals with the concept of a politcal override. It is widely recognized that this phenomenon does exist. It has been written about by Kearney and Huyeser[1], Read[2], Kerins[3], Carter[4], Cohen[5], and House[6], to name a few.

Behavioral evaluation has been the chief focus of the scholarly attention given to evaluation of programs up to this time. Perhaps, because of its difficulty, the problem of financial evaluation has been largely ignored to the extent that only recently references to its need have begun to appear. For example, Sciven[7] wrote, in 1967, "The costing of curriculum adoption is a rather poorly researched affair," and little has happened since that would cause him to change his mind. The only known evaluation model to include financial evaluation as a formal step in the evaluation process is that by Provus[8]. He lists Stage V, the last stage, of his evaluation model as an evaluation of program cost. This is done by comparing the cost to that of other programs with the same product. However, in describing this phase of the evaluation he writes, "Cost benefit analysis is the ultimate rational step in the process of program development and assessment put forth in the Discrepancy Model. In anticipation of its eventual use, the cost-benefit is listed as Stabe V."

Provus appears to be saying comparison of program costs is essential, but no satisfactory method of comparison has yet evolved. We have learned to identify costs, however. Edward Kelly[9] has identified some of the cost variables for alternate ways of teaching freshman English at Syracuse University. Phillip Doughty[10] has actually identified the costs for four different methods of instrumentation for

Geology 102 at Florida State University. This has allowed the comparison of the methods based on unit costs.

So, we see some progress. We can now compare programs based on cost. But, in comparing costs, do we compare development costs, operating costs, total cost, or unit cost? Financial evaluation answers these questions but is more than just comparing costs. Financial evaluation must include benefits, and should include the time value of money.

Financial Evaluation

Financial evaluation attempts to lump all costs over time into one representative figure by applying time values of money principles. Proposals can be compared using the Equivalent Uniform Annual Cost, Present Worth, or Rate of Return on Investment techniques. These techniques can be used to choose between alternate programs based on projected costs and benefits, and to some extent, to evaluate programs after the fact.

Difficulties with Financial Evaluation

There are several difficulties involved in performing the financial evaluation of evaluation programs. Three major ones are: (a) lack of a control group, (b) the post-audit dilemma, and (c) the unknown life of new knowledge.

In real-life, as opposed to laboratory studies, a control group is seldom, if ever, available, and many confounding effects are present. The proper research methodology for building a control group is that of matching subjects to form pairs for later comparison tends to create more control problems than it solves."[11] Kerlinger indicated "matching has severe limitations. If we try to match, say, on more than two variables, or even more than one, we lose the subject."[12] The implication here is that control groups are not feasible in this type of analysis.

The second difficulty with financial evaluation is related to the first. It is perhaps not generally realized that post-audits can never yield a definitive answer to the question "Did we make a good decision?" There are several reasons for this. The first is because, in a world of risk - and that's the world we live in - there is a difference between a good decision and a good outcome. For example, it is a good decision to accept a bet involving a gain of five dollars if a fair coin is tossed and comes up heads vs. a loss of one dollar if it shows tails. But it is a bad outcome if tails eventuates! A second reason is that we never know what effects a treatment not tried might have had. Since it is just as difficult to formulate additional treatment groups as it is to formulate a control group, comparison between treatments is not usually feasible. Despite the fact that, in the real world, it is almost impossible to answer the question "Did we make the best decision?", we can certainly ask "Was the outcome a good one." Since that is the best that can be hoped for, the paper speaks to a methodology for doing that.

The third difficulty involves the unknown life of new knowledge. Much has been written about the half-life of an engineer. Certainly different types of knowledge have different lives, but there does not seem to be general agreement on what these lives are.

The remainder of this paper describes three examples of financial evaluations of education programs. Two hypothetical examples are given. One uses the Equivalent Uniform Annual Cost method and the other uses the Rate of Return on Investment method. The last example is a case study evaluating a real-life investment of a substantial sum in a graduate program by a major corporation.

Equivalent Uniform Annual Cost

Consider the following example. Prior information shows there are five alternative methods of instructional development that will accommodate the meeting of behavioral objectives in a particular course. Method One is a conventional lecture-discussion method with instructional materials developed by the instructor. Method Two calls for the instructor to be temporarily released from some teaching duties in order to develop a slide-tape package. Instructor contact with individual students during the time the course is offered would be reduced. Method Three calls for an outside consultant to develop course materials for a lecture-discussion arrangment. Instructor workload during the semester would be less than in Method One but more than in Method Two. Method Four calls for an outside consultant to develop a slide-tape package. This would be slightly more extensive than the instructor developed package and, hence, would require less work during the semester. Method Five calls for the purchase of a commercially available slide-tape package. This product would be very extensive and would require the least work, during the semester, for the instructor. Initial cost of the package is relatively high.

Development costs, material costs, hardware costs, wages and benefits, have all been identified for each alternative. These have been totaled and summarized for a ten year life and are shown in Figure 1. The costs shown in year zero are development and initial purchase costs. For the slide-tape methods, new equipment is purchased in year five. An increasing salary scale has not been used in order to keep the example simple.

If one were to compare these five methods based on costs what cost would be correct to use? Comparing development cost shows Method One to be least expensive. Comparing operating costs shows Method Five to be best. Total cost also indicates that Method Five is least costly. None of these methods are useful as a basis for rational choice among the alternatives.

The value of a fixed amount of money varies over time. A dollar today has more value than the prospect of obtaining a dollar ten years from now. Funds occurring at different points in time cannot be directly compared. One method of comparing money at different points in time is the Uniform Equivalent Annual Cost technique (hereafter called Annual Cost Comparison).

An Annual Cost Comparison is often used for those projects in which profits are usually not incurred but must be done because they are necessary. All costs are converted to uniform equal annual cost through the use of an interest rate. The interest rate used is generally the minimum attractive rate of return at which the organization can invest its funds. An interest rate of eight percent is used here for illustrative purposes.

An Annual Cost Comparison for the five methods is shown in Figure 2. This shows that Method Two has the lowest equivalent annual cost at $1,697 per year. Method Five, which has the lowest total cost, turns out to be only the third most attractive alternative at an equivalent annual cost of $1,766 per year.

Decisions about which alternative to choose should not be dictated by this outcome. If behavioral and political evaluations showed all five alternatives to be equal, then Method Two would be chosen, based on the financial evaluation. If behavioral results showed that a lecture-discussion format produced a significantly greater amount of learning, the choice would be reduced to Methods One and Three. Method Three would be chosen because of its lower equivalent annual cost of $1,947 per year. If political considerations dictated that the work be done by the staff, the choice would be reduced to Methods Two and Three, making Method Two the selection.

In actual practice, decisions would probably be made by weighing results from each of the three types of evaluation. A financial analysis will provide more meaningful information with which to make a decision.

COSTS FOR FIVE METHODS OF INSTRUCTIONAL DEVELOPMENT

Year	Instructor Developed Lec.-Disc.	Instructor Developed Slide-Tape	Consultant Developed Lec.-Disc.	Consultant Developed Slide-Tape	Purchase Commercial Slide-Tape
0	$ 0	$ 4,000	$ 3,000	$ 6,000	$ 7,000
1	2,000	1,000	1,500	750	500
2	2,000	1,000	1,500	750	500
3	2,000	1,000	1,500	750	500
4	2,000	1,000	1,500	750	500
5	2,000	2,000	1,500	1,750	2,700
6	2,000	1,000	1,500	750	500
7	2,000	1,000	1,500	750	500
8	2,000	1,000	1,500	750	500
9	2,000	1,000	1,500	750	500
10	2,000	1,000	1,500	750	500
Total	20,000	15,000	18,000	14,500	14,200

Figure 1

ANNAUL COST COMPARISON FOR FIVE METHODS

1. Instructor Developed Lecture-Discussion		
development cost	= $	0
equipment replacement	=	0
operating cost	=	2,000
Total	$	2,000
2. Instructor Developed Slide-Tape		
development cost = $4,000 (0.14903)	= $	596
equipment replacement = $1,000 (0.6806) (0.14903)	=	101
operating cost	=	1,000
Total	$	1,697
3. Consultant Developed Lecture-Discussion		
development cost = $3,000 (0.14903)	= $	447
equipment replacement	=	0
operating cost	=	1,500
Total	$	1,947
4. Consultant Developed Slide-Tape		
development cost = $6,000 (0.14903)	= $	894
equipment replacement = $1,000 (0.6806) (0.14903)	=	101
operating cost	=	750
Total	$	1,745
5. Purchase Commercial Slide-Tape		
development cost = $7,000 (0.14903)	= $	1,043
equipment replacement = $2,000 (0.6806) (0.14903)	=	223
operating cost	=	500
Total	$	1,766

Notes:[13] Factor to convert a present amount to ten uniform annual amounts at eight percent interest = 0.14903
Factor to convert an amount five years in the future to a present amount at eight percent interest = 0.6806

Figure 2

Rate of Return on Investment

The Rate of Return on Investment technique amounts to finding the interest rate at which costs would have had to be invested in order to obtain the outcomes which were achieved. Surely, most education programs have benefits. The trouble is identifying them in terms of dollars. Having someone learn to read is a benefit, but what is it worth in dollars?

There are some educational situations that do lend themselves to a Rate of Return on Investment analysis. These are programs where we can identify the results of changes in behavior, rather than just measure the behavior change itself. Two examples of this technique will be presented.

An example. Consider a manufacturing process that is experiencing a large amount of scrap. The cause is identified as inadequate training of the employees involved. A training program is developed to satisfy the needs. After the program has been conducted, the amount of scrap is reduced significantly. Evaluation of the program is desired.

In reviewing the program, the total cost is determined to be \$12,000. Reductions in scrap amount to \$8,000 per year. The process will be in operation three years, after which time it will be eliminated. The useful life of the training is thus assumed to be three years.

The Rate of Return on Investment here is the interest rate which allows us to invest \$12,000 in a lump sum and receive in return \$8,000 per year for three years. In terms of an equation involving interest

$$\$8,000 = \$12,000\,(crf,i,3)$$

where (crf,i,3) is the capital recovery factor for three years at some unknown interest rate i. Solving for (crf,i,3)

$$(crf,i,3) = \frac{\$\,8,000}{12,000} = 0.667$$

We now look in a set of interest tables to find the interest rate at which the capital recovery factor for three years is equal to 0.667.[13] The closest value is at 45% where the table value is 0.669, so we can say that the Rate of Return on Investment is about 45%.

Stated another way, we can say that, over the three years, the \$12,000 cost of the program will be recovered, together with an additional return of 45% of the unrecovered balance being realized each year.

All that remains is to compare our Rate of Return on Investment against some established reference. Ideally, we would know the minimum attractive rate of return at which the organization is willing to invest its money. However, this figure is often not readily available.

The next best reference point is the cost of borrowed money. This at least establishes a floor below which the minimum attractive rate of return should not fall. A reasonable figure at the time this study was made might be 7%.

Our final determination in the financial evaluation is made in the following manner. Any program with a Rate of Return on Investment less than 7% would be deemed unsuccessful. Programs with a rate slightly above 7% should be considered questionable, since the minimum attractive rate of return is almost always greater than the cost of borrowed money.

Programs with a Rate of Return on Investment significantly above 7% would be considered successful. Our example manufacturing training program would definitely be considered a success. The Rate of Return on Investment of 45% is clearly an attractive investment when compared to a reference value of 7%.

A case history. This technique has been applied in one case where the results were quite enlightening. A major corporation desired to evaluate its graduate work study program. This was a program where a university offered a graduate level program in engineering administration at the company's location. Costs were quite high and the company was concerned about whether this education program was worth the investment.

Prior to the time of the financial evaluation, there prevailed a "feeling" that the program was successful. Discussions with graduates of the program indicated that the knowledge acquired in the program had been very beneficial on the job. Since all graduates were enthusiastic about the worth of the program, the feeling that it was successful seemed well justified. After calculating the Rate of Return on Investment for the program, a clear answer was obtained as to the degree of success of the program.

The calculations in this case were not as straightforward as in the manufacturing training program. Costs of the program were easily obtained, but, initially, the savings involved appeared very difficult to identify. Since increased benefits and reduced costs are equally beneficial to the company, they are both considered as benefits in such studies.

Fortunately, the problem of identifying profits could be overcome by taking advantage of the education the students had received in the program. Each graduate of the program held the degree Master of Science in Engineering Administration. They had received extensive education in economic analysis, probability and statistics, and operations research. One would be hard pressed to find a better qualified group of people to estimate cost savings than ~~the~~ graduates of this program.

At the time of the evaluation, 32 people had graduated from the program. One had left the company. The remaining 31 were surveyed.

One of the questions they were asked was:

> We would like to calculate the return on investment. We realize it is hard to be exact, but please give your best estimate of the amount of money you have saved or made for the company as a result of your MSEA education. It is important that we have this information, so please try to make an estimate.
>
> $__________ money saved or earned for company as a result of MSEA education.

Notice that this question does not ask for the total money the individual has earned or saved for the company, but only the amount attributable to his graduate education. An alternate approach here could have been to choose a control group who did not go through the program. Each group could have been asked for the total amount of money earned or saved for the company. The difference between the two groups could be attributed to the education program. While the second approach is attractive from an experimental design point of view it was not chosen here. There are several reasons.

First, accurately selecting a control group would be nearly impossible for the reasons previously described. Second, the graduates went through the program at different times making a control group identification even more complex. Third, estimating the total amount of money earned or saved for the company is a rather staggering question to ask someone. However, asking the amount resulting from the education program is more reasonable. Here he can think of specific examples of where his knowledge allowed him to make better decisions. For example, he might recall the time when he used linear programming to find the optimum solution to a manufacturing scheduling problem or when his knowledge of time value of money directed him to make the right decision on which test system to install. For these reasons, it is felt that the method used gave more accurate results than would have been obtained using the control group approach.

Of the 31 people surveyed, 26 responded. Of those, 20 were able to make an estimate. The responses were:

$ 0	$25,000	$ 50,000	$100,000
$ 0	$30,000	$ 50,000	$100,000
$ 7,500	$35,000	$ 75,000	$100,000
$12,500	$50,000	$100,000	$500,000
$15,000	$50,000	$100,000	$700,000

In three of the cases, the individuals gave a range. The mid-range value was used.

Having collected the returns, the battle was half over. The dollar amounts still had to be converted into Rates of Return on

Investment. There were several complicating factors.

First, the cost occurred over a period of time. Graduates took from three to seven years to complete the program. For ease of computation, the cost was assumed to be a lump sum payment two years prior to each individual's graduation.

Second, how were the savings distributed? Again, for ease of computation, the total savings reported by each graduate was assumed to be evenly divided from the present time back to the time two years before graduation. It is possible to test the reasonableness of this assumption. The test is discussed later in the paper.

Last, what time period should be used? The useful time span for the knowledge acquired cannot be assumed to be fixed as in the manufacturing training example. The first graduate of this program graduated less than seven years prior to the evaluation. Surely the life of the knowledge is more than seven years. Is there any decay of knowledge at all? There probably is some, but certainly the rate of decay of "management science" type knowledge is not nearly as rapid as for the hard sciences. Another factor is the advancement of the individual. As he rises to higher positions in the company, he makes bigger decisions where application of his education allows bigger savings. This phenomenon tends to cancel out the decay of knowledge. Still, what time period should be used?

In this case, the dilemma was solved because of the magnitude of the savings involved. This magnitude indicated that the interest rates would be quite large. For large interest rates, the factors in the interest tables very rapidly approach the infinite life values. For an interest rate of 50%, for instance, the capital recovery factor for an infinite life is 0.50000 and for a life of 16 years is 0.50076.[13] Thus, for this case, calculations based on table values assuming an infinite life can be used with no significant effect on the results.

As an example of how the Rate of Return on Investment was calculated for each person, consider the individual who had indicated a savings of $30,000. It had been about 4.6 years since his graduation. To this figure is added 2 years, giving a total of 6.6 years. Dividing $30,000 by 6.6 years gives an annual savings of $4,545. The cost of this person's education was set at $5,000 and assumed to occur as a lump sum two years before his graduation. The cost is arrived at by taking the internal company cost per course per student times the number of courses taken by the individual. The internal company cost per courses consists of university fees, books, and company overhead costs for secretarial services, etc. It does not include the student's work time spent in class. The typical student spent two hours of company time in class per week. It was assumed that this results in no significant decrease in efficiency for a professional employee.

As an alternate way of computing the cost of a graduate's education is to take the total cost of the program and divide by the number of graduates. This gives a larger value for the cost because people who do not graduate are, in a sense, charged as overhead against those who do graduate. But what we are after is knowledge and not diplomas. This method implies that those who do not graduate learn nothing and only those who receive a diploma acquire knowledge. The method used by the authors, on the other hand, implies that someone who goes half way through the program learns half as much as a graduate. Also, it is implied that he saves half as much as a graduate, as opposed to zero saving implied in the alternate method. This assumption in the method selected by the authors seemed more realistic than those in the alternate method. The alternate method would be useful as a quick indicator of the relative cost of a program, but it is not appropriate for the more in-depth analysis desired here.

Since an infinite life can be assumed with no appreciable reduction in accuracy, the Rate of Return on Investment for the individual with an annual savings of $4,545 can be calculated quite simply.

$$\frac{\$4,545}{\$5,000} \times 100\% = 91\%$$

The same method was used to calculate the Annual Rate of Return on Investment for the remaining 19 individuals. The results for all 20 are given below.

ANNUAL RATE OF RETURN ON INVESTMENT FOR 20 MSEA GRADUATES

0%	91%	218%	357%
0%	109%	245%	357%
27%	132%	264%	435%
45%	152%	303%	1320%
65%	178%	326%	3540%

The mean value is 408%. This indicates that money invested in this educational program is paying a Rate of Return on Investment of 408%. This says that the average graduate each and every year returns 408% of the total cost of his education to the company. Comparing the 408% Annual Rate of Return on Investment to the 7% cost of borrowed money shows this program to be overwhelmingly successful.

After completing the calculations, the data was reviewed to insure that the savings percentages did not correlate with the length of time since graduation, thus indicating that the savings were relatively uniform over time for each individual. Hence, the simplifying assumption, made previously, that the savings occurred evenly over time was reasonable.

Of course the 408% figure is only an approximation. The assumptions made for computational ease may effect the accuracy slightly. More significantly, the graduates' estimates of savings are surely not exact, because they are, in most cases, subjective. However, the relative magnitude of the Rate of Return on Investment showed the program to be successful regardless of what tolerance limits are applied. In any case, the approximate 408% figure provided far more meaningful information than the previous "feeling" that the program was successful. In evaluating the program, it should perhaps be also noted that a fair number of students not taking the Engineering Administration degree program elected to take certain of the courses offered. In one case, such a student reported to his professor "as a direct result of my exposure to non-linear programming in your course, our company succeeded in selling a three million dollar project." Others reported savings of up to half a million as a result of better decisions due to use of decision analysis, and term projects in other areas produced reports of equally impressive savings.

Summary

The literature has alluded to the need for financial evalution, but little has been accomplished. This is probably due to the several difficulties involved: (a) control groups are often not feasible, (b) it is impossible to post-audit a decision, (c) the life of the benefits is often not known, and (d) subjective data must sometimes be used. For these reasons it is perhaps not justifiable to seek other than an order of magnitude answer to the question, "Did the decision result in a favorable outcome?" In the two hypothetical examples presented, meaningful results were shown. In the case history described, we feel the results eloquently attest to the fact that the investment in the program resulted in a far greater return than would be required for the approval of a more traditional capital expenditure.

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3

THE DEPARTMENT HEAD IN FACSIMILE

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Pity the poor department head!

Students knock on his door to voice their displeasure with the length of a homework assignment required by a zealous new assistant professor. They complain of dull lectures given by an older faculty member who should have retired ten years ago--but still has five years to serve. They dispute a negative tenure decision on a more popular teacher who has used the classroom to champion every student cause (and gives easy grades).

Faculty members complain of the building renovations across the street, and the fact that the construction workers arrive at 7:30 a.m. and usurp all the parking places. They deplore the increased institutional emphasis on athletics--and the fact that the major donors to the athletic program obtain all the choice football seats. They worry about the laxity of academic standards...in other departments across the campus.

The administration, using a new formula developed by the Office of Institutional Research, has suggested that the department occupies too much space. A departmental recommendation to recruit and extend an offer to a full professor at another institution is denied by the dean because of insufficient funding and because the department already has too many full professors. The policy of "extra compensation" to faculty for their participation in conferences and short courses is to be changed, with faculty expected to contribute to such programs on a "release time" basis.

While each of the preceding incidents is likely to have occurred and on more than one campus, they probably have not been thrust upon the same department head all at the same time. Nonetheless, the department head is faced with conflicts. He must make decisions. Sometimes his authority is commensurate with the expectations of responsibility held by the administration, the faculty and the students; many times it is not. Sometimes the less routine requirements for a decision are shared with the senior members of the faculty, permitting additional insights into a situation and also diffusing the accountability for the decision. Shared decision making, however, does not reduce the seriousness of a problem nor always lead to a better solution.

The Academic Department Head Game

Some decisions involve a unique situation, but more often common elements exist across a number of events, and a single decision and its consequences have value as a learning experience. Under a grant from the EXXON Educational Foundation, a computer-based management game has been developed in an attempt to reproduce some of the more significant decisions confronting the academic department head in a university. To understand the structure, content and usefulness of the game, consider the following three department heads and the situations confronting them.

Dr. Richard (Dick) Walker has been serving as chairman for four years, during which the department has made reasonable progress. Teaching reports have been good, if not outstanding. The eight faculty have published a number of significant articles, and one individual has produced a text. While the level of sponsored research could be raised further, some funding has been generated, and this has been adequate to support an increasing number of graduate students. On several occasions the dean has expressed his pleasure with the activities of the department. However, Dick has just been informed of the resignation of one of the younger potential "stars" in the department--quite a disappointment. A brief description of the young man would read as follows:

Dr. Albert Kelly is 33 years old and received his Ph.D. from the University of Wisconsin. He took a two-year post-doctoral fellowship at Princeton and has been an assistant professor on the faculty for three years. He is one of the more conscientious teachers and has expressed no definite preference for teaching either service, lower division, upper division, or graduate courses; he has taught at least one course in each category. A most careful researcher, he has published six articles and has also received an NSF Research Initiation Grant and has attracted a number of graduate students. He is well-liked by the students and faculty and has been elected a college representative to the faculty senate--one of the few assistant professors to serve on that body. He is married and has two children.

Dick Walker feels justifiably concerned with Dr. Kelly's resignation. Apparently he has accepted an offer with only a slight salary increase at the rank of associate professor and at a comparable, not a more prestigious institution. During his stay on the faculty, Dr. Kelly has received above average salary increases, had been asked to teach no more than two courses a semester; his teaching load coupled with his research activity and advising of graduate students had been only an average load in the department. Dr. Kelly had not been particularly outspoken in voicing any complaints; he had been told to expect a promotion and significant salary increase in the next year or two and had seemed satisfied with this arrangement. Dick is uncomfortable and is now asking himself, "Where did I go wrong with Dr. Kelly?" If he had given him a larger salary increase, a lighter teaching load, and/or recommended him for promotion at the end of three years, Dr. Kelly might have chosen to stay, but a number of other faculty could have been unhappy with this obviously preferential treatment.

To compound his difficulties, Dr. Walker has interviewed a candidate as a replacement who has almost the same potential as Dr. Kelly but, unfortunately, his interest in teaching does not fill the vacancy left by Dr. Kelly. The candidate will teach only upper division and graduate in his specialty. If an offer is extended to this candidate, some changes will have to be made in existing teaching assignments, and a few faculty will be less than satisfied with their new teaching obligations. Should Dick extend an offer to the candidate and accept the resulting dislocation of faculty teaching preferences? Alternatively, a candidate can be sought who could more neatly fit into the instructional gap left by the vacancy, but the prospects of finding someone with the same overall potential as the present candidate are not good.

Dr. Carl Herakovich is a new department head. His immediate concern is with the productivity (or lack thereof) of Dr. M. Stone Hunter, a former Air Force officer who has "retired" into his present faculty position after receiving tenure two years ago. He has since managed to lower his golf handicap by six strokes. Not only has Dr. Hunter ignored any obligation toward research and creative scholarship, but his teaching leaves much to be desired. He functions best in the teaching of service courses, but even here, sporadic student complaints are a continuing source of embarrassment to the department. It is unlikely that Dr. Hunter will leave, although he has threatened to do so if his teaching load is increased from the present nine hours to twelve. As a department head, Carl is now debating assigning a twelve-hour teaching to a poor teacher to encourage his resignation. It is not even certain that Dr. Hunter would resign under this increased pressure, and if it were certain, the ethics of exposing more students to a poor teacher just to secure a resignation are questionable.

On the more general subject of faculty productivity and rewards, Carl is concerned with the use of annual salary increases as a means of furthering departmental objectives. A number of department chairmen in the college follow a policy of allotting some monies in equal proportion to all faculty in order to partially compensate for the ever increasing cost of living. Some lesser proportion of the total monies is then divided among the faculty, with the more productive faculty receiving larger increases. A few of Carl's associates, however, use all salary increases as leverage for advancing goals, so that some faculty receive no increase whatsoever, while others are rewarded handsomely. As a result, in those departments superior faculty have been less likely to resign for more attractive positions elsewhere, but the less productive faculty have been outspoken in their criticism of the department and the department head. Carl is debating the extent to which salary increase monies are "owed" the faculty or can be used as an immediate, direct, tangible reward for productivity.

Dr. Lon Savage has been a department head for one year and faces the difficult task of re-orienting department objectives. He has inherited a faculty--approximately half of whom are tenured--who have good teaching reputations, but who have been quite slack in creative scholarship. They are willing to accept heavier than average teaching loads in order not to be bothered with this other requirement. They are more than willing to serve on college and university committees to fulfill a service commitment within the university. They do little outside the university, and with few exceptions, are unwilling to redirect their energies, so that the department has almost no regional or national visibility. Lon also faces a new dean who is emphatic in his requirement that the level of research funding and scholarly productivity be brought up to the existing average level across the college. Lon realizes that the mechanism for re-orienting departmental objectives will have to be accomplished with new faculty and with the denial of tenure to a number of non-tenured faculty members, including some who are fine teachers.

The one faculty member with some ability and orientation toward scholarship--Dr. Wilson Dingle--is also faculty advisor to the campus Gay Liberation Group. Within the department, he tends to go his own way; he is active in the community in seeking the acceptance of the homosexual. He is to be considered for tenure this year. A number of faculty are unappreciative of the publicity given the department through his activities.

Each of the preceding department heads is facing one or more dilemmas. What to do? Interestingly enough, Dick Walker, Carl Herakovich, and Lon Savage are real people, and they did face these and other problems. They did so through the gaming situation that permitted the simulation of five years in the life of an academic department. Dick, Carl and Lon each served as the head of the Department of Statistics in the State University of Id. They made decisions vital to the success of that department and had the chance to observe the consequences of their decisions. As a matter of interest, at different times Dr. Albert Kelly did resign for Dick, but not for Carl nor for Lon. On the other hand, none of the department heads had the good fortune to secure the resignation of Dr. M. Stone Hunter, although two made a concerted effort to obtain it.

Playing the game

In the Academic Department Head Game, each participant serves as Head of the Department of Statistics and is required to make two decisions per year--one at the start of each semester--for a five-year period. The participant is provided with an initial roster of eight faculty in the form of profiles (similar to that given for Dr. Albert Kelly), which include a personal sketch of the individual, as well as some insight into his professional interests and abilities. Then, through the duration of the game, one or more may choose to resign, or if a person is non-tenured, his services may be terminated. Additional faculty must then be secured, and it is not unusual for a department to change in composition over the five years of its existence.

The Decisions and Results

In the game, as in reality, the objectives of the department have to be achieved through its faculty. As a result, the critical decisions in this simulation exercise revolve around the recruitment and retention of faculty and the assignment of faculty work loads.

The institution operates on a semester basis, with two semesters constituting an academic year. A total of ten decisions are made over the five-year gaming period. The first is made just prior to the start of the fall semester, the second just prior to the start of the spring semester, the third decision prior to the start of the fall semester of the second academic year, and so forth. For purposes of the exercise, it is assumed that the department head can function in a "strong leadership situation." If, as in many university settings, there is an element of senior faculty involvement in the decision process, it is assumed that the persuasive powers of the department head are such that his will can prevail.

Teaching assignments: The department has a teaching obligation at both the undergraduate and graduate level. Service and introductory courses are taught to lower division students, and junior, senior, graduate and advanced graduate courses are taught in three distinct areas of statistics. The assignment of courses to individual members of the faculty must be accomplished each semester.

Some faculty will be involved in advising graduate students on theses and dissertations; a few faculty will also engage in sponsored research. This latter work load is generated through the initiative of the individual faculty member.

The size of the department is initially assumed to be eight faculty (plus the department head). This size can be increased through securing research funding and additional graduate student enrollment. As one might expect, a faculty member is more likely to secure research support if he is initially assigned a lighter teaching load. The funding can then be used to increase the support of graduate students and increase the size of the department.

Salary Increase Recommendations: The spring decision will require an allocation of available salary increase monies to the faculty for the following academic year. To assist the department head in making this decision, he is provided a report of faculty productivity through the previous calendar year. The department head receives an indication of individual teaching effectiveness and scholarly productivity, research activity and time spent in service to the university and the profession.

Promotions and Non-Reappointments: It is assumed that the department head has the prerogative of initiating promotion and non-reappointment recommendations. The latter decisions have to be made within the framework of the "1940 Statement of Principles on Academic Freedom and Tenure" of the AAUP.

Recruiting: The game participant is also involved in recruiting replacements for faculty who either resigned or were denied tenure. The recruiting process is initiated with the request made by the department head for resumes by rank and with specific subject matter capabilities. He is then provided resumes of those who have chosen to be considered applicants and can rank his order of preferences to whom employment offers will be extended. Success in the recruitment of faculty includes a random element but is also dependent upon the reputation already achieved by the department.

The Results: Effects of the preceding decisions are found in the reported satisfactions or dissatisfactions of the faculty, the productivity of these same faculty, and the annual review made by the dean. Every year each faculty member has the opportunity of reporting his satisfaction regarding salary, teaching load, teaching preference, the number of graduate students who choose to associate themselves with him, and the general reputation of the department. A composite of these satisfactions will influence the decision of the faculty member to remain with the institution or resign and seek employment elsewhere. A second measure of the success of the department head is found in the composite of the annual reports of the faculty. These include the teaching effectiveness of the whole faculty, the number of articles they have contributed to the literature, books published, if any, research support generated, and service to the university and to the profession. As one might expect, two department heads working with an identical faculty may achieve different levels of faculty satisfaction and of department productivity. The department head who assigns a lighter load to an individual with greater potential for scholarship and research is more likely to see this potential become a reality. On the other hand, the department head who assigns a heavier teaching load to those faculty with poor teaching capabilities will probably see a decline in the teaching reputation of his department.

A final measure of the success of the department is seen in the annual review of that department made by the dean of the college. This last assessment will be very close to the composite of the annual faculty activity reports. However, the game can be played "against" one of four different deans. The game administrator can select a dean who is teaching oriented, teaching and service oriented, publications and research oriented, or a balance of these. All game participants then manage their departments for the same dean. This great flexibility permits the game to be adapted by the game administrator to different university settings or objectives.

Conclusions

The game model has been constructed around an individual data base which maintains information relevant to each faculty member. Fifty such faculty have been defined and any eight may be used to initiate game play. The remaining 42 then serve as the reservoir from which faculty are recruited. Because of this flexibility, game play can be structured to simulate specific situations, e.g., faculty who are all tenured, a preponderance of faculty in the lower ranks, or a faculty consisting of "teachers" with a dean who is research-oriented. The values of the various parameters have been developed with the assistance of a consulting psychologist. Each faculty member is characterized by such stress factors as salary, rank, teaching load and preference, number of graduate students, and the reputation of the department. Each faculty member is also categorized by indices regarding his teaching ability and level of scholarly productivity.

The Academic Department Head Game has been designed as both an orientation and a training device for the new or the aspiring department head. It could also be employed by others, either within or outside the university, who might profit from a better understanding of some of the significant decisions required in the administration of an academic department. Obviously, the game does not include many decision situations that confront the department head on a daily basis. No requirement is made for the response to the group of students who have come in to complain about the length of the homework assignments required by the new assistant professor. The department head in the game is not required to respond to the complaint of a faculty member who cannot find a parking place and is habitually late to meet his first class. Even in a broader frame of reference, excluding the allocation of salary increase funds, no provision is included within the game for the stewardship function; the department head is not required to request and maintain a budget. On the other hand, a number of profound decisions are required of the game participant--particularly those relating to recruitment and retention of faculty and the assignment of faculty work loads. Through the mechanism of the game, the department head has the opportunity to make decisions, observe the results of these decisions, and then make additional decisions. Further, he can use this vehicle as a focal point for discussing "real world" situations with other game participants.

The game is now completed. While additional refinement of the game model is likely to continue, game instructions and the program will be provided upon request from the authors.

4

RESOURCE ALLOCATION FOR A COLLEGE OF ENGINEERING

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Introduction

Management science models which express the organizational environment and its dynamics in mathematical relationships have been applied in many fields. Although these models have been developed and are being taught in universities, very few techniques have been applied to universities themselves until just recently. In recent years, models have been developed in which problems that are encountered in university administration are examined. For example, David S. P. Hopkins[1] established a cost simulation model for a university, in which levels of activities are related to the requirements that reflect on the university resources. Another approach to this problem is that of Sung M. Lee[2] in which goal programming was used as a model to analyze multiple, competitive and conflicting goals with varying priorities. Lee applied this technique to the optimum allocation of resources in a school of business administration. It is this work of Lee that motivated this paper. It was felt that since goal programming was of value in analyzing the allocation problems of a business school, it could be equally useful in studying an engineering college.

The objective of this paper is to present a method for the allocation of funds in a college of engineering. This method must recognize that certain requirements such as financial stringencies, quality and diversity of academic faculty, maintenance of existing levels of faculty, etc., should be met. As most of these requirements are incommensurable, a priority structure has been constructed for the formulation of the model. The College of Engineering being studied in this paper is not necessarily a real school, but should be considered a composite of several different schools of engineering, and thus serves as a useful example to study.

There are two major goals that a college of engineering must consider. One is the goal of maintaining approximately the current faculty levels. That is, the number of assistant, associate or full professors should not change drastically from year to year. Major changes in employment levels would require considerable firing and hiring, with the expected negative effect on employee morale. In this paper we permitted only small changes in the faculty levels in each category.

The second major goal of any college of engineering is to satisfy as closely as possible the standards of the engineering accrediting group known as the Engineer's Council for Professional Development (ECPD). In their "Objectives and Procedures for Accrediting Programs in Engineering in the United States" the ECPD[3] makes the following statement: "The overall competence of the faculty may be judged by such factors as the level of academic training of its members; the diversity of their backgrounds; their non-academic engineering experience; their experience in teaching; their interest in and enthusiasm for developing more effective teaching methods; their level of scholarship as shown by scientific and professional publications; their degree of participation in professional, scientific and other learned societies; recognition by students of their professional acumen; and their personal interest in the student's curricular and extracurricular activities."

Of these factors, only two seem reasonably easy to measure, namely level of academic training and diversity of background. Information on both of these can be obtained from a standard college catalog. For example, for an engineering college, the level of academic training can be measured by the highest degree achieved by the faculty member. The diversity of background can be measured by the location of the last degree. Was the last degree from the university being studied, or was it from elsewhere? More bluntly, is the faculty member an inbreed or not?

There are further goals that were covered in this effort, but they are of less importance. For example, we considered the goal of maintaining a desirable faculty-student ratio, and the goal of covering all classes listed in the catalog. All these goals were included to try to meet all the objectives of the college.

Model

The following assumptions are made in developing the model:

1. It is a single-time-period model; i.e., planning horizon is limited to one year.

2. All faculty will work the same number of months per year. In reality, most faculty are on a nine-month basis, while some are on eleven months. However, the nine-month faculty members usually are also able to teach summer school; so this assumption is reasonable.

3. In arriving at the estimated number of student credit hours needed for each session, an average figure is used both for undergraduate and graduate students load levels.

4. Each department has certain number of research and teaching assistants.

For the model, we define the following variables:

x_1 : Number of research assistants

x_2 : Number of teaching assistants

x_3 : Number of instructors

x_4 : Number of inbred assistant professors without PhD

x_5 : Number of non-inbred assistant professors without PhD

x_6 : Number of inbred assistant professors with PhD

x_7 : Number of non-inbred assistant professors with PhD

x_8 : Number of inbred associate professors without PhD

x_9 : Number of non-inbred associate professors without PhD

x_{10}: Number of inbred associate professors with PhD

x_{11}: Number of non-inbred associate professors with PhD

x_{12}: Number of inbred full professors without PhD

x_{13}: Number of non-inbred full professors without PhD

x_{14}: Number of inbred full professors with PhD

x_{15}: Number of non-inbred full professors with PhD

x_{16}: Number of part-time professors

x_{17}: Number of staff

The Goals

The goals can be stated mathematically as follows:

1. Level of academic training goal. Two criteria can be hypothesized to meet this goal. They are:

ECPD requirements. Although the ECPD Standard does not specify precisely what is meant by "level of academic training," it is possible to quantify this goal by the constraint that, at most, 10% of the faculty should be without PhD's. This constraint can be expressed algebraically as follows.

$$x_4 + x_5 + x_8 + x_9 + x_{12} + x_{13} \leq (0.1) \sum_{i=4}^{15} x_i$$

Of course, this constraint may have to be violated; that is, we may end up with more than 10% of the faculty without PhD's. The amount we exceed this goal will be denoted by d_1^+. Then the constraint can be written as

$$x_4 + x_5 + x_8 + x_9 + x_{12} + x_{13} - d_1^+ = (0.1) \sum_{i=4}^{15} x_i$$

where d_1^+ is the positive deviation from the goal.

Stable employment requirement. ~~Suppose that 30.13% of the~~ present engineering faculty do not possess PhD degrees. This figure is not uncommon at some of the older, more established engineering schools. Because of stability of employment requirements, it must be expected that this percentage should not decrease significantly. This yields another constraint regarding the percentage of faculty without PhD. Assuming that there will be a maximum attrition rate of 1% (retirements, deaths, etc.), the projected percentage for next year should be at least 30.13 x 0.99 = 29%. This can be expressed as follows:

$$x_4 + x_5 + x_8 + x_9 + x_{12} + x_{13} \geq (0.29) \sum_{i=4}^{15} x_i$$

For goal programming, this constraint is written as:

$$x_4 + x_5 + x_8 + x_9 + x_{12} + x_{13} + d_2^- = (0.29) \sum_{i=4}^{15} x_i$$

where d_2^- is the negative deviation from the goal.

As can be seen, this goal is in direct conflict with the preceding goal. It is impossible for both goals to be satisfied simultaneously. At least one of these goals will have to be violated.

2. Diversity of background goal. As before, two criteria can be defined to quantify this goal:

ECPD requirement. As with the above goal, the ECPD standards do not define precisely what is meant by "diversity of background." One possible way to quantify this goal is to examine the number of inbred faculty. We quantified this constraint by specifying that, at most, 30% of the faculty should be inbreeds. This can be expressed algebraically as follows:

$$x_5 + x_7 + x_9 + x_{11} + x_{13} + x_{15} \leq (0.3) \sum_{i=4}^{15} x_i$$

The corresponding goal programming constraint is:

$$x_5 + x_7 + x_9 + x_{11} + x_{13} + x_{15} - d_3^+ = (0.3) \sum_{i=4}^{15} x_i$$

Stable employment requirement. Suppose that 53.8% of the total faculty in the college of engineering are inbreeds (This is probably a little high, but not unusual in engineering schools). Because of stability requirements, this percentage should not decrease considerably. This yields another constraint for the diversity of background goal. Assuming 1% attrition rate, projected percentage of inbred faculty for next year should be at least 53%. This can be expressed in the following goal constraint:

$$x_5 + x_7 + x_9 + x_{11} + x_{15} + d_4^- = (0.53) \sum_{i=4}^{15} x_i$$

3. Maintenance of the existing level of faculty goals. In order to avoid major upheavals in the number of faculty in each category, it will be assumed that the number in each category does not change very much from year to year. This objective can be achieved by a series of goal statements.

a. Suppose that 4.5% of the current faculty are inbred assistant professors with PhD. Then to maintain this approximate percentage, the following goal can be specified:

$$x_6 = (0.045) \sum_{i=4}^{15} x_i$$

The corresponding constraint for goal programming is:

$$x_6 + d_7^- - d_7^+ = (0.045) \sum_{i=4}^{15} x_i$$

b. Suppose 7.3% of the current faculty are assistant professors with PhD's from other universities. Then to maintain the approximate percentage, the following constraint can be specified:

$$x_7 + d_8^- - d_8^+ = (0.073) \sum_{i=4}^{15} x_i$$

c. Suppose 5.94% of the current faculty are inbred assistant professors without PhD's. Then the following constraint can be specified:

$$x_4 + d_5^- - d_5^+ = (0.059) \sum_{i=4}^{15} x_i$$

d. Suppose that 2.73% of the current faculty are assistant professors without PhD's and terminal degree from other universities. Then the following constraint can be specified:

$$x_5 + d_6^- - d_6^+ = (0.0273) \sum_{i=4}^{15} x_i$$

e. Suppose that 16% of the current faculty are inbred associate professors with PhD's. Then the following constraint can be specified:

$$x_{10} + d_4^- - d_4^+ = (0.16) \sum_{i=4}^{15} x_i.$$

f. Suppose 15.1% of the current faculty are associate professors with PhD's from other universities. Then the following constraint can be specified:

$$x_{11} + d_{12}^- - d_{12}^+ = (0.151) \sum_{i=4}^{15} x_i$$

g. Suppose 2.73% of the current faculty are inbred associate professors without PhD's. Then the following constraint can be specified:

$$x_8 + d_9^- - d_9^+ = (0.0273) \sum_{i=4}^{15} x_i$$

h. Suppose 2.73% of the current faculty are associate professors without PhD's and terminal degree from other universities. Then the following constraint can be specified:

$$x_9 + d_{10}^- - d_{10}^+ = (0.0273) \sum_{i=4}^{15} x_i$$

i. Suppose 20.5% of the current faculty are inbred full professors with PhD's. Then the following constraint can be specified:

$$x_{14} + d_{15}^+ - d_{15}^- = (0.205) \sum_{i=1}^{15} x_i$$

j. Suppose 15.1% of the current faculty are full professors with PhD's from other universities. Then the following constraint can be specified:

$$x_{15} + d_{16}^- - d_{16}^+ = (0.151) \sum_{i=4}^{15} x_i$$

k. Suppose 4.11% of the current faculty are inbred full professors without PhD's. Then the following constraint can be specified:

$$x_{12} + d_{13}^{-} - d_{13}^{+} = (0.041) \sum_{i=4}^{15} x_i$$

l. Suppose 3.2% of the current faculty are full professors without PhD's and terminal degree from other universities. Then the following constraint can be specified:

$$x_{13} + d_{14}^{-} + d_{14}^{+} = (0.032) \sum_{i=4}^{15} x_i$$

4. Broad categories of faculty. Suppose 21% of the faculty are assistant professors, 37% of the faculty are associate professors, 42% of faculty are full professors, and 5% of faculty are part-time. Then we have the following goal constraints:

$$\sum_{i=4}^{7} x_i + d_{17}^{-} - d_{17}^{+} = (0.21) \sum x_i$$

$$\sum_{i=8}^{11} x_i + d_{18}^{-} - d_{18}^{+} = (0.37) \sum x_i$$

$$\sum_{i=12}^{15} x_i + d_{19}^{-} - d_{19}^{+} = (0.42) \sum_{i=4}^{15} x_i$$

$$x_{16} + d_{20}^{-} - d_{20}^{+} = (0.05) \sum_{i=4}^{16} x_i$$

5. Number of academic faculty goal. Suppose the projected student enrollment in the engineering college for next year is estimated to be 2110. Average number of credit hours taken (graduate and undergraduate) is assumed to be 15, and the desired class size is assumed to be 20. Then we have:

$$\text{Total student credit hours} = \frac{(2110)\ (15)}{20} = 1583$$

Assuming an average teaching load of 12 hours for graduate assistants, 10 hours for instructors, and 5 hours for the rest of the faculty, we have the following goal:

$$12x_2 + 10x_3 + 5\sum_{i=4}^{16} x_i = 1583$$

The corresponding goal programming constraint is:

$$12x_2 + 10x_3 + 5\sum_{i=4}^{16} x_i + d_{25}^- - d_{25}^+ = 1583$$

Also, faculty-student ratio of 1/9 is assumed as ideal. This gives the goal constraint:

$$\sum_{i=1}^{15} x_i + d_{26}^- - d_{26}^+ = 223$$

6. Number of graduate research assistants. We set the desired graduate research assistants to faculty ratio as 1 to 2. This can be quantified as follows:

$$x_1 + d_{21}^+ - d_{21}^- = (0.5)\sum_{i=4}^{16} x_i$$

7. Number of teaching assistants. We set the desired teaching assistant to faculty ratio as 1 to 5. This can be quantified as the following goal constraint:

$$x_2 + d_{22}^+ - d_{22}^- = (0.2)\sum_{i=4}^{16} x_i$$

8. Number of instructors. Suppose the desired instructor/faculty ratio is 1 to 20. This can be quantified as follows:

$$x_3 + d_{23}^- - d_{23}^+ = (0.05)\sum_{i=1}^{16} x_i$$

9. Number of staff. The desired support staff/faculty ratio is 1/6. This can be quantified as follows:

$$x_{17} + d_{24}^- - d_{24}^+ = (0.167)\sum_{i=2}^{16} x_i$$

10. Budget goal. The total budget for next year consists of the total amount paid for faculty, teaching and research assistants, and staff this year, plus a predetermined amount of increment over the pay base for the above classifications in the engineering school. The estimated average salary figures for next year are shown in Table 1. Suppose the dean has a total of $7,500,000 to

be used for salaries. Then from Table 1 the following constraint can be specified:

$$4028\ x_1 + 4028\ x_2 + 11{,}880\ x_3 + 14{,}040\ x_4$$
$$+ 14{,}040\ x_5 + 16{,}200\ x_6 + 16{,}200\ x_7 + 17{,}496\ x_8$$
$$+ 17{,}496\ x_9 + 22{,}080\ x_{10} + 22{,}680\ x_{11} + 24{,}494\ x_{12}$$
$$+ 24{,}494\ x_{13} + 32{,}400\ x_{14} + 32{,}400\ x_{15} + 24{,}840\ x_{16}$$
$$+ 8{,}100\ x_{17} - d^+_{salary} = 7{,}500{,}000$$

The Objective

The objective of the college of engineering is to meet all the goals specified above. However, as we have already seen, the first two are mutually conflicting, indicating that at least one of these two goals will be violated. It is possible that there exists additional conflicts in the goals so that several goals may be violated. Some of these goals are more important to the dean than other goals. Thus, the goals can be ranked according to their importance to the dean.

In conversations with a few deans of engineering we came up with the ranking of the goals as indicated in Table 2. As can be seen, it appears that administrators of engineering colleges feel that faculty stability is of prime importance, as is evident from the high ranking given to maintaining current faculty employment levels in all categories. This is in line with the well established principles of tenure at universities. The ECPD standards are next in importance.

The ranking of the goals is exploited in goal programming. The highest priority goals are examined first, and effort is made to achieve these as closely as possible. Then the next highest priority goals are examined, and an attempt is made to achieve these as closely as possible, but without disturbing the degree of achievement of the highest priority goals. This is continued until all goals are examined.

However, there is no general-purpose, high-speed-goal-programming computer code available. Therefore, we used the well known MPSX simplex code with weights on the goals. The highest priority goal was weighted the most, and the weights decreased with decreasing priority. The weighted goal objective function is:

$$10^{10}\ (d_2^- + d_4^+) + 10^8\ (d_{17}^- + d_{17}^+ + d_{18}^- + d_{18}^+ + d_{19}^- + d_{19}^+$$
$$+ d_{20}^- + d_{20}^+) + 10^6\ (d_i^+ + d_i^-)_i = 5,\ldots,16$$

$$10^4 (d_{25}^- + d_{25}^+ + d_1^+ + d_3^+)$$

$$+ 10^2 (d_{26}^- + d_{26}^+) + 10 (d_i^+ + d_i^-)_{i = 20,\ldots,24} + 0.00001\, d_{salary}^+$$

The objective is to minimize this deviation function.

Results

For the sample problem given in this paper the results ~~of~~ the computer are given below:

Goal attainment

1.	Maintain stable employment to all faculty	Achieved
2.	Maintain desired distribution of academic staff	Achieved
3.	Maintain desired number of faculty	Achieved
4.	Maintain desired faculty student ratio	Achieved
5.	Maintenance of desired number of	
	part-time professors	Achieved
	research assistants	Achieved
	teaching assistants	Not Achieved
	instructors	Not Achieved
	staff	Achieved
6.	Maintenance of ECPD requirements	
	for quality	Not Achieved
	for diversity	Not Achieved

Variables	Deviational Variables
$x_1 = 342$	$d_1^+ = 24$
$x_2 = 33$	$d_3^+ = 51$
$x_3 = 5$	$d_8^+ = 1$
$x_4 = 13$	$d_{10}^+ = 1$
$x_5 = 6$	$d_{13}^- = 2$
$x_6 = 10$	$d_{20}^- = 6$
$x_7 = 17$	$d_{22}^- = 13$
$x_8 = 6$	$d_{23}^- = 6$
$x_9 = 7$	$d_{salary}^+ = 0$
$x_{10} = 36$	
$x_{11} = 36$	
$x_{12} = 7$	
$x_{13} = 7$	
$x_{14} = 46$	
$x_{15} = 34$	
$x_{16} = 5$	
$x_{17} = 44$	

Since the highest priority was assigned to the maintenance of stable employment to all faculty members, these goals were achieved without difficulty. Job security, achieved by maintaining employment stability, is vital, not only to provide motivation, but also to create an environment congenial for higher learning. Once the basic need of job security is satisfied, the higher needs like recognition become predominant. Thus all goals are achieved except the desired number of teaching assistants and instructors, and the two ECPD requirements of quality and diversity.

Since the underachievement of 13 teaching assistants and 6 instructors is not large compared to the total number of faculty in the College of Engineering, this underachievement should not be of much concern. On the other hand, the overachievement of 24 professors without PhD's and 51 inbred faculty for the two ECPD requirements should be of much more concern, and probably should be an area to which the dean of the college may want to focus greater attention for future faculty hiring procedures.

Conclusions

From this study it is evident that the administration of a college of engineering can be significantly influenced through the use of goal programming. It is planned eventually to expand this study by examining a particular engineering college and by considering additional ECPD requirements such as enthusiasm of faculty, level of scholarship, recognition of students, etc.

Acknowledgement

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Table 1. Estimation of salaries for the different categories of faculty.

Category	This Year's Average Salary	% Increase	Next Year's Estimated Average Salaty
Graduate Assistants	3,783	6	4,028
Instructors	10,928	8	11,880
Assistant Professor without PhD	12,920	8	14,040
Assistant Professor with PhD	14,900	8	16,200
Associate Professor without PhD	16,096	8	17,496
Associate Professor with PhD	20,866	8	22,680
Full Professor without PhD	22,534	8	24,494
Full Professor with PhD	29,800	8	32,400
Visiting Professor	22,850	8	24,840
Staff	7,530	7	8,100

Table 2. The ranking of the goals.

Rank	Goal
1	d_2 : maintain current ratio of PhD to non-PhD faculty
	d_4 : maintain current ratio of inbred to non-inbred faculty
2	d_{17} : maintain current level of assistant professors
	d_{18} : maintain current level of associate professors
	d_{19} : maintain current level of full professors
	d_{20} : maintain currently level of part-time faculty
3	d_i, i=5, 16 : maintain current levels of faculty in each of the separate categories
4	d_{25} : meet student load requirements
	d_1 : satisfy ECPD quality standards
	d_3 : satisfy ECPD diversity standards
5	d_{26} : achieve a desirable faculty-student ratio
6	d_i, i=21,..,24 : achieve desirable levels of faculty-support staff ratios
7	d_{salary} : do not exceed the budgeted salary value

5

AN ALGORITHM FOR FORECASTING UNIVERSITY POPULATION

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R. P. Sadowski

Background and Literature Review

In the past two decades, many new statistical techniques have emerged for forecasting independent demand. Prior to Brown's[1] development of exponential smoothing, arithmetic and moving average techniques were predominant. An even more recent development in forecasting a time series has been introduced by Box and Jenkins.[2]

Since Brown first developed exponential smoothing, this technique has been expanded and embellished to extreme complexity; seasonality, cycles, trends and even extrinsic variables have been incorporated within the smoothing context. Most of the models that utilize exponential smoothing to weight the age of data, however, are naive models that assume independent demand. Oftentimes, independence is assumed simply to permit utilization of the large number of exponential smoothing models and computer programs which are available at little or no cost.

Few models are available which predict demands that are dependent on known or forecastable information. This is probably because this dependence is itself system dependent. Because of this system dependence, it is usually not possible to create a general purpose algorithms and programs for dependent demand. The following model was developed for a specific system: a university where demand (student population in this case) is quite dependent upon the current population of the university, and in particular, upon that part of the university which tends to recycle itself into a new class of populus (freshmen become sophomores, sophomores become juniors, etc.).

Several flow models of educational systems have been developed for planning. At the national level, Armitage and Smith[3] and Clough and McReynolds[4] have provided recent contributions in this area. These models describe the growth of a system over time, and they characteristically relate demands in one period to those in the next by means of Markov-like transitions. Such models make an important contribution by showing how transition rates can be used to model policy variables and enrollment constraints. These concepts have provided the basis for the forecasting technique to be developed in this paper.

During the past several decades, most universities have been subjected to various periods of growth and decline in their student enrollments. Even during times of relatively stable enrollments for the total university, there have been fluctuations in the student population of the various segments of the university, such as colleges, schools, departments, classes, etc. This variability makes it extremely difficult for a university to plan with respect to the long term commitment of resources, such as housing, laboratories, faculty, etc.

The Model

There are numerous factors which affect enrollemnts, and thus the final demand for a university resource. To create a model which would include all relevant variables to forecast enrollment projections with sufficient detail and accuracy for microscopic use (classroom size information) would be an extremely difficult task. Although these factors may have different effects on the various levels of enrollment, the aggregate effect can be treated as a transition value. Furthermore, many categories of the enrollment are fairly easy to predict, at least in the short term. For example, the enrollment for the junior class of a given department for a fall semester is primarily dependent on the number of sophomores in the previous spring semester. Minor adjustments will occur due to dropouts, transfers, etc., but these can be easily combined and modelled as a trend.

As a class progresses through the university, it suffers a certain amount of attrition during each official academic period. Although this attrition occurs throughout the academic period, the accounting procedures at most universities reflect this as a discrete function. The reasons for growth (or decline) patterns of a class are many; however, most classes follow a definite pattern in their progression. Utilizing this concept, the growth rate or attrition for a given class, as it progresses from one transition period to the next, can be expressed as a fraction. If one further assumes that this growth rate remains fairly constant from one year to the next, regardless of the class size, such a value can be used to predict future enrollment.

This concept can be expressed mathematically by defining a matrix, E_k, which contains the enrollment values of a given university segment for the academic year staring in year k. Thus,

$e_{ij(k)}$ = the enrollment in the ith time period for the jth class of the academic year staring in year k,

where

$$i = 1, \ldots, m$$
$$j = 1, \ldots, n.$$

Normally the value of m would be two (semester system) or three (quarter system) and the value of n would be four or five (most universities operate either four or five year programs). The growth or transition rate can be expressed as a similar matrix, T_k. Thus,

$t_{ij(k)}$ = the transition rate of the jth class of the academic year starting in year k as it progresses from the ith to the i+1 time period;

or

$$t_{ij(k)} = \begin{cases} \text{if } i=1, \ldots, m-1 & \\ \quad e_{i+1,j,(k)}/e_{i,j,(k)}, \quad \text{for } j=1, \ldots, n & \text{(I)} \\ \text{if } i=m & \\ \quad e_{1,j+1,(k+1)}/e_{m,j,(k)}, \quad \text{for } j=1, \ldots, n-1 & \text{(II)} \end{cases}$$

where (I) is the transition rate from semester to semester and (II) is the transition rate from one academic year to the next academic year. In order to obtain the enrollment projections or forecasts for the next time period, the appropriate transition rate is multiplied by the current enrollment. Thus,

$f_{ij(k)}$ = the forecast for the ith time period of the jth class of the academic year staring in year k,

or

$$f_{ij(k)} = \begin{cases} \text{if } i=1 & \\ \quad t_{m,j-1,(k-2)} * e_{m,j-1,(k-1)}, & \text{for } j=2, \ldots, n \\ \text{if } i=2, \ldots, m & \\ \quad t_{i-1,j,(k-1)} * e_{i-1,j,(k)}, & \text{for } j=1, \ldots, n \end{cases}$$

Although the notation becomes rather awkward, the concept is quite simple. For example, assume that it is desired to predict the enrollment in a given department at a university which has a four-year program (n=4) under a semester system (m=2). Further, assume that the current time period is the fall semester (i=1) of the academic year starting in 1977 (k=77) and the department enrollments for the past three semesters are as shown in Table 1.

Academic year	k=76	k=76	k=76
Semester	Fall (i=1)	Spring (i=2)	Fall (i=1)
Class, j=1	200	174	215
j=2	155	144	160
j=3	165	158	170
j=4	150	145	152

Table 1. Enrollment Data, $e_{ij(k)}$

j	1	2	3	4
$e_{1,j,(76)}$	200	155	165	150
$e_{2,j,(76)}$	174	144	158	145
$t_{1,j,(76)}$	0.870	0.929	0.957	0.966
$e_{1,j,(77)}$	215	160	170	152
$f_{2,j,(77)}$	187.05	148.64	162.69	146.83

Table 2. The Spring Semester Forecasts

Using this data and the preceding model, the enrollments for the spring semester of the 1977 academic year are forcasted as follows:

$$f_{2,j,(77)} = t_{1,j,(76)} * e_{1,j,(77)}, \quad \text{for } j=1, \ldots, 4$$

where

$$t_{1,j,(76)} = e_{2,j,(76)} / e_{1,j,(76)}, \quad \text{for } j=1, \ldots, 4.$$

The results and computations are shown in Table 2.

These forecasts for the spring semester could then be used to calculate forecasts for the fall semester of 1978, which could in turn be used to forecast the enrollment for the spring of 1978, etc. There are two potential problems with using such a technique, particularly if forecasts beyond one year are desired.

The first problem is that the forecasts for a fall semester do not include an estimate for the freshman or first class. For example, the fall 1978 forecasts would not include an estimate for the first year class, the fall 1979 forecasts would not include an estimate for the first and second year classes, etc. Therefore, in order to obtain complete forecasts beyond one year, estimates for the successive first year fall semester enrollment must be created. There are two ways to accomplish this. One method is to estimate these values totally independent of the transition concept. For example, a smoothed projection of the previous first year classes, or simply a best estimate can be used. An alternate method would involve using the expected, or known, number of applications as a dummy spring enrollment for the j=0 class, and then using the transition formulas to project the fall enrollment. In this case, the transition value, $t_{2,1,k}$, would obviously be less than 1. The second method could be particularly useful if the intent is to limit the projected enrollment.

The second problem associated with using such a forecasting method is that a large one-time increase or decrease could lead to inaccurate forecasts for the next academic year. Ideally, the computed transition rates should be as representative as possible of the next time period. One method of achieving this would be to smooth the transition rates by using a moving average or exponential smoothing technique[1]. Exponential smoothing is a special kind of weighted average which is suited for data processing applications. The most current estimate is a weighted sum of the last estimate and the trend occurring in the most recent period.

Applying the technique of exponential smoothing to the transition rates would yield the following:

$$t'_{ij(k)} = \alpha t_{ij(k)} + \alpha(1-\alpha)t_{ij(k-1)} + \alpha(1-\alpha)^2 t_{ij(k-2)} + \ldots + \alpha(1-\alpha)^{\ell} t_{ij(k-\ell)} + \ldots$$

or,

$$t'_{ij(k)} = \alpha t_{ij(k)} + (1-\alpha)t'_{ij(k-1)},$$

where

α = the smoothing constant, where $0 < \alpha < 1$

$t'_{ij(k)}$ = the smoothed transition rate for the jth class of the academic year staring in year k as it progresses from the ith to the i+1 time period.

By varying the value assigned to α, more or less weight is given to the most recent transition rate. Using this concept the smoothed transition rate, $t'_{ij(k)}$, is used to compute the forecast, rather than the calculated transition rate, $t_{ij(k)}$.

At this point, it is important to note that this concept represents a substantial departure from normal forecasting methods. Applying exponential smoothing in the normal manner would lead to a forecast which would be a weighted average of the past enrollments. The concept presented here provides a forecast based on the most recent enrollment and a weighted average of the transition rates.

Model Verification

In the development of a prediction model with potential application in the real world, the accuracy of the results must be considered. This accuracy is obviously somewhat dependent upon the application and method of application. The most common, and probably the best, way of establishing the accuracy of a forecasting technique is to actually utilize the technique in a given situation for a number of time periods and compare the forecasted values to the actual values. However, if sufficient historical data exists, this data can be used to assess the accuracy of the technique over the time period for which data is available. This procedure was adopted for the verification of the proposed technique. Two similar situations with fundamentally different applications were considered. The first involved the prediction of dormitory housing requirements at the University of Massachusetts, while the second involved the prediction of undergraduate enrollments in the School of Engineering at Purdue University. Actual historical data was used in both situations.

The forecasting technique was initially developed for the housing office at the University of Massachusetts during the early seventies to forecast future dormitory housing demand. One of the major functions of the housing office is to minimize the dormitory rates by maintaining as high an occupancy level as possible, so that overhead expenses can be spread over a large populus, thus making the dormitory system more affordable and appealing to students. As an aid to accomplishing this task, the previously presented forecasting technique was developed to predict on-campus dormitory demand so that regulations could be adjusted to maintain an appropriate occupancy level.

The University of Massachusetts, like any other university campus, contains a number of variables that affect its enrollment, and thus, the final demand for dormitory housing. The actual forecasts were calculated by considering several independent segments of the university population, each of which has a unique effect on the housing demand. Four basic categories were considered: married undergraduates, non-married veteran undergraduates, non-married and non-veteran undergraduates, and graduate students. In addition, each of the above categories was further divided into male and female.

Utilizing available historical data, forecasts by class and semester were computed for each of the resulting categories. Historical information as to the fraction of each group that actually patronized university housing was then included and the resulting values combined to obtain a single forecast representing the total housing demand. Unfortunately, only a limited amount of housing data was available for verification. Forecasts were computed and compared to actual housing demand for only one academic year, or two semesters. Rather than attempting to forecast a single number for each semester, a range of values was calculated by utilizing multiple values for the smoothing constant ($\alpha = 0.2, 0.3, 0.4, 0.5$). The fall semester forecasted range was 11,572 to 11,789 with an actual occupancy of 11,417. The spring semester forecasted range was 10,431 to 10,521 with an actual occupancy of 10,661. Although both of the actual occupancy values fell outside the forecasted ranges, the first below by 155 (1.26%) and the second above by 140 (1.31%), the forecasts were considered to be quite accurate as compared to previously used methods. Also, for the magnitude of the numbers under consideration, the range is rather small, less than 2% and 1%, respectively.

An alternative method of obtaining a range of forecasted values would be to use a single value for the smoothing constant and then use an absolute or relative deviation about the calculated value. If this method is adopted, the user should be cautioned in the selection of a smoothing constant, since the final forecasted value consists of a composite of values, each of which may react differently to varying values of the smoothing constant. The potential user should be aware that as the smoothing constant is increased, the amount of weighting given to the most recent transition rate is also increased. In the long term, it is recommended that a different smoothing constant be considered for each category in the model. This may provide a more accurate forecast as the user gains expertise with the technique.

Since only a limited amount of data was available from the University of Massachusetts application the authors felt it was necessary to further test the technique in an attempt to provide better verification of its accuracy. To this end, ten years of historical data were obtained for the Schools of Engineering at Purdue University. During the time spanned by this data, some rather substantial enrollment changes occurred due to the changing economic environment over the ten years under consideration from 1967 to 1976. Thus it was felt that this would constitute a rigorous test of the technique. Five different enrollment categories were chosen: the total engineering enrollment and the enrollment for each of four different schools, ranging in size from large to small. For each category, forecasts were calculated by class (n=4) for each semester (m=2) using five different values for the smoothing constant (α = 0.1, 0.2, 0.3, 0.4, 0.5).

The first five years of data were used to allow the system to approach a steady state, and statistics on the accuracy were collected for only the most recent five years. The results were quite variable and appeared to be very dependent on the population size as well as the value of the smoothing constant, α. Because of this apparent dependence, the results will be discussed separately.

The forecasts for the total engineering enrollment were by far the most accurate. The average error ranged from a low of 1.16% to a high of 29.14%, depending upon the class, semester, and smoothing constant. The most accurate results were consistently achieved for α = 0.5, which implies that the most recent transition rates should be given a high weighting when computing the forecasts. For a smoothing constant of 0.5, the average error ranged from a low of 1.16% to a high of 5.55%, with an overall average error of 3.77%. The largest errors were found to occur in the prediction of the sophomore class, for both semesters. A possible reason for this is discussed later. The enrollment values, by class, for this category ranged from approximately 900 to 1600.

The forecasts for the four individual schools were not as accurate as the total enrollment forecasts. Again the best overall accuracy was achieved for α = 0.5 with the average error ranging from a low of 1.26% to a high of 19.88%. The highest errors consistently occurred in the prediction of the sophomore class. The average errors for the junior and senior classes were always less than 8%. The enrollment values, by class, for these categories ranged from approximately 40 to 300.

One of the reasons for the high error in the prediction of the sophomore class is probably due to the student classification system used by Purdue. All first year engineering students are classified as general engineering students. Only after they have completed the general engineering requirements are they classified in the school of their choice. This normally occurs at the start of their second year, but may occur much later. Thus, the basis of the sophomore forecasts for the schools was the total engineering enrollment. This could account for much of the error at this level. Also, external factors, such as the job market, have had a substantial impact on engineering enrollment in the past several years.

Summary

The accuracy attained using this algorithm may not be as good as desired (after all, the exact enrollment is what one seeks.) The method, however, was found to better existing techniques for forecasting student populus. In addition, a relatively small amount of unstable data was used to verify the model. It is quite possible that fine tuning this technique with gained experience could result in much greater accuracy. From this experience, it is possible to build a history to place confidence limits on the forecast.

Another use of this technique, previously not mentioned, would be to forecast the dynamics of a university. For instance, if a university was to suffer an unexpected attrition, should it allow a very large freshman class to enter? If it does, how much room will there be for future freshman classes? What would the final effect be?

To summarize, it appears that this technique offers reasonable forecasts as is. With time, the forecast could be improved and confidence limits assessed. It also appears that the dynamics of a university can be studied to assess decision policies that may have an adverse long term effect.

6

COST AND ORGANIZATION IN ENGINEERING COLLEGES

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R. G. Nevins

Everyone seems to be concerned with the costs of higher education these days. "Accountability" and "cost-effectiveness" are now favorite words, and political weapons as well, of many administrators in educational institutions.

We in engineering colleges are newly sensitive to suggestions of high costs and inefficiencies in our operations. In the past 20 years we have seen bulges in enrollments which strained our capacity, followed by steadily declining enrollments. The study of engineering seems not to be as attractive as it once was, although new engineering graduates still receive more job offers and are employed at higher salaries than most other new graduates of our universities; predictions are now made that many more engineers will be needed within the next few years than will be graduated.

True accountability and cost-effectiveness are not the costs per credit hour or the number of students per faculty member, which are the standards commonly computed in detail and offered for comparison of efficiencies in education. It is impossible to include the most important factor in determining what is received per dollar of cost--quality.

As in many industries, high cost graduates may be cheaper per unit of output received than cheaper ones who can produce little or nothing of value. It is possible to discuss several factors affecting efficiency of the operation of engineering colleges without mentioning quality, and it is the purpose of this article to do so.

It is standard knowledge in engineering that maximum output occurs when all production lines are balanced and run at constant maximum speed.

Suppose that all courses in all degree-granting departments are required and given in sequences without replication, i.e., course requirements for every degree are completely specified, invariant, and offered once in sequence so that students are lock stepped into the curriculum they have chosen, and are required to maintain the schedule by the standard program.

Suppose further that each faculty member can teach--and has completely under control--three courses, and that equal numbers of students are admitted each semester into each curriculum leading towards a degree. The number of faculty which then would be required by a proposed conventional curriculum at Kansas State University is given by the graph (shown in figure 1) for various numbers of students admitted each semester into each curriculum, i.e., students per major per semester. It is assumed that one section of each class is taught until the capacity of 25 per lecture section and 12-25 per laboratory section is reached, and that each faculty member can handle three courses.

The number of faculty required increases slowly as the total number of students increases, because there are a few service courses taken by all majors. These necessitate the use of multiple sections at smaller total enrollments than occur in courses offered in the majors. A large jump in the number of faculty required occurs when single section capacities are reached in the majors.

It is obvious that if student admissions were controlled to fit the course requirements, capabilities, and organization for efficient use of the faculty, great economies could be made without changing the quality of instruction.

Approximate Behavior of the New Curriculum

About two years ago our industrial engineering department modeled our then proposed new curriculum to see how the number of faculty needed to man the courses required would vary with changing enrollments, assuming the fractions of students enrolled in the various curricula remained the same, and the courses they took were distributed according to that which actually occurred in the spring semester of 1971. The students were distributed as shown in table 1.

The faculty required was estimated on full-time equivalents of nine semester credit hours of recitation and six semester credit hours of laboratory. Sections were limited to 25 in lecture classes, and 12-25 in the laboratories. The proposed new curricula required a total of 134 courses in the College of Engineering, of which 90 would be offered in the spring semester.

The faculty required as a function of enrollment was determined for enrollments of from 600 to 1,400 students in increments of 200, and plotted as curve F_n in figure 1.

In an effort to estimate the effects of introducing core curricula which would include a total of 104 courses, of which 67 would be taught during the spring semester, the same model, limitations on section enrollments, and faculty teaching loads were used to determine the number of faculty required as a function of total enrollment.

This number is shown as curve F_c of figure 1.

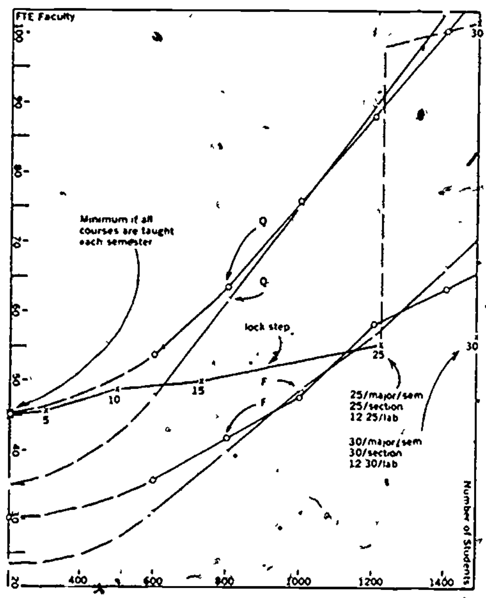

Figure 1 Faculty required as a function of enrollment.

It is seen that this core curriculum would be more efficient than the new curriculum only at student enrollments of fewer than about 800. As the current undergraduate enrollment at Kansas State is about 1,000, little change in efficiency would be made if these curricula were adopted instead of the new one proposed.

Impedance Mismatch in Versatility--A More Realistic Estimate of Faculty Requirements

The curves F_c and F_n show the faculty needed for the spring semester only. What effect, if any, does the fall semester have on the total faculty required?

A faculty member cannot be used efficiently in low enrollments situations unless he can teach a number of different courses equal to two semesters' full teaching loads. At three courses per semester--a modest teaching load according to many college administrators--a faculty member would need to have six different courses under control to be really efficient. It is unreasonable to expect faculty members of engineering colleges to be this versatile.

Engineering colleges with small enrollments require more faculty members to man their curricula, because of differing course content, than are required by the numbers of students in individual courses.

The curves in figure 1, extrapolated to zero enrollment (with the assumption that each faculty member can teach three different courses) show that a significant number of faculty members would be needed to man the courses required by the curricula offered even if they were presented to empty classrooms.

A certain minimum faculty is needed no matter how low enrollments fall.

Several simple fractions can be used as measures of the maximum efficiency with which a faculty member can be used.

These are:

K/2L = fractional teaching load made up by teaching different courses without repitition, and

1-K/2L = fractional teaching load which must be made up by repitition of courses or other duties,

where

K = number of different courses a faculty member can teach.

L = number of courses which forms a full teaching load in one semester.

Let

N = the total number of required courses.

R = the number of required courses offered for "regular" students in a given semester.

M = the total number of required courses offered in a given semester.

To attain maximum efficiency, M should equal R, and R should be half of N, for this would keep the smallest number of faculty at full teaching loads for both semesters while teaching all different courses.

Table 1. Distribution of Enrollment into Various Curricula

Curriculum Identification Number	Semester Number 2	4	6	8
500	80	0	0	0
505	12	5	13	14
520	24	24	28	21
525	40	24	35	48
530	66	61	71	71
550	8	15	24	23
560	39	53	57	65
580	29	18	15	21
	298	200	243	263
			Total	1,004

Using subscripts 1 and 2 to designate spring and fall semesters, respectively, it is obvious that

$$M_1 + M_2 \geq N$$

with the equality possible practically if, and only if, the lock-step organization is used. To accomodate irregular students, it is necessary that M be greater than R.

This inequality appears to hold for all engineering colleges in the United States, with the exception, perhaps, of the military academies.

It could be argued that a measure of inefficiency of use of the instructional staff is

$$2\left(\frac{M - R}{N}\right),$$

which is the fraction of total course offerings made in excess of those required for the regular students.

We hypothesize that

$$2\left(\frac{M - R}{N}\right) = 1 - K/2L$$

tends to hold for small college enrollments, i.e., the impedance mismatch between the versatility required of a faculty member for inefficiency and that which is reasonable to expect of him tends to be made up by replication of enough course offerings to make up full-time teaching loads.

The alternatives, of course, are to keep faculty members busy at sponsored research or other duties (such as teaching small graduate classes which could not be justified on economic grounds), while waiting their turn to teach required courses they know how to teach, in another semester.

The efficient use of faculty is not the only consideration in organization for over-all efficiency. Some courses must be offered each semester to accommodate irregular students. The above equation should be modified to read

$$2\left(\frac{M - R}{N}\right) = 1 - \frac{K}{(1 - k)2L},$$

where k is the fraction of the teaching load L, consciously used to accommodate the irregular students to increase the efficiency of use of their time.

We believe that K is normally 3 to 4, L about 3, and k about ¼.

Thus, the curves F_n and F_c of figure 1, which show the faculty needed to man the courses offered in the spring semester, are unrealistic measures. While these members are teaching courses they know how to teach, others must be waiting their turn to teach different required courses the next semester--courses which the currently teaching faculty cannot teach well.

A more realistic measure of the total number of faculty required is

$$Q = \frac{N}{M} F.$$

The factor N/M is the ratio of the total number of required courses to that offered in a given semester, The curves Q_n and Q_c show this more realistic estimate in figure 1.

Formulas for F_n and F_c which fit the data obtained from the model are

$$F_c = (a + bn) = 4.3 + 0.0445N;\ n \geq 600,$$

and

$$F_n = (a + bn + \frac{c}{n - d}) = 4.3 + 0.0445n + \frac{1000}{n - 400},\ n \geq 600;$$

and for Q_n and Q_c

$$Q_n = \frac{N_n}{M_n} (a + bn + \frac{c}{n - d}) =$$

$$\frac{134}{90} (4.3 + 0.0445n + \frac{1000}{n - 400}),\ n \geq 600$$

$$Q_c = \frac{N_c}{M_c} (a + bn) = \frac{104}{67} (4.3 + 0.0445n),\ n \geq 600,$$

where F and Q are numbers of faculty, and n numbers of students.

The total faculty required for the more realistic estimates Q_n and Q_c are given in table 2.

Table 2. Total Faculty Required

	Enrollment				
	600	800	1000	1200	1400
Q_n	54	63	75	88	101
Q_c	48	62	76	90	104

The number of students per faculty member are given in table 3.

Table 3. Students Per Faculty Member.

	Enrollment 600	800	1000	1200	1400
n/Q_n	11.1	12.7	13.1	13.7	13.8
n/Q_c	12.5	12.9	13.1	13.3	13.6

The costs per student credit hour are easily computed from

$$C = \frac{(FTE)\$}{(cr)n}$$

where

C is the cost per student credit hour,
(FTE) is the number of faculty, Q_n or Q_c,
(cr) is the average number of credits taken by a student,
n is the number of students, and
\$ is the average salary per faculty member.

Costs per student credit hour as computed from this formula for various curves of figure 1 are shown in table 4.

The costs per student credit hour shown in table 4 were computed assuming \$ = 16,000, and (cr) = 16.

Costs per student credit hour must be used with caution. Using F_n in the formula yields

$$C = \left(\frac{4.3}{n} + 0.0445\right)\left(\frac{\$}{(cr)}\right).$$

If $n > 1000$, $4.3/n < 0.0043$, and the part of the cost which varies with n is less than ten percent of the cost per student credit hour. Thus, this index is a mixed one--it depends on both the slopes of the (FTE)-n curves (which have something to do with efficiency) and on n (which by itself does not).

This weak dependence on n is apparent in table 4. It indicates that costs per student credit hour for similar curricula at different institutions should be compared (with caution) only if enrollments, curricula, average student course loads, and average faculty salaries are nearly alike.

Costs per student credit hour are often unrelated to total expenditures. What does it matter if a few credit hours are very expensive if the total is an insignificant fraction of the overall cost? Relatively few expensive graduate student credit hours may provide for a

Table 4. Costs Per Student Credit Hour.

Enrollment	Proposed New Curricula Q_n	F_n	Core Curricula Q_c	F_c
600	$90	$60	$81	$52
800	80	54	78	50
1000	77	49	77	50
1200	75	49	76	48
1400	74	46	76	48

much cheaper overall cost per student credit hour by providing graduate student instructors as teachers to extend the productivity of senior faculty. A cheap product can be good and reliable if the few essential parts, while expensive, are of high quality. It is not necessary (nor true) that the best inexpensive product be made entirely of the cheapest possible parts.

The Place of Core Curricula

The curves, which are only qualitative in spite of their analytical character, indicate that the core curriculum would be more efficient than the proposed new curriculum at enrollments lower than 800.

The surprising finding that the core curricula investigated require a larger faculty than the proposed new curricula is due to the fact that the two curricula have not been compared under equivalent circumstances. The multipliers N/M, which account for the versatility impedance mismatch of the faculty, were taken to be somewhat different for the two curricula (inadvertently, for the comparison was made before the mismatch was recognized).

It is to be expected that (FTE) for both the proposed new curricula and the core curricula examined should converge as n increases. When the student body is large enough, the number of faculty required depends only on the limits chosen for class size, and curricular structure has little effect on efficiency in this case.

Colleges of engineering are organized the way they are for historical and political reasons. The traditional division into departments, which is encouraged by the founders' societies and accrediting groups (in spite of increasing overlapping in teaching and practice brought on by the better understanding of nature now expressed in generalized theories), was efficient when enrollments at colleges such as ours were at about 1,400. It is becoming marginally efficient as enrollments decrease.

A completely unrelated factor--the nationwide proliferation of junior colleges--also makes some core curricula appear attractive. It is likely that increasing numbers of students will enter engineering curricula as transfer students from these junior colleges. Engineering curricula should be organized to make this transition as smooth as possible.

The traditional structure becomes naturally less efficient as enrollments drop. This is true not only for the reasons previously discussed, but also because the easiest way to maintain departmental work loads as the number of students decrease is to require that curricular students take more courses within their own departments. Who can dispute successfully the argument that each department knows what is best for its students? And which faculty admits that it cannot teach its own students better than any other? Or is unable to select 90 lectures, 45 at a time, to design any number of "special" courses "particularly tailored" for its students? In a time of declining enrollments every degree-granting department tends to become a self-contained engineering college which is guaranteed to be inefficient.

The Place of Service Departments in the Present Structure

The present structure of traditional engineering schools is shown in figure 2. There are usually six to eight degree-granting departments and one or two service departments, if any.

Because of this structure, service departments have always been in poor political positions within universities. They have no students of their own and are unable to keep degree-granting departments from absorbing the content of their courses, to maintain teaching loads in the presence of declining enrollments. Although many service departments have disappeared, their courses have re-emerged in other curricula.

Modern engineering analyzes, synthesizes, and designs by using mathematical models. The construction of such models is not natural--novices must learn a foreign language (mathematics) and use it to describe realities newly experienced in engineering laboratories. Service courses should be those early ones in which students learn how to fit mathematical models to physical realities. In particular, mechanics courses are the only ones in which students can make descriptions built on past experience involving their own senses.

The essential inefficiency which occurs in colleges of engineering with traditional structure and fewer than 800 students is that the departments form too many subdivisions and offer too many courses which increasingly overlap those taught in other departments.

An administrative departmental structure, such as shown in figure 3, may have advantages, provided there are fewer service departments than curricula.

In an organization such as this, each faculty member would belong to two groups--a curricular committee and an administrative unit. The curricular committee would, as in the traditional organization,

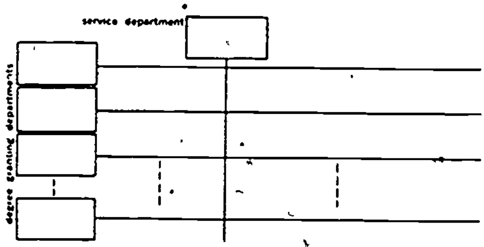

Figure 2. Conventional organization of engineering colleges.

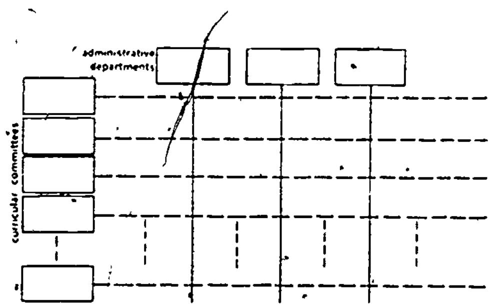

Figure 3. Administrative unit organization of engineering colleges

recommend courses and establish curricula. These are academic matters and, as before, who knows what is best for curricular students? This structure would satisfy most external political interests. But teaching would be done only within the administrative units, with courses and faculty assigned according to economic policies established by the dean.

This organization would provide university administrators with real means for mainlining engineering instruction along modern directions and for increasing the efficiency of college teaching. The separation of the curricular committees from the administrative units forms the real strength of this organization, for it allows honest confrontation between the committees for establishing degree requirements without allowing direct economic benefits to accrue from decisions supposedly made for academic reasons.

These administrative units could be the most important defenses against proliferation of engineering colleges within a university.

A Few Closing Remarks (Some of Which Have Been Substantiated)

With conventional structure and curricular requirements the minimum enrollment in colleges of engineering should be more than 1,000 to attain reasonable efficiency. It appears that for class size limitations of 25 for lecture recitation sections, and 15-25 in laboratories, with seven degree-granting departments and one service department, maximum efficiency can be attained with an enrollment of about 1,200 or more.

Higher efficiencies of instruction would be obtained with core curricula at total enrollments of 800 or fewer.

Costs per student credit hour are not very good indicators of efficiency. The real cause of inefficiency in teaching at small total enrollments is an impedance mismatch between what a faculty member must be able to teach for maximum efficiency, and what it is reasonable to expect of him.

The development of versatility should be encouraged among the faculty. Core interest groups, the teaching of small graduate classes, exchange of faculty among departments, and individual research all tend to increase versatility. Small graduate programs which are impossible to justify using cost criteria alone are among the things which increase the efficiency of instruction in the long run. In a certain sense they are almost free as they can be of by-products of the versatility mismatch of the faculty.

Attempts to increase efficiency by deleting single departments are likely to reduce total expenditures without changing efficiency much. Less money will be spent, but that which is spent will be used about as inefficiently as before.

Overall efficiency would be improved by closing enough engineering colleges to cause minimum enrollments at the remaining ones to rise to at least 1,200. If this is not possible for political reasons, shifts to core curricula should be made as enrollments decrease below 800.

HOW DO ACADEMIC ADMINISTRATORS SPEND--AND THINK THEY SPEND--THEIR TIME?

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With the large number of different activities that occupy administrators of engineering education, it is difficult to determine how much time should be allotted each activity in order to maintain high overall efficiency and performance. When an engineering dean or department head becomes frustrated with his reduced scholarly output or performance, he may feel the need to employ an administrative aide or assistant to help relieve him of a portion of his more routine assignments, so that he can put a larger share of his energies toward research, teaching, professional writing, and other professional work.

In order to find out how the typical engineering education administrator thinks he distributes his time and how these values compare with actuality, a study was undertaken. A questionnaire was completed by a group of administrators and a work sampling study was carried out. It was felt that if an administrator could simultaneously compare how he was spending his time with how he thought he was spending it and how he should be spending it, he would have the facts to make some constructive changes in his work procedures. These changes might involve a forced change in his work schedule, a reassignment of priorities, a further delegation of responsibilities, or the employment of an administrative assistant or aide.

For this investigation the work performed by engineering administrators was classified into 19 categories:

1. research, including thesis supervision
2. teaching (both graduate and undergraduate)
3. professional writing
4. routine dictation
5. planning
6. professional reading
7. advising
8. university meetings
9. college meetings

10. department meetings
11. administrative
12. routine clerical
13. professional consultation
14. talking with manufacturing representatives
15. course preparation
16. continuing education
17. visitation
18. personal
19. other

Sixteen engineering administrators participated in the study. Ten of these were heads of engineering departments and six were deans in a college of engineering (one dean, one associate dean and four assistant deans).

Each of the 16 administrators was asked to complete a questionnaire which listed 15 activities. (The fifteenth activity included course preparation, continuing education, visitation, personal and other). The administrators were asked to record the percentage of their time taken up by each of the 15 activities. They were also asked to state an ideal percentage of time to be spent on each of the activities.

In the work sampling study of the 16 administrators 150 random observations of each administrator were made over a five week period, resulting in a total of 2,400 random observations.

The survey required six random observations per day Monday through Friday (six observations/day x five days/week x five weeks). Since the various administrators were remotely located in relation one to another, their secretaries were telephoned at the appropriate random time, and they asked their supervisors exactly what they were doing at the time of the call. A table of random numbers was used to determine the exact time of day for each telephone call. Although this method of data collection was not ideal, it did permit making the study over a relatively short period of time and no personnel problems arose from the repeated queries as to what an administrator was doing at a particular time of day.

Do Administrative Aides Change the Picture

As some of the department heads did not have administrative assistants, we investigated whether those department heads with administrative assistants were spending a significantly higher proportion of their time on professional endeavors. The study revealed that, on the average, the eight administrators with administrative assistants were spending more time on research, thesis supervision, teaching, and professional writing than the eight administrators who did not have assistants. The difference in how the two groups were spending their time was significant at the 0.10 level.

Table 1 reflects this trend. It also shows that administrators without an assistant are spending more time on advising and have less time to participate in university meetings and course preparation.

The seven work activities (research and thesis supervision, teaching, professional writing, advising, university meetings, professional reading, and course preparation) were considered to be of major importance and of a professional nature that in combination should occupy the typical engineering education administrator at least one third of his time. To determine whether deans and department heads with administrative aides divide their time differently from those without aides, a test of means using independent samples was made. Assuming normality, the t statistic for testing the significant difference of two means was applied. The computed value of t was 1.51.

t_{10} at fourteen degrees of freedom = 1.345

Therefore, at the 0.10 level we feel that there is a significant difference in how the two groups divide their time.

In order to estimate the average proportion of time spent on the aforementioned professional activities by those with an administrative aide and the proportional decrease in time among those without one, a one-way analysis of variance was made. The technique used is referred to as "multiple regression with dummy variables" and is useful to analyze the impact of qualitative data.

Arbitrarily it was decided to assign $x_1 = 0$ for deans and department heads with administrative aides and $x_2 = 1$ for those without aides. The one-way analysis of variance library program, QSASE, generated the following regression equation from our input data.

$$y = 34.27 - 7.403X$$

By substitution in this equation, $x_1 = 0$ for the group with administrative aides and $x_2 = 1$ for the group without administrative aides, the average proportion of time that each group spends in professional activities can be estimated:

$$Y_0 = 34.27 - 7.403(0) = 34.27\%$$

$$Y_1 = 34.27 - 7.403(1) = 26.87\%$$

We therefore estimate that 34.27% is the average time spent by deans and department heads with administrative aides on professional activities. The partial regression coefficient (b = -7.403) indicates the estimated average decrease in the proportion of professional time spent by deans and department heads without administrative aides.

Similar statistical analyses were made based on department heads only. The results were similar. Those department heads with administrative aides were able to spend a significantly higher proportion of their time on professional work.

A chi-square "goodness of fit" test was made for each dean and department head in order to determine if administrators are able to estimate accurately how they are allocating their time. The test hypothesis used was:

Table 1. Distribution of Time by Administrators with and without Administrative Assistants.

#	Research & Thesis Sups	Teaching (Graduate & Undergrad)	Profess Writing	Advising	Univ Meeting	Profess Reading	Course Prep	Total
Administrators With Assistant								
1	0.00%	13.78%	0.00%	0.86%	0.00%	1.72%	9.48%	25.84%
2	11.27	8.27	3.76	6.76	5.26	2.25	5.26	42.83
3	7.90	9.03	1.70	4.72	10.73	6.21	6.21	46.03
4	6.66	10.00	0.00	13.34	1.66	0.83	0.83	33.32
5	7.20	0.00	3.60	0.90	6.30	15.51	0.00	31.51
6	0.00	0.00	0.00	0.78	16.40	3.20	0.00	20.30
7	1.90	19.00	3.80	10.48	6.66	1.90	1.90	45.64
8	11.50	0.00	3.45	4.60	6.90	1.15	1.15	28.75
Administrators Without Assistant								
1	1.48	2.20	2.20	5.14	0.00	5.14	0.73	17.25
2	3.88	18.44	1.94	2.92	1.94	2.94	1.94	34.00
3	2.91	0.00	0.00	1.94	12.62	11.65	0.00	29.12
4	16.19	6.60	0.00	1.90	0.00	0.95	2.85	28.49
5	0.00	8.14	0.00	9.88	4.65	0.00	2.41	25.58
6	0.00	0.00	0.00	33.04	2.60	9.56	0.00	45.20
7	0.00	0.00	0.00	11.66	6.66	3.33	0.00	21.65
8	0.00	0.00	0.00	4.20	9.45	0.00	0.00	13.70

Table 2. Calculation of X^2 Test Statistic for Administrator "A"

Activities	Observed (fa)	Expected (fe)	fa-fe	$(fa-fe)^2$	$\Sigma\frac{(fa-fe)^2}{fe}$
Research & Thesis Supervision	14	17.70	-3.70	13.69	0.77
Teaching (both Graduate and Undergraduate)	16	35.40	-19.40	376.36	10.63
Professional Writing	18	17.70	0.30	0.09	0.01
Routine Dictation	7	12.40	-5.40	29.16	2.35
Planning	20	8.85	11.15	124.32	14.04
Professional Reading	11	3.54	7.46	55.65	15.72
Advising	8	5.31	2.69	8.76	1.65
University Meetings	19	19.47	-0.47	0.22	0.01
College Meetings	26	8.85	17.15	294.12	33.23
Departmental Meetings	4	8.85	-4.85	12.09	1.36
Administrative	6	17.70	-11.70	136.90	7.73
Routine Clerical	3	3.54	-0.54	0.29	0.82
Professional Consulting	14	14.15	-0.15	0.02	0.01
Talking with Manufacturing Representatives	1	1.77	-0.77	0.59	0.33
Personal Course Preparation Continuing Education, Visitation and Other	10	1.77	8.23	67.73	38.26
					X^2 = 126.26

Ho: There is no difference between what deans and department heads are doing from what they believe they are doing.

Ha: What deans and department heads are doing is different from what they believe they are doing.

Table 2 provides the calculation of the chi-square test statistic for a given administrator. The x^2 value of 126.26 is significantly greater than x^2 = 29.14 for 14 degrees of freedom. Therefore, we reject Ho and accept that there is a significant difference between what department head A is doing according to the work sampling results and what he believes he is doing according to his questionnaires. Similarly, all the other administrators sampled provided data resulting in chi-square values that caused us to reject Ho and accept that there is a significant difference between how engineering education administrators believe they spend their time and how they actually spend it.

Conclusion

In summary, it can be concluded that many administrators in engineering departments do not have a realistic idea of how much of their time is being spent on the various duties, responsibilities, and functions related to their positions.

A technique that can provide them with factual information on how they are spending their time is work sampling. We recommend that every administrator should periodically have his secretary sample his work as described here so that he will know how he is spending his time and can make appropriate changes in his work schedule when it seems desirable.

Secondly, it can be concluded that with the increasing volume of data, controls, and reports required by so many segments of society, the academic engineering administrator cannot be productive in professional activities unless he is provided adequate support to relieve him of the ever-increasing volume of administrative detail.

8

ADMINISTERING ENGINEERING AND TECHNOLOGY PROGRAMS ON THE SAME CAMPUS

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Two of the most significant events in engineering education in the late sixties and early seventies were the national decline in enrollments in schools of engineering and the advent of engineering technology into the baccalaureate field.[1] Had each event occurred alone, its significance might have been somewhat lessened. They occurred, however, simultaneously, and thereby created a stir of national interest in engineering education circles. Institutions which had been providing associate degree programs in technology expanded their offerings to include baccalaureate programs in engineering technology (BET). Schools of engineering also expanded their offerings to include the BET program in order to meet student interest and bolster lagging enrollments. While ASEE provided nationally recognized criteria for the academic development of BET programs,[2] and ECPD accepted the responsibility for their accreditation,[3] the development of their administrative structures has been an institutional function.

Institutions undergoing the development of BET programs or the reorganization of existing programs seek guidance regarding the appropriate administrative structure for their kind of institution. This question is of particular interest to those institutions housing programs in engineering and engineering technology on the same campus. The purpose of this paper is to report the results of a national survey recently conducted to provide information on the administrative structure of BET programs and to draw attention to the administrative interfacing of engineering and engineering technology on the same campus.

The Survey

Upon finding that no national agency maintained a complete listing of institutions offering BET programs, Moore and Will developed in 1973 a listing of 95 such institutions.[4] I surveyed these institutions to learn of the administrative structures under which their BET programs were offered. Of the 95 surveyed, 73 responded with positive indication of their BET program offerings. Their responses are recorded in table 1 in such a way as to categorize institution types based on their program offerings. The predominant administrative structure in use by each category is then revealed. Since institutions were asked only to report their particular administrative structure and not to judge its success, implications drawn from the survey results are those of the author alone.

Table 1. Administrative Location of BET Programs

73 Institutions offer the BET program	41 offer both the associate and BET programs 32 offer the BET program only
41 Institutions offer both the AAS & BET	38 administer both programs in same unit 3 administer the programs in separate units
41 Institutions offer both the AAS & BET	18 have a School of Engineering on campus 23 have no School of Engineering on campus
18 Institutions offer both the AAS & BET School of Eng on campus	9 administer both programs outside the School of Engineering 9 administer both programs in a School of Engineering
32 Institutions offer the BET program only	25 have a School of Engineering on campus 7 have no School of Engineering on campus
25 Institutions offer the BET only School of Eng on campus	23 administer BET in School of Engineering 2 administer BET outside School of Engineering

Of the several administrative structures in use, these three seemed typical:

1. Engineering and engineering technology administered as separate academic units reporting to separate deans.

2. Engineering and engineering technology administered as separate academic units reporting to the same dean.

3. Engineering and engineering technology administered in the same academic unit with common faculty reporting to a dean.

The first and second of these administrative structures are similar in that they require separate academic units for engineering and engineering technology. They differ, however, in that these units administratively report to either separate deans for to the same dean. The survey reports both of these administrative structures to be commonly employed. Some of the advantages and disadvantages in the administration of both engineering and engineering technology under the same dean, a dean of engineering, are suggested in the discussion below.

<u>When Same Dean Administers BET and Eng. Programs</u>

Advantages

1. *Promotes upward academic mobility of associate technology graduates into engineering programs.*

2. *Promotes cooperation among faculty and more efficient utilization of classroom and laboratory facilities.*

3. *Promotes the professional upgrading of both engineering and technology faculties.*

4. *Promotes professional development in technology students through association with engineering students.*

5. *Provides for greater administrative and budgetary flexibility.*

6. *Promotes the development of joint courses and activities.*

Disadvantages

1. *May result in considerable loss of unit identity for technology.*

2. *Faculty and administrators must be knowledgeable about engineering and technology programs, sensitive to their differences, and dedicated to the success of both programs.*

3. *Tendency toward common course and laboratory materials for both programs and an intermix of teaching assignments at the graduate and undergraduate levels.*

4. *Because of enrollment pressures and personal biases, students may be advised into programs in which they have no interest or aptitude.*

5. *Technology students and programs may be termed second rate by virtue of direct comparison with engineering.*

6. *Differences in faculty degree requirements and experience will result in problems regarding promotion, tenure, salary increases*

and contract terminations.

Obviously, the advantages listed for administering both units under the same dean are the disadvantages of administering them under separate deans.

The advantages and disadvantages posed here are not complete, nor are items cited in order of importance. There is certain to be disagreement on whether certain items are indeed advantages or disadvantages. They are presented, however, in order that developing institutions are made aware of the nature of structures most commonly used and of some prospective problems with each.

The third of these administrative structures, with a common faculty reporting to a dean, requires a complete mix of faculty reporting to a dean, requires a complete mix of faculty and academic resources which may obscure unit identity. When this results, students of both programs may suffer the consequences. An intermix of teaching assignments at the graduate, undergraduate and associate levels is probable, especially in smaller programs. Many faculty who are highly motivated to research, publication and graduate studies are not by nature suited to instruct technology students. Faculty willing to devote the time and patience necessary to instruct technology students are not likely to be dedicated to research.

Because of differences in objective and philosophy, a single laboratory facility cannot meet the needs of both engineering and engineering technology unless it is very carefully and elaborately prepared. In an environment such as this, the unit administrator must have a thorough knowledge of both programs, their differences and objectives, and must have an understanding of the characteristics of students in both programs. He must mold a cooperative and understanding faculty in order that flexibility is developed to meet diverse needs. Both faculty and administrators must be continually alert in order that course materials and courses do not blur into a similarity not suited for either program. If an institution is committed to serving its community with programs of high quality, it should select an administrative structure offering greater possibility for success.

Conclusions

The development of administrative structures in which BET programs are housed has not followed a central pattern.

The survey revealed that both the nature of the BET program offered and its administrative location are influenced by the presence of a school of engineering on campus and the offering of associate degree programs.

For greater success, institutions contemplating the proper administrative location of their BET programs should arrange to house their Associate and BET programs in the same academic unit and should provide for unit identity. Locating this unit in a school of engineering or a school of applied science is of less significance to its success and should depend on a consideration of the relative advantages and disadvantages of each location.

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9

PLANNING FACTORS STUDY FOR TECHNOLOGY EDUCATION (INCLUDING FACULTY SALARIES)

R. Bruce Renda
Purdue University

Need For The Study

As academic resources become scarcer, the division of the academic pie becomes more competitive and more difficult to accomplish. Technology educators need reliable cost figures (national as well as campus-specific) in order to meet the following objectives:

1) Successful survival of the annual or bi-annual fiscal decision-making process,

2) Elimination or reduction of intradepartmental and intraschool inequities,

3) Realistic planning for future program expansion or improvement,

It is possible to generalize and classify the budgeting process according to four basic types:

1) Formula-funding

2) Add-on or subtract-from

3) Zero-base budgeting

4) "Equitable" distribution of the wealth or poverty

In practice the actual budgeting process may be a combination of varying degrees of one or more of the above. Regardless of the type of budgeting used, in order for a dean or a program director to justify his budget requests, it is important for him to have accurate, reliable, and convincing cost figures.

It is the intent of this paper to report on the continuation of the "Planning Factors Study for Technology Education" initiated in 1978.

History

While Dr. L. J. Meriam was serving as dean of the Duke University School of Engineering, he initiated a cost study involving 14 engineering schools in the Southeastern Section of ASEE for the academic years 1967-68. Beginning with the academic year 1976-77, this study has become a national study sponsored by ASEE and ECC and conducted by the University of Florida College of Engineering. Since there are a great many educational similarities between engineering and technology programs, there is a need to generate cost and planning factors data for comparative purposes for these two types of programs. During the Second Annual Technology Leadership Conference held at Purdue University on October 17, 1977, the author of this paper made a short oral presentation to see what interest there was among the technology educators to conduct such a study. The response was enthusiastic. During the Third Annual Technology Leadership Conference held again at Purdue University on October 15, 1978, the participants were invited to comment on a draft of the proposed questionnaire for this study. A conscientious and concerted effort was made to make the questionnaire used as similar as possible to the one used by the Engineering Schools.

Caution In Use of Data

This study is only as good as the data provided by the participants. Caution should be exercised in the analysis of the data since there was room for varying degrees of interpretation of instructions, definitions, etc. Forty-six of the 156 schools which were contacted participated in this survey this year. This response is very gratifying as this is the second year of what is now an annual study. We are looking forward to an increased number of participants in the years to follow so that we may improve the validity and accuracy of the survey. It is difficult to arrive at a base common to all schools—let alone a base common to those institutions which have both engineering and technology programs combined under one administrative unit. Budgeting and accounting system anomalies are commonplace. For example, the Purdue University School of Engineering and Technology at Indianapolis utilizes a departmental structure for the respective engineering technology and engineering programs. In the School of Engineering and Technology budget, a specific number of positions are assigned to each department. Departmental budgets include faculty salaries, benefits, supplies and expenses, and travel. Determination of relative amounts in support of the engineering technology programs for these departmental categories is, therefore, straightforward. However, wages and salaries plus benefits for all administrative, clerical, and support personnel are charged against the Dean's Office along with all capital equipment expenditure. These costs often cannot be directly allocated to one specific program or department. In these and similar instances, a uniform technique for pro-rating costs into an appropriate classification is essential.

Interpretation of Data

Exhibit I - Displaying the salaries for administrative personnel as well as faculty in technology programs is self-explanatory. It is obvious that there are few administrators on the associate and assistant deanship level.

Exhibits II-A, B and C - Showing the comparative salaries for engineering administrators and faculty versus technology administrators and faculty contain more reliable data for faculty than for administrators. It is interesting to note that on the instructor and the assistant professorship level, the average salaries for engineering and technology are about the same. For associate professorships, salary differences range from $1,000-$1,800 and for full professors the difference varies from $3,000-$4,500 (depending upon whether one uses E.C.P.C. figures or U.F.C.E. figures) for the academic year 1977-78, whereas the gap has increased to $2,000 and $6,000 respectively in the academic year 1979-80!

Exhibit III - Contains a great deal of cost information for technology programs which requires a careful analysis in conjunction with the questionnaire that accompanied the study. The institutions that participated in the study will receive a more detailed analysis of this exhibit as well as an analysis of their own costs soon.

Exhibit IV - Shows the cost analysis for engineering programs versus technology programs. There are a number of interesting conclusions that one can draw. The author wishes to point out a couple of the comparisons that seem to be most significant:

a. For the academic year 1978-79, the engineering programs received instructional support of approximately $77 per student credit hour taught versus $60 for technology programs, whereas the 1977-78 figures were $75 and $45, respectively.

b. In the academic year 1978-79, the engineering faculty taught 281 student credit hours per semester versus 274 credit hours for technology faculty, whereas the 1977-78 figures were 256 and 333 respectively.

It is tempting to make a sweeping statement that in general technology programs are underfunded and technology faculty is underpaid.

Acknowledgment

The author wishes to thank Mrs. Marsha Mandelbaum, Mrs. Georgia Ann Edie, Mrs. Patricia Fox, and Mrs. Susan Herrmann for their valuable help in preparing this study.

*Technology refers to any technology program accredited or accreditable by ECPD (ABET).

Exhibit I

ENGINEERING TECHNOLOGY
FACULTY SALARIES

12 Month Terms		Maximum	Minimum	Average	
Deans	1979-80	50,000	17,305	35,470	(32)
	78-79	46,000	17,305	32,914	(29)
	77-78	46,500	18,500	33,585	(26)
Associate Deans	1979-80	39,000	18,855	31,913	(8)
	78-79	38,000	17,535	30,351	(11)
	77-78	35,100	25,685	29,279	(5)
Assistant Deans	1979-80	38,905	24,000	32,445	(4)
	78-79	35,748	25,932	26,373	(5)
	77-78	32,640	24,000	27,655	(1)
Department Heads	1979-80	39,624	13,543	27,027	(30)
	78-79	37,368	10,596	25,164	(32)
	77-78	37,793	16,200	25,789	(22)
9/10 Month Terms					
Professors	1979-80	36,898	16,500	25,378	(35)
	78-79	35,241	16,884	23,517	(29)
	77-78	27,250	17,000	22,012	(33)
Associate Professors	1979-80	30,700	12,900	21,789	(40)
	78-79	29,700	12,550	19,575	(38)
	77-78	23,205	15,941	18,947	(33)
Assistant Professors	1979-80	24,000	13,000	18,411	(40)
	78-79	27,780	12,000	17,488	(33)
	77-78	18,875	14,484	16,534	(33)
Instructors	1979-80	26,684	9,194	16,192	(27)
	78-79	24,264	9,194	14,542	(20)
	77-78	20,490	11,000	14,514	(33)

Exhibit II - A

1977-78

SALARIES

ENGINEERING - UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING (UFCE)
AND
ENGINEERS COUNCIL FOR PROFESSIONAL DEVELOPMENT (ECPD)
VS
TECHNOLOGY - PURDUE UNIVERSITY AT INDIANAPOLIS (PU-I)

12 Month Terms		Maximum	Minimum	Average	
Deans	(UFCE)	58,018	28,064	39,383	(88)
	(ECPD)	N/A	N/A	N/A	
	(PUI)	46,500	18,500	33,585	(26)
Associate Deans	(UFCE)	56,478	23,744	36,446	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	35,100	25,685	29,279	(5)
Assistant Deans	(UFCE)	44,811	17,924	29,504	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	32,640	24,000	27,655	(7)
Department Heads	(UFCE)	56,603	16,981	35,251	
	(ECPD)	29,502	23,705	26,518	(57)
	(PUI)	37,793	16,200	25,789	(22)
9/10 Month Terms					
Professors	(UFCE)	51,415	14,150	26,583	
	(ECPD)	30,511	20,911	25,149	(62)
	(PUI)	27,250	17,000	22,012	(33)
Associate Professors	(UFCE)	32,570	12,877	20,692	
	(ECPD)	22,534	17,324	19,877	(61)
	(PUI)	23,205	15,941	18,947	(33)
Assistant Professors	(UFCE)	24,928	9,750	17,143	
	(ECPD)	18,677	15,229	16,782	(61)
	(PUI)	18,875	14,484	16,534	(33)
Instructors	(UFCE)	33,490	7,924	13,405	
	(ECPD)	14,930	12,250	14,939	(28)
	(PUI)	20,490	11,000	14,514	(33)

(UFCE) UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING
1978-79 Engineering Faculty Salary Survey sponsored by the ASEE and ECC and conducted by the University of Florida College of Engineering. Figures shown were reduced by 6.0% to make them comparable to the 1977-78 figures of the other two surveys.

(ECPD) ECPD Survey of Institutional Data 1978-79. Engineering Education: February 19. Figures shown are for the academic year 1977-78.

(PUI) PURDUE UNIVERSITY AT INDIANAPOLIS - Purdue University School of Engineering and Technology at Indianapolis:

Exhibit II - B

1978-79

SALARIES

ENGINEERING - UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING (UFCE)
and
ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT (ECPD)

VS

TECHNOLOGY - PURDUE UNIVERSITY AT INDIANAPOLIS (PU-I)

12 Month Terms		Maximum	Minimum	Average	
Deans	(UFCE)	61,500	29,748	41,746	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	46,000	17,305	32,914	(29)
Associate Deans	(UFCE)	59,867	25,200	38,633	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	38,000	17,535	30,351	(11)
Assistant Deans	(UFCE)	47,500	19,000	31,275	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	35,748	25,932	26,373	(5)
Department Heads	(UFCE)	60,000	18,000	37,367	
	(ECPD)	31,597	25,166	28,232	(36)
	(PUI)	37,368	10,596	25,164	(32)
9/10 Month Terms					
Professors	(UFCE)	54,500	15,000	28,178	
	(ECPD)	31,352	22,621	26,591	(39)
	(PUI)	35,241	16,884	23,517	(29)
Associate Professor	(UFCE)	34,525	13,650	21,934	
	(ECPD)	24,051	18,485	20;988	(41)
	(PUI)	29,700	12,550	19,575	(33)
Assistant Professor	(UFCE)	26,424	10,335	18,172	
	(ECPD)	19,907	16,091	17,823	(41)
	(PUI)	27,780	12,000	17,488	(33)
Instructors	(UFCE)	35,500	8,400	14,210	
	(ECPD)	16,358	13,277	14,313	(23)
	(PUI)	24,264	9,194	14,542	(20)

(UFCE) UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING
1978-79 Engineering Faculty Salary Survey sponsored by the ASEE and ECC and conducted by the University of Florida College of Engineering.

(ECPD) ECPD Survey of Institutional Data 1979-80. Engineering Education: February 19
Figures shown are for the academic year 1978-79.

(PU-I) PURDUE UNIVERSITY AT INDIANAPOLIS - Purdue University School of Engineering and Technology at Indianapolis

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Exhibit II - C

1979-80

SALARIES

ENGINEERING - UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING (UFCE)
and
ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT (ECPD)

VS

TECHNOLOGY - PURDUE UNIVERSITY AT INDIANAPOLIS (PU-I)

12 Month Terms		Maximum	Minimum	Average	
Deans	(UFCE)	67,000	17,596	43,927	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	50,000.	17,305	35,470	(32)
Associate Dean	(UFCE)	71,333	20,460	43,545	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	39,000	18,855	31,913	(8)
Assistant Deans	(UFCE)	50,000	17,300	33,127	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	38,905	24,000	32,445	(4)
Department Heads	(UFCE)	69,692	19,400	40,307	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	39,624	13,543	27,027	(30)
9/10 Month Terms					
Professor	(UFCE)	57,800	16,416	31,590	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	36,898	16,500	25,378	(35)
Associate Professor	(UFCE)	35,891	12,200	23,920	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	30,700	12,900	21,789	(40)
Assistant Professor	(UFCE)	28,356	11,500	19,804	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	24,000	13,000	18,411	(40)
Instructors	(UFCE)	30,000	6,750	15,360	
	(ECPD)	N/A	N/A	N/A	
	(PUI)	26,684	9,194	16,192	(27)

(UFCE) UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING
1979-80 Engineering Faculty Salary Survey Sponsored by the ASEE and ECC and conducted by the University of Florida College of Engineering.

(ECPD) ECPD - N/A

(PUI) PURDUE UNIVERSITY AT INDIANAPOLIS - Purdue University School of Engineering and Technology at Indianapolis.

EXHIBIT III
NATIONAL SUMMARY
TECHNOLOGY

	1. TOTAL DIRECT INSTRUCTIONAL SALARIES	2. TOTAL INSTRUCTIONAL COSTS	3. TOTAL INSTRUCTIONAL SALARIES / STUDENT CR. HR.
77-78	$428,481.35 (33)	$494,890.26	$39.43
78-79	393,717.00 (46)	495,849.00	49.50
79-80	417,537.00 (46)	512,156.00	51.35

	4. TOTAL INSTRUCTIONAL COSTS / STUDENT CR. HRS.	5. INSTRUCTIONAL OPERATING EXP / STUDENT CR. HRS.	6. INSTRUCTIONAL FACULTY SALARIES / INSTRUCTIONAL FTE
77-78	$44.73	$2.74	$23,565.63 (33)
78-79	60.44	3.01	19,523.00 (46)
79-80	59.76	3.45	21,619.00 (46)

	7. INSTR SUB-FACULTY SALARIES / INSTR SUB-FACULTY FTE	8. RESEARCH FACULTY SALARIES / RESEARCH FACULTY FTE	9. RESEARCH SUB-FACULTY SALARIES / RESEARCH SUB-FACULTY FTE
77-78	$7,991.31	$22,851.78	N/A
78-79	11,747.00	N/A	N/A
79-80	10,246.00	N/A	N/A

	10. TOTAL INSTRUCTIONAL AND RESEARCH FTE'S	11. TOTAL STUDENT CR. HRS. / FACULTY FTE	12. HEAD COUNT / FALL ENROLLMENT
77-78	26.23	331 (33)	677
78-79	N/A	274 (46)	491
79-80	N/A	261 (46)	585

	13. TOTAL UNDERGRAD CR. HRS. CONVERTED TO SEMESTER BASIS	14. TOTAL GRAD CR. HRS. CONVERTED TO SEMESTER BASIS	15. TOTAL STUDENT CR. HRS. CONVERTED TO SEMESTER BASIS
77-78	6,782	222.5	7,005.05
78-79	5,112.00	N/A	5,112.00
79-80	5,426.00	N/A	5,426.00

	16. JUNIOR & SENIOR HEADCOUNT	17. JUNIOR & SENIOR HEADCOUNT / FRESHMAN & SOPHOMORE HEADCOUNT	18. PH.D. DEGREES / BACHELOR'S DEGREES
77-78	271.48	N/A	N/A
78-79	261.07	1:1.8	N/A
79-80	239.83	1:2	N/A

	19. MASTERS DEGREES / BACHELORS DEGREES	20. OFFICE SPACE / TOTAL INSTR. & RESEARCH FTE	21. TEACHING LAB SPACE / JUNIOR & SENIOR HEADCOUNT
77-78	N/A	144.75	146.24
78-79	N/A	171.63	138.60
79-80	N/A	165.30	169.50

	22 RESEARCH LAB SPACE / RESEARCH FACULTY	23 RESEARCH LAB SPACE / GRADUATE HEADCOUNT	24 JUNIOR & SENIOR HEADCOUNT / INSTRUCTIONAL FACULTY FTE	25 GRADUATE HEADCOUNT / INSTR. FACULTY FTE
77-78	N/A	N/A	16	N/A
78-79	N/A	N/A	12.12	N/A
79-80	N/A	N/A	10.57	N/A

EXHIBIT IV

NATIONAL SUMMARY

ENGINEERING - UNIVERSITY OF FLORIDA COLLEGE OF ENGINEERING (UFCE)

vs

TECHNOLOGY - PURDUE UNIVERSITY AT INDIANAPOLIS (PU-I)

1. TOTAL DIRECT INSTRUCTIONAL SALARIES

77-78 $1,938,000 (88) vs $428,481 (37)
78-79 2,052,700 (90) vs 393,717 (46)

2. TOTAL INSTRUCTIONAL COSTS

$2,460,840 vs $494,890
2,656,190 vs 495,849

3. TOTAL INSTRUCTIONAL SALARIES / STUDENT CR. HRS.

$59.36 vs $39.43
59.83 vs 49.50

4. TOTAL INSTRUCTIONAL COSTS / STUDENT CR. HRS.

77-78 $75.38 vs $44.73
78-79 77.42 vs 60.44

5. INSTRUCTIONAL OPERATING EXP / STUDENT CR. HRS.

$6.44 vs $2.74
7.87 vs 3.01

6. INSTRUCTIONAL FACULTY SALARIES / INSTRUCTIONAL FTE

$28,110 vs $23,566
30,700 vs 19,523

7. INSTR SUB-FACULTY SALARIES / INSTR. SUB-FACULTY FTE

77-78 $9,780 vs $7,991
78-79 10,430 vs 11,747

8. RESEARCH FACULTY SALARIES / RESEARCH FACULTY FTE

$25,400 vs $22,852
28,150 vs N/A

9. RESEARCH SUB-FACULTY SALARIES / RESEARCH SUB-FACULTY FTE

$8,560 vs N/A
10,750 vs N/A

10. TOTAL INSTRUCTIONAL AND RESEARCH FTE'S

77-78 184.10 vs 26.23
78-79 178.12 vs N/A

11. TOTAL STUDENT CR. HRS. / FACULTY FTE

256 vs 331
281 vs 274

12. HEADCOUNT / FALL HEADCOUNT

1,968.18 vs 677.41
2,063.86 vs 491.00

13. TOTAL UNDERGRAD CR. HRS. CONVERTED TO SEMESTER BASIS

77-78 28,231 07 vs 6,782.55
78-79 30,102.80 vs 5,112

14. TOTAL GRAD CR. HRS. CONVERTED TO SEMESTER BASIS

4,787.78 vs 222.5
5,247.44 vs N/A

15. TOTAL STUDENT CR. HRS. CONVERTED TO SEMESTER BASIS

32,645.79 vs 7,005.05
34,305.25 vs 5,112.00

16. JUNIOR & SENIOR HEADCOUNT

77-78 780.18 vs 271.48
78-79 807.87 vs 261.07

17. GRAD HEADCOUNT* / JUNIOR & SENIOR ENROLLMENT

.36 vs N/A
.41 vs 1:1.8

18. PH.D. DEGREES / BACHELOR'S DEGREES

.07 vs N/A
.08 vs N/A

19. MASTERS DEGREES / BACHELORS DEGREES

77-78 .30 vs N/A
78-79 .29 vs N/A

20. OFFICE SPACE / TOTAL INSTR. & RESEARCH FTE

215.15 vs 144.76
225.43 vs 171.63

21. TEACHING LAB SPACE / JUNIOR & SENIOR HEADCOUNT

73.22 vs 146.24
61.34 vs 138.60

22. RESEARCH LAB SPACE / RESEARCH FACULTY

77-78 1,698.52 vs N/A
78-79 2,018.07 vs N/A

23. RESEARCH LAB SPACE / GRADUATE HEADCOUNT

193.92 vs N/A
171.71 vs N/A

24 JUNIOR & SENIOR HEADCOUNT / INSTRUCTIONAL FACULTY FTE

12.22 vs 16
13.21 vs 12.12

25 GRADUATE HEADCOUNT* / INSTRUCTIONAL FACULTY FTE

4.42 vs N/A
5.46 vs N/A

*For the technology programs this ratio is Junior & Senior Headcount / Freshman & Sophomore Headcount

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METHODS OF FACULTY EVALUATION AND DEVELOPMENT

Otis E. Lancaster
Pennsylvania State University

Lifelong learning is today accepted as the key to success in engineering. This is true whether the engineer is in industry, a private consultant, or in charge of his own company. The problems he faces are new each year, if not each day. Obsolescence continually creeps up on all. The only way to keep ahead of it is through a pattern of continual learning.

These statements may be more true for faculty members than for other engineers, because in many ways they are more independent, and the products they market are less carefully scrutinized. When an industrial company employs a new engineer, it usually has a training period for him. He is introduced to the activities, products, and goals of the company. Many times the company gives him experience in research, design, development, and production before assigning him a work area.

Universities should have, and some do have, programs for the training and development of their faculty. Before discussing the nature of a development program, the question, "What are faculty supposed to do?" must be answered. Without an answer, any development program would be premature. Many would say that the question is stupid, and the answer obvious. The faculty are to teach, conduct research, and participate in the continuing education of others. But like all obvious statements in textbooks, the duties are usually illusive.

In more specific terms the faculty are to prepare men for professional engineering work in industry, in government, in universities, and in private consulting. They are to prepare men to use knowledge---knowledge that exists or knowledge which might exist. The emphasis in on use.

The function of engineering faculty is to prepare men for professional engineering work, that is develop students who can and want (1) to use knowledge in new creations and in modification of present things, and (2) to supply missing links in useable knowledge. This requires that the faculty not only know the existing subject-matter, its limitations, and the chances of extension in various directions, but they also should know how it is being used and be able to conceive other ideas for its use in an economical practical way (design). They must be able to supply some missing links in useable knowledge. Finally, they must be able to impart these things to students.

Engineering faculty have two professions: engineering and teaching, so development programs should be two pronged. The subject-matter or knowledge prong has long been considered. Throughout its history ASEE has sponsored short courses in various areas. For many years the National Science Foundation has had a faculty fellowship program for 9 to 15 months of study. The universities have had a tradition of sabbatical leave. All these have helped some faculty keep abreast of the scientific side of the subjects. Even these programs within themselves are insufficient. The professors must continue to learn on their own.

There is an area in which it is much harder for men to learn by themselves, even if they are motivated to do so. It is the area of using knowledge, the use of present knowledge in industries, and the specific knowledge needs for further use in design and production. This development can come best through association with industry or design projects. The DuPont Company has a Year in Industry program in which a faculty member works on DuPont's engineering problems and then returns to the academic world. The Ford Foundation established the Residency in Engineering Practice, now administered by ASEE. NASA and ASEE have jointly sponsored Summer Institutes at various NASA laboratories on research and on design.

PROGRAMS FOR ENGINEERING DEVELOPMENT

- DuPont Year in-Industry
- Ford Foundation Residency in Engineering Practice
- ASEE—NASA Summer Fellowships
- Sabbatical Leave
- Consulting

At an ASEE Section Meeting in May 1971, four leaders from industry pointed out many weaknesses of our graduate programs, and stressed that there was a need for closer relations between faculty and companies in order to produce a match in the education and duties of engineers in non-academic positions. There is a long way to go in developing faculty who can direct learning toward this match. Even the intent of the year with industry is misconstrued. One young professor wanted to take this year to write papers to strengthen his publications for promotion. Lip service is given to the importance of engineering and the preparation of students for work with industry, yet to a large extent promotions are based on published papers or dollars of research, much if not most of which are in science or mathematics.

The NASA Summer Institutes on Design, which the author helped set up, were intended to help faculty develop the competence necessary to direct graduate programs on applied engineering. This was an initial step. All programs constitute just a drop in the bucket. Many more programs for the development of faculty on using knowledge in engineering are needed.

Faculty Training Programs

For the most part, the engineering faculty has not had any special training for directing the learning of others. They enter the field as amateurs and often remain that way. The number of programs to help them become good teachers has been quite limited; this is the fault of the system and the pay-off-function. A recent survey showed that, contrary to what is sometimes stated, over 60% of faculty members are at colleges and universities because they want to teach and enjoy teaching.

It seems logical that it is up to the Society and the colleges and universities to prepare and administer programs for the development of engineering faculties. There have been some national two-week programs. Now there are some two-day programs in each of the ASEE regions. The overall philosophy has not been to develop models for others to mimic, but to study those subjects which could be a basis for each teacher to design his own effective methods compatible with the personality and his students. The subjects considered are psychology, speech, listening, testing, programmed learning, visual aids, stimulating creativity, and research on improvement of learning.

For the last 14 years The Pennsylvania State University has had a seminar on teaching for all new faculty, where by definition a new faculty member is a person teaching at The Pennsylvania State University for the first time. Consequently, the set of participants consists of graduate assistants, instructors, assistant professors, associate professors, professors, and department heads. The present dean and five of the department heads went through the program.

Currently the program is modeled after the ASEE-PSU programs of 1960-63: a concentrated two weeks with hours from 8 a.m. to 5 p.m. daily with outside preparation at night. At PSU however, the program is held during the week preceding and the week following the fall semester. The second week permits the discussion of real problems encountered in teaching the previous term. Years ago the seminar was held regularly for one period a week throughout the school year. Many preferred this arrangement, since current topics could be discussed immediately. The present arrangement makes it easier to concentrate on the practicum (workshop). The present program includes nine practicums.

Requirements for Good Teaching

Perhaps this is the time to state that we do not become better teachers by just listening to ideas on teaching. To teach effectively one must fulfill four steps of learning: motivation, response, reinforcement, and transfer.

The seminars can motivate the professor to develop ideas on teaching, and can supply some time for the initial response. If permanent changes are to be made, teachers must demonstrate (response) good leadership in their classrooms; then, for its continuation the teachers must receive feedback (reinforcement) in the form of praise, pay, or awards for jobs well done; and lastly, they must transfer the good techniques from the practice session to a real class and to other classes.

In order to give that continual motivation, raises and promotions should be based upon truly meritorious performance. A development program is doomed to fail unless there is an evaluation program. We must know which way is up.

WHY EVALUATE INSTRUCTION?

- To help improve teaching
- To develop some standard of acceptable performance
- To help make decisions on promotion
- To help make meritorious salary changes

Several years ago PSU President Walker asked me to chair a committee to measure teaching effectiveness. Although it was recognized that the only true measure of a teacher's effectiveness was the achievement of his students and their continual interest in the field, comparative measurements of such factors were not always possible. Moreover, an absolute scale did not appear to be as practical as a relative or comparative scale. Hence, the committee suggested four factors to be used for the evaluation, when feasible:

1. Comparison of scores on common tests and examinations in multiple section courses

2. Achievement in subsequent courses which require the knowledge of the course taught

3. Opinion of students

4. Opinion of colleagues

Evaluations using these four factors were pilot-tested on the teaching of English composition. Table 1 gives some of the results.

Table 1. Evaluation of Teaching English Composition I

Instructor Code	Student Rating	Faculty Rating	Common Examination	Subsequent Course	Total
04	3.8	3 2	3 2	3 6	13.8
06	3.5	3.1	4 5	3 0	14.1
10	4 1	4 3	3 5	4 5	16 4
12	3.9	3.4	3 0	3.3	13.6

The Importance of Student Opinions

Student opinions have received an amazing amount of attention. Hundreds of questionnaires have been developed with the number of questions ranging from 6 to 150. Our committee made some steps that are fundamental in strengthening the usefulness of such questionnaires.

1. Use a random sample (for then and only then can probability theory be used for interpretations).

2. Insure that all students in the sample respond or devise a way of estimating the effect of the nonresponses.

3. Collect information after students have had time to use material learned (two years afterwards).

4. Keep it simple (six questions) and easy to respond.

A random sample of 40 students are selected for each faculty member from rosters of students taught by them two years before. The students on the rosters for all three terms are numbered consecutively, then by use of a table of random numbers the 40 specific numbers (students) are selected. (The sample size of 40 was based upon standard deviations obtained in pilot tests). The questionnaire listing the instructor's name and the course is mailed along with a self-addressed, stamped envelope to each of the 40 students. The questionnaire explains that it is a sampling survey and stresses the importance of having all respond.

The random number of the student is placed in the upper right-hand corner. This number is removed when the questionnaire is returned. After a reasonable time for the students to respond, the numbers are compared to the original set and those students who have not responded are sent a second questionnaire, and so forth. Each new mailing is coded by color to tell whether it is the first, second, third, or fourth mailing.

THE PENNSYLVANIA STATE UNIVERSITY
OPINIONNAIRE ON TEACHING EFFECTIVENESS

The College of Engineering is concerned with the quality of instruction and is requesting opinions of students in order to help maintain a high level of teaching. You have been randomly selected as one of a sample of 40 students to participate in the systematic poll on the professor listed below. Since lasting impressions are considered the most important ones, you are being asked about instruction you received about two years ago. Please consider each question carefully. Record your opinion by encircling the appropriate response and insert this opinionnaire in the enclosed stamped envelope and mail.

It is essential that a response be obtained from each individual. To insure that all responses are obtained, some provision must be made for contacting those students who do not respond to the first query. Consequently, the number in the upper right hand corner of the opinionnaire will be detached as soon as this form is received. Thus your response will not be associated with your name unless you sign the report.

Instructor____________________ Course____________________

	5	4	3	2	1
1) How would you rate student teacher relationships?	Strong atmosphere of good will and cooperation		Satisfactory	Good will & cooperation seldom present	
2) Were important objectives met?	Definitely		Fairly well	Scarcely	
3) Was learning enhanced by the instructor's method of presentation?	Presentation very meaningful		Presentation helpful about half the time	Presentation seldom helpful	
4) Was thinking and independent work stimulated?	Highly stimulating		Average	Little stimulation	
5) Did grading procedures seem valid and accurate?	Directly related to objectives & achievement		Adequate	Slightly related to objectives & achievement	
6) How does this instructor rank with others you have had in this University?	One of the best		Satisfactory or average	One of the least good	

The six questions relate to student/faculty relationships, objectives, methods for enhancing learning, thinking and creativity, grading, and overall teaching effectiveness. The responses are tallied on a page showing the distribution on each question from one to five. A computation is made for the mean on each item. The results of an individual survey and the distribution for the whole faculty population are made available to the faculty member, the department head, and the dean of the college, for two purposes: to help faculty to improve, and for consideration in raises, promotions, and terminations. It should be stressed that this is only one of the pieces of input for the second consideration. The faculty is asked to survey their own students to get additional information to assist with the first.

It can be shown that these student opinions are reliable and seem to be independent of the grades received. Student opinions are important and should be obtained. They do not give the whole answer, but they should not be ignored.

The evaluation of the development of faculty as engineers must not be overlooked. This, too, may be estimated by the effect upon the students, as well as from the instructor's activities, interests, and approaches. The feedback from the student's employers would be good, but it would be difficult to trace the effect to a special individual.

In summary, a program for the development of faculty is a must. This development should have two parts: (1) development as an engineer who can and does use information on current problems; (2) development as a teacher who can and does give effective guidance (teaching) for student learning. The first can be done by programs in cooperation with industries and government laboratories. The second can be motivated by seminars and institutes on pedagogy at national, regional, and local levels. Both take continual development or lifelong learning. Methods for evaluating the effectiveness of each should be employed with ample rewards and recognition for improved and outstanding performance so as to maintain motivation. One instrument for doing this is student opinions. With strong developmental programs the day for amateurism for faculty should be past, and the day of professionalism should be at hand.

11

A PLAN TO INCREASE AND IMPROVE SCHOLARSHIP

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Newark College of Engineering

Many promising young faculty members fail to realize their creative potential. Such disappointments are particular problems for small universities and colleges trying to encourage the growth of faculty research to support their graduate program and improve the intellectual ambience at their campus. For these institutions an important question is: What can the institution do and what kind of conditions can it provide to help stimulate the release of these creative forces?

To consider how faculty research should be increased, it would seem worthwhile to consider how the professional environment changes for the new teacher as he begins his first faculty position. Although most Ph.D. candidates experience the anxiety associated with qualifying examinations and thesis work, they generally exist in a relatively protected environment. Those new Ph.D.'s who choose an academic career are abruptly faced with new conditions of teaching a full load, contributing to college activity and, of course, engaging in creative research. To meet these responsibilities there is now no advisor greatly committed to their supervision and guidance. There are no short term goals such as the Ph.D. degree upon which the creative activity can be focused, and, unlike conditions in industry, there is no well defined work structure.

Structure and Security

Academic research goals tend to be more long-range and vague. The lack of structure requires that the discipline so necessary for a successful research effort must come completely from the individual researcher. In a study of scientists and creativity, Pelz and Andrews[1] conclude that "...younger scientists, perhaps, gain security from the situation: from their group, their colleagues, their chief. With advancing years, security must lodge increasingly in the man himself." The problems of doing creative work in an environment with no external structure is familiar to all free lancers, artists, writers, composers, etc.

The academic institutions already established as centers of research provide a work environment which helps the new faculty member, usually selected from a group of the best Ph.D.'s, make the transition between graduate student experience and his first faculty position. In an interesting Occasional Paper from ERIC,[2] Collins surveys the available literature in which questions of research productivity are considered. Collins cites Crane[3] who "found that scientists at 'major' universities were significantly more productive in the number and quality of their publications than scientists at 'minor' universities." However, the very vitality of major institutions as research centers imposes a different set of pressures on new (and old) faculty members.

At these major institutions, the new faculty member most frequently is assigned a senior faculty researcher under whose guidance he does creative work. A continuity is established between his graduate and postgraduate career. Of course, there are now additional responsibilities, such as teaching and committee work. However, as a creative person, he becomes part of a team. As time passes the new researcher is expected to become more independent in his research. Thus, he must begin to generate new ideas for research, attract funding from outside sources, and supervise graduate students. If he fails to develop in this way, tenure is denied him.

Those institutions struggling to develop a research capability, however, find themselves in a double bind. They generally attract faculty with less potential and then do not provide conditions for creative work which help to ease the transition from the graduate to the postgraduate environment. Having fewer seasoned researchers, they often hire the new man to carry the full burden of the creative work in his area of interest. Many meet such a challenge and grow intellectually. Too many, however, fail to realize their creative potential under such conditions.

The question of autonomy has been considered by Pelz and Andrews.[1] They write:

> "...a relatively high level of individual autonomy was effective mainly in ... those (situations) which were neither very tightly coordinated nor loose. In the latter, where members already enjoyed considerable freedom; the most autonomous scientists were below average in performance."

The institution suffers of course, but so does the new teacher and, ultimately, his students. Clearly, the young teacher who is releasing his creative energy will be a more vital and interesting teacher.

The question those in each institution aspiring to a higher level of research must ask is: Under what conditions do new young faculty prosper as researchers? Collins[2] summarizes the most significant literature in which "the research environment that best facilitates the work of productive researchers" is discussed. According to Collins, four themes stand out:

Interaction with Colleagues

1. ... the most effective of (scientists) regularly interact with colleagues.[4]

2. ... older scientists are less likely than younger ones to participate in research groups with colleagues; but they are also more likely to make contacts outside the laboratory situation.[5]

3. Group research efforts are most effective when member's average tenure in the organization is low enough so that they still have an interest in 'broad pioneering,' but high enough so that their interests have not narrowed to highly specific areas.[4]

Interaction with Administrators, Supervisors

1. The scientist performs better when the supervisor/administrator works in the scientist's own discipline and when the administrator is viewed as highly competent and motivated.[6]

2. ... The optimal situation seems to be that in which the administrator gives neither complete autonomy or (sic) complete direction, but interacts frequently and gives the scientists the opportunity to participate in critical decisions... participatory rather than directive or laissez-faire leadership.[5,6]

Diversity of Interests and Activities Among Others in the Organization

1. ... the more diverse the interests of colleagues who then interact with each other in the research organization, the greater everyone's resultant productivity.[4,6]

Physical and Financial Resources

1. ... the availability of funds for research was only effective depending upon the amount of autonomy with which a scientist and/or his organization would use them (sic).

Newark Program To Increase Faculty Research

These research findings in the field of research productivity have formed the basis of a new program at Newark College of Engineering (NCE) designed to increase the amount of faculty research. We are one of two state supported institutions in New Jersey offering a full range of degree programs in engineering. A list was developed of research areas reflecting, to a great extent, national priorities in research. We tried to assess our faculty competence in each of these research areas. A final list matching national research interests with faculty interests and ability was subsequently drafted. We selected from this final list three research areas to begin our program. In two cases, energy resources and biomedical research, there already existed a fair amount of research activity, but with no apparent coordination. Thus, the faculty engaged in these two areas of research had no external funding to support their efforts. In the third area, noise abatement, no current activity existed. However, a number of the faculty were working in the closely related fields of acoustics and vibrations. Research groups were formed in each of the three areas with a senior researcher chosen as leader.

Several young, inexperienced faculty members were included with the veteran researchers in each of the groups. The functions of each group were to develop and coordinate research activity in their particular area. Toward this goal they were expected to conduct research, organize seminars for their group, attend courses elsewhere if necessary, survey the literature, and recommend appropriate purchases.

To initiate and coordinate this program we formed a coordinating committee comprised of some of our most mature and experienced researchers. They were also selected because they represented a broad spectrum of interests and backgrounds, and because they had been sensitive to the ebb and flow of research interests nationally. Additional criteria for selecting the members of this committee were their interest in teaching, in the professional activities of the younger faculty, and in the professional growth of the college. The responsibility of this committee has been to identify the areas of research in which the college ought to get involved to maintain its recency, and to maintain a knowledge of the research interest of their colleagues with particular emphasis on the younger people.

Although none of the initial three groups was given a specific budget, they were all encouraged to request funds from a special account as needed to support their efforts. In the first year these funds were expended in sending members of the groups to conferences, in taking courses, and in purchasing supporting documents. In addition, they visited various industrial and government laboratories whenever they felt these visits would further support their activity.

Organizational Problems

In organizing this program we have encountered several problems. First, it was impossible to find people for the coordinating committee meeting all of our criteria. Second, each member of this group, although enthusiastic about the program, has his own professional interests which include nine hours of teaching. Thus, they are not able to make a continuous contribution to the program. However, the Associate Dean for Research, who chairs the coordinating committee, has provided the continuity. Third, we have not been able to identify competent leadership in each of the areas in which NCE ought to develop some research activity. At a time of decreasing engineering enrollment we can't hire people with leadership qualities and research experience as we would like. Fourth, we have encountered resistance from some of our more experienced faculty at the idea of being diverted from their immediate professional activities to provide leadership of a group. In this last situation we have divided the leadership of the group between an experienced older man and a younger colleague. This procedure has worked extraordinarily well. The younger man in each case has pursued his tasks with vigor and enthusiasm, and as a result, developed leadership and professional talents. Of course, no member of the faculty was coerced into becoming identified with a group effort. We therefore lost the potentially valuable help of some experienced researchers who preferred to work alone, as did some of our younger faculty.

The Associate Dean for Research, who is himself engaged in an active research program, has mainted close personal contact with each of the groups. An atmosphere of mutual respect has developed between the members of the groups and the dean. This climate of cooperation between the administration and the faculty groups has been extremely helpful in resolving occasional personality conflicts and in jointly working out funding priorities.

The program has been in operation for one year. We feel that if this program works, significant increases in research productivity at the college will not be realized for at least three (or as many as five) years. However, a progress report can be made on the first year of activity:

More people at the college are currently engaged in coordinated research efforts. Interesting proposals have been written in the areas in which we already have expertise. Thses may not be funded, but it is ovvious that the groups from which these proposals were generated will write others. The group which is in the process of developing its expertise is ready to develop a specific research program. Most important, the climate for research at NCE has improved.

Our hope is that the program we have been developing at Newark College of Engineering will help our institution in two ways. First, younger faculty will find the conditions of their transition from graduate school to their first teaching position easier to make, so that they can more fully realize their potential as teachers and researchers. Second, the research activity at the college will change for the better both qualitatively and quantitatively.

Conditions for Success

The program as outlined above would work at other institutions, provided several key conditions were to be met. First, some level of research effort must already exist at the institution so that a small group of leaders among the faculty can be identified. In addition, a number of potential researchers must be present who could effectively work with the established researchers. Leadership available should be in fields which are growing in national interest. If such leadership does not exist at the institution, a few carefully selected appointments must be made. Overall support must be provided by the administration to assist the researchers whenever necessary. The level of institutional commitment to research must be high enough to justify the appointment of a Dean for Research, a fully dedicated person, with a budget sufficient to provide a measure of internal research support, some academic support (short courses, conferences, visitations, seminars), adequate administrative assistance for handling proposals, reports, papers, and even some equipment funds. The institution must provide release time for researchers to enable them to commit, at minimum, one uninterrupted day per week to their creative efforts. A clear commitment by the administration to the criterion of scholarship as one of the paths to advancement would be additional and tangible signs of the institutional dedication to creative research as one of its goals.

In sum, the institution must identify leaders and potential researchers. The administration must commit itself to supporting scholarship by providing leadership, appropriate rewards, and economic support. Finally, the administration must demonstrate an understanding of the special nature of creative work.

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12

ALMOST EVERYTHING YOU'VE EVER WANTED TO KNOW ABOUT ELECTRICAL ENERGY MANAGEMENT

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Abstract

Energy consumption during 1976 at the four Carolinas manufacturing plants of Fiber Industries, Inc. (FII), dropped 10.2 percent from 1975 levels as the result of a vigorous nine-point energy management program.

That 10.2 percent drop in energy consumption translates into $3.4 million in savings and the non-use of 1.2 trillion Btu's (British thermal units) of energy. The latter is roughly equal to the amount of energy required to heat 12,200 normal sized Charlotte area homes for an entire year.

With over half of the annual FII energy dollars being spent for electrical power, even a small percent reduction in kwd and kwh results in significant savings.

This paper details the FII electrical energy management program, including the basic program organization, a review of current equipment available, techniques to employ and pitfalls to avoid, evaluation of claims made by vendors, response to possible upcoming peak load pricing rates and current areas of activity.

Background

Fiber Industries is a Celanese Corporation subsidiary producing polyester and nylon fibers. The company is owned 62.5 percent by Celanese and 37.5 percent by Imperial Chemical Industries, Ltd. of Great Britain.

FII headquarters as well as the firm's extensive research and development operations are located in Charlotte, N.C. The company operates man-made fiber plants near Salisbury and Shelby in North Carolina and near Greenville and Darlington in South Carolina.

The combined kw demand of all four plants exceeds 100,000 kw, with an average monthly load factor of better than 90 percent. In 1977, it is projected that FII will purchase approximately $19 million of electricity. This cost would be closer to $21 million without the intense effort directed to electrical energy management.

In some product lines, the cost of energy is second only to raw materials in terms of cost per pound of final product, ahead of labor and capital. With monthly electric bills of over $500,000 at both the Shelby and Salisbury plants, even a small reduction in kw demand results in a substantial savings.

Organization

In the view of FII, the basic tasks of a successful energy management program are to: (1) maximize producer energy, (2) minimize consumer use of energy, (3) maintain a high energy load factor, and (4) use energy in its most economical form.

Since 1973 when FII initiated its formal energy management program, the approach has been centered around the First Law of Energy Management which states that, "Plant Utilities Are Always Adequate To Meet Production Demands". Put in other words, whenever production or output of a plant is threatened because the supply of an energy source or utility is inadequate, the consumption of that utility declines to the level at which the plant can meet the production targets, until a new energy source is developed.

For example, production at one plant was threatened due to one of three steam boilers being down for emergency repairs. Quick action by the plant maintenence and operating personnel located and corrected numerous small steam leaks and faulty steam traps, to the degree that full production continued with only two steam boilers on line.

The challenge of energy management, therefore, is to create an energy awareness and to provide the tools which will reduce energy consumption on a continuous basis, to the low levels which are achieved during the emergency situation, BUT to do so in a manner that does not strain plant maintenance, engineering and operating personnel. FII is not an energy company. Energy and utilities support the main function of the business which is to make quality nylon and polyester products at the lowest possible cost.

As with any cost reduction plan, the success of the energy management program depends on the response at the plant level. At each FII plant, energy coordinators are responsible for seeing that: (1) interest is stimulated in energy saving projects which will result in real and lasting savings, (2) operators and foremen are provided with the necessary tools to become a part of the energy management team, and (3) energy management is an integral part of each department's operation. FII has followed a well structured approach to energy management, centered around the following nine major guidelines:

1. Obtain Total Management Commitment
   This usually means first getting the commitment of the president of the company. Without this commitment, energy management is doomed from the start.

2. Obtain Employee Cooperation
   Similar to the first guideline, the cooperation of the operating people is vital to the success of the energy management program.

3. Make Appropriate Energy Surveys
While this may appear fairly obvious, it is amazing how little time and effort is dedicated to this step. A thorough survey pays off every time.

4. Analyze Survey Results
Now that all the data are available, what is to be done with it? Here again, often too little time is devoted to analyzing where and why energy is used in each part of the plant.

5. Set Conservation Goals
It is difficult to set realistic goals at the first attempt, but it is necessary, for without goals the plants have nothing to strive for, or no method for measuring performance.

6. Develop Reporting Format
Good communications are vital to energy management, just as they are to any other program.

7. Implement Engineering Changes
This guideline covers the complete spectrum from merely disconnecting excess light fixtures to the addition of computer-based enthalpy controls on air washers to use outside air during winter months.

8. Provide Necessary Equipment
While adequate equipment is obviously important, it is sometimes difficult to resist the urge to overkill, just to assure that the project will be a success. For example, putting in a minicomputer to merely log kw demand, when a simple data logger would do the job at one-tenth the cost.

9. Monitor Results
The tendency is for situations to return to their previous state after a change has occurred, unless continued monitoring is carried out. Here is where an otherwise successful energy management program may suffer defeat after six months or even several years unless continued monitoring is recognized as a major requirement.

While minor rearranging of these guidelines may be required from time to time, the success of the entire program depends upon a step-by-step approach, with each stage dependent upon successful completion of the preceding stage.

The major thrust of effort at FII has been to make people aware of the importance of energy management, to provide the necessary tools, techniques and equipment, and then to continually monitor the results to ensure gains that have been made are maintained.

Power and Energy Data

The upper part of Fig. 1 details in simplified fashion how the kw demand value is obtained from the utility kwh meter. Each time the meter disk makes one complete revolution under the influence of the voltage and current coils, the photocell energizes the relay and transfers contacts A and B, providing a kwh output pulse. At the end of the demand interval, usually 15, 30, or 60 minutes, a clock pulse is given for two to six seconds, signifying that a new interval has begun.

The A, B, and clock contacts are used by the demand monitoring or control equipment to develop the curve shown in the lower part of Fig. 1. The kwh pulses are merely added to each other over the demand interval. A line connecting the tops of the columns of pulses describes the accumulation of kwh pulses during the interval. The actual kwh per pulse and the number of total pulses recorded during the interval will depend on the plant load and the PT and CT ratios for the specific kwh meter. The fictitious mouse fanning the lower bearing in Fig. 1 illustrates that the disk speed increases proportionally to an increasing demand for power, hopefully not to the level that causes bearings to overheat!

It is important to note at this point that the slope of the line, mathematically speaking, is defined as rise over run, which is kwh divided by time, (one half hour in this case), which is equal to kw demand. That is to say, the total kwh of energy consumed, divided by the time over which it was consumed, yields the average kw demand for power over that time interval. This means that by detecting the slope of the line early in the interval, corrective action can be taken to reduce the slope by shutting off loads, lowering the average kwd to a more acceptable value. It follows that a flat line of zero slope would indicate no further energy consumption, a zero demand for power. Taken to the extreme, a line with a negative slope would indicate negative energy consumption, with a reversal of power flow; i.e., on-site generation of power back into the utility company's transmission system. This could occur if large capacity generation equipment was a part of the plant utility system.

The exact length of the demand interval will vary by power company, one of the most common being 30 minutes. This interval length is most frequently associated with the time for power company generators, transformers, and transmission lines to build up sufficient heat due to overload conditions to do permanent damage to the equipment.

However, as kwd peaks increase, and as a few power company customers attempt "peak-splitting", the demand intervals are being reduced to 15 or even five minutes. In a few cases, a "floating interval" is used, where there is no identified beggining and end to the interval. The kwd peak is then the highest average kwd for any successive 30 minutes during the power company billing period. There are some extreme situations where the power company will refuse to supply the customer with kwh pulse information. In that case, the customer has to install his own PT's and CT's and appropriate kwh meter or other transducer, if he wishes to obtain kwd information.

The data in the chart shown in Fig. 2 are somewhat different in nature from that in Fig. 1, in that the ordinate is now kw instead of kwh, and the abscissa is now days instead of 30-minute intervals. This "Profile of Peak kw Demand at the FII Shelby South Substation" illustrates the fact that the plot of highest average daily kwd values can have a positive, negative, or zero slope, and still represent a valid profile of the plant's demand for power over a given period of time. In this case, the chart in Fig. 2 illustrates the six days that manual load management procedures were used to limit kwd peaks. The power company contract under which the Shelby plant operates includes a 12-month 100 percent demand ratchet, which provides a strong economic incentive to stay below the previously established kwd peak.

Available Equipment

By this time, the reader may have suspected that with all of the money to be saved in electrical energy management, many manufacturers would have jumped on the bandwagon and started marketing some sort of monitoring or controlling equipment. This is exactly the case, and at last count, over 75 manufacturers believe that they know how to monitor and control electrical power and energy.

While space limitations do not allow a review of all available equipment, the vendors listed in Fig. 3 are a good cross section of what is available on the market today. The control schemes are divided by cost and capability into four basic categories, from simple manual surveillance to total energy control systems.

Category I describes the monitoring type of equipment which logs kwd data and alarms when a preset value is reached. The success of this system relies on the proper action by the operator in carrying out manual control of demand. Over the past two years, seven of these units have been installed at the four FII plants and at the R&D Center in Charlotte.

Two of these demand recorders were installed at the Shelby plant in July 1975, at an approximate cost of $5,000. During the first year of using the records in conjunction with a manual kw shedding program, demand charges in excess of $30,000 were avoided. Similar results have been obtained at the other plant locations. This experience has proven that the proper approach to electrical energy management is to first monitor the incoming power and energy, and develop a method of manual control before investing in more sophisticated controllers.(1)

Category II describes the hardwired type of equipment which actually makes decisions about when equipment should be shut off, in what order, and for how long. The shed and restore sequence and the equipment priority can be easily changed by the operator using plugs or switches on the front of the controller. This type of equipment is usually limited to demand control only and the associated energy savings which may result. For this reason, it is most frequently used in small buildings and plants where more sophisticated capabilities such as logs, charts, and equipment optimization are not required.

Category III describes the minicomputer type of equipment which has the capability of demand and energy control as well as logs, alarms, trend charts and optimization routines. In fact, the capability is limited only by memory size and I/O expansion. A word of caution is necessary at this point. One of the major computer manufacturers was called in to discuss the capabilities of his system. It was mentioned that FII desired to investigate the concept of enthalpy control of air handling units by computer control, and at that point the salesman asked how to spell the word enthalpy! This experience pointed up the fact that there is a very wide range of capability and proven field experience between vendors of computer-based energy management systems. The wise engineer takes everything the vendor says with two grains of salt before believing any of his claims. Also, keep in mind that the software programming cost can equal and sometimes exceed the hardware cost, especially if the customer has to do the bulk of the system development work.

A Category III system is currently being installed at the Salisbury plant, which will initially perform demand control as well as energy reduction through cycling of about 30 air handling units. Future potential applications include enthalpy optimization of the same air handling units, chiller optimization, (most likely in the open loop), data collection for utilities monitoring, and other energy management tasks not yet defined or even thought of.

Category IV describes the total energy control type of equipment which has all of the Category III features plus complete monitoring and control of several thousand points. It should be realized that a certain amount of overlap exists between Categories III and IV equipment, depending on the vendor involved and the options under consideration. In general, the Category IV equipment is best suited to large plants, large office buildings, college campuses, or any application where thousands of points must be monitored or controlled, usually via some multiplex method of data communication.

Survey Techniques

It became apparent early in FII's energy management experience that many vendors glossed over the importance of taking a survey of the plant loads to identify those that were really available for demand control. In some cases, the vendor acknowledged that such a survey was necessary, but underestimated the time and manpower required to do a thorough job. It thus became apparent that a formal, standardized survey method had to be developed if any truly useful information was to be obtained. The outcome was the survey form shown in Fig. 4. Using one sheet for each motor control center (MCC) in each plant, all loads of five horsepower, or five kVa and larger, were tabulated and evaluated regarding their availability for use in the electrical energy management program.

The survey approach involved using current updated electrical drawings where available, backed up with field checks to verify exact conditions where questions existed. Approximately 60 manhours were required at each plant to complete the initial survey, with a minimum of follow-up time to resolve occasional questions that arose when reviewing the survey results.

A similar form was used for detailed lighting surveys in each plant. The sample lighting survey form is shown in Fig. 5. The typical lighting survey covered tow days and one night at each plant and has resulted in significant lighting reductions in some plant areas.

While the resulting dollar savings were sometimes not as significant as those found in the motor survey for demand control, the lighting reduction program continues to serve as a constant visual reminder to the plant personnel that FII is engaged in an ongoing energy management program.

Where Do We Go From Here?

The current electrical energy management program centers around several main topic areas. It is now apparent that peak load pricing rates will be made available to 50 industrial customers selected at random in North Carolina in the near future. An analysis of the preliminary peak load rate schedule proposed by Duke Power Company indicates that FII would not benefit from being on such a rate in its present form. The development of this rate concept in North Carolina will be watched closely, and if seen to become economical, could give rise to new energy management programs such as rearrangement of certain plant operations or the capital investment in chilled water storage for making large quantities of chilled water during off-peak hours.

A current electrical energy management program involves improvement of the efficiency of the electrical system. As shown in Fig. 6 the overall system's efficiency is only approximately 81 percent which in 1977 will result in the loss of several hundred million kwh and several million dollars. This does not include the additional costs associated with the additional air conditioning required to remove the heat resulting from this lost energy.

The detection and changeout of large underloaded induction motors to smaller and/or higher efficiency induction motors will contribute greatly to improved system efficiency and power factor. The detection of such underloaded motors is greatly aided by the use of a portable torque analyzer recently brought on the market. It is basically an optical tachometer calibrated to read out directly in percent of shaft horsepower to the load. (2) The principle of operation is based on the fact that the slip rpm of an induction motor is linear from 10 percent load to 110 percent load.

The greatest benefits of the torque analyzer appear to be in the following areas:

1. Ability to quickly locate underloaded induction motors;
2. Ability to watch loading of equipment versus other conditions such as throughput, filter conditions, temperature and pressure;
3. Ability to determine true motor efficiency at any load when used in conjunction with conventional kw monitoring on the motor input leads;
4. Ability to assist in sizing future motor requirements based on actual load data; and

5. Ability to assist maintenance mechanics in periodically checking motor loading, which would help detect worn bearings, clogged filters, etc.

Other approaches to improving electrical system efficiency include the possible changeout of eddy current clutch drives to d-c drives, the addition of capacitors for power factor improvement, and the use of permanent magnet a-c synchronous motors for the variable frequency inverter drives on the spinning machines.

Other current programs are centered around the evaluation of computer-based systems for the optimization of chillers, steam boilers and air compressors. The advent of the micro-processor for dedicated tasks such as optimization presents new cost effective opportunities.

Summary

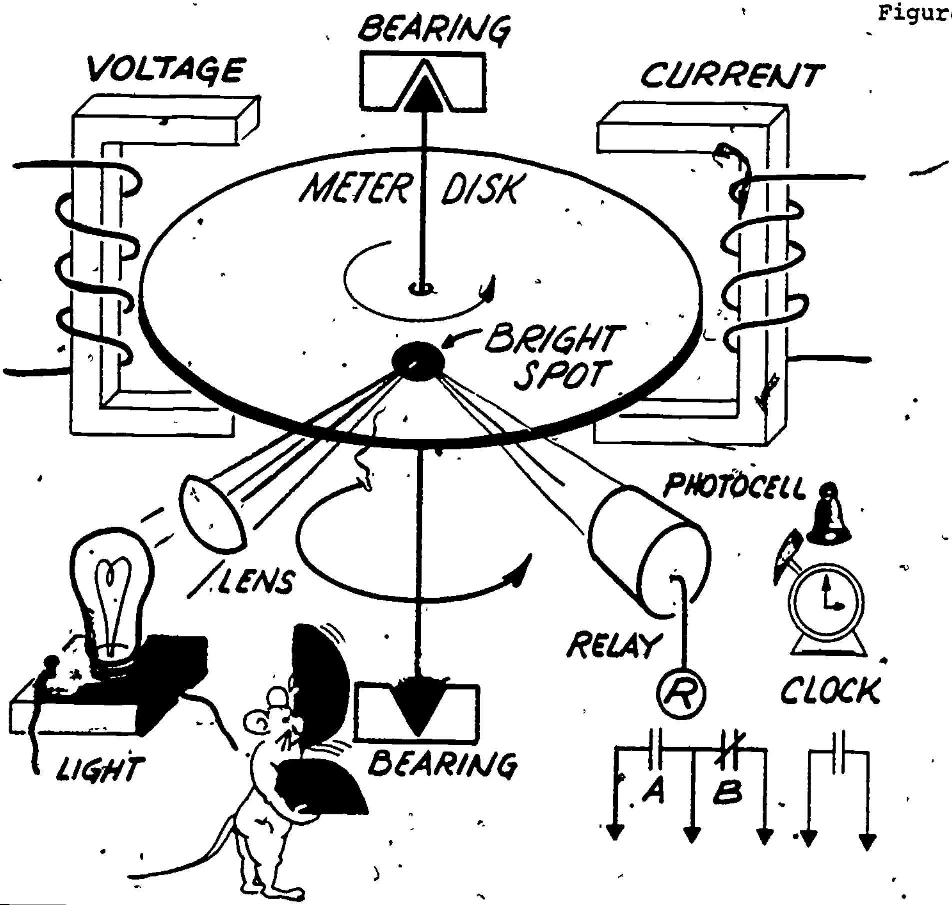
This paper has presented the FII electrical energy management program with details on organization, equipment selection, survey techniques, and current areas of activity. While space does not permit a detailed review of all data, concepts and activities, it is hoped that the information presented will whet the appetites of those involved with the generation, control, measurement and use of electrical energy, to do further investigation into the challenging field of energy management.

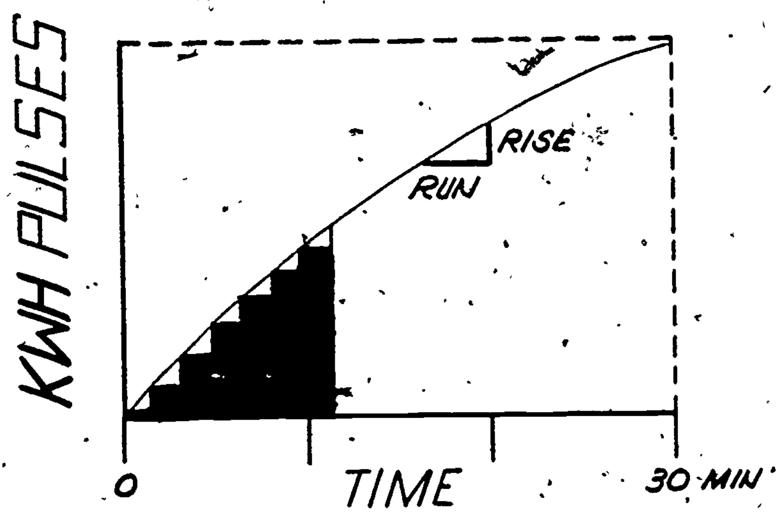
Footnotes:

(1) The Application of Electrical Power Monitoring Schemes at a Polyester Manufacturing Facility, by W.L. Stebbins, presented at the Spring, 1975 IEEE Textile Industries Committee Conference at Charlotte, N.C.

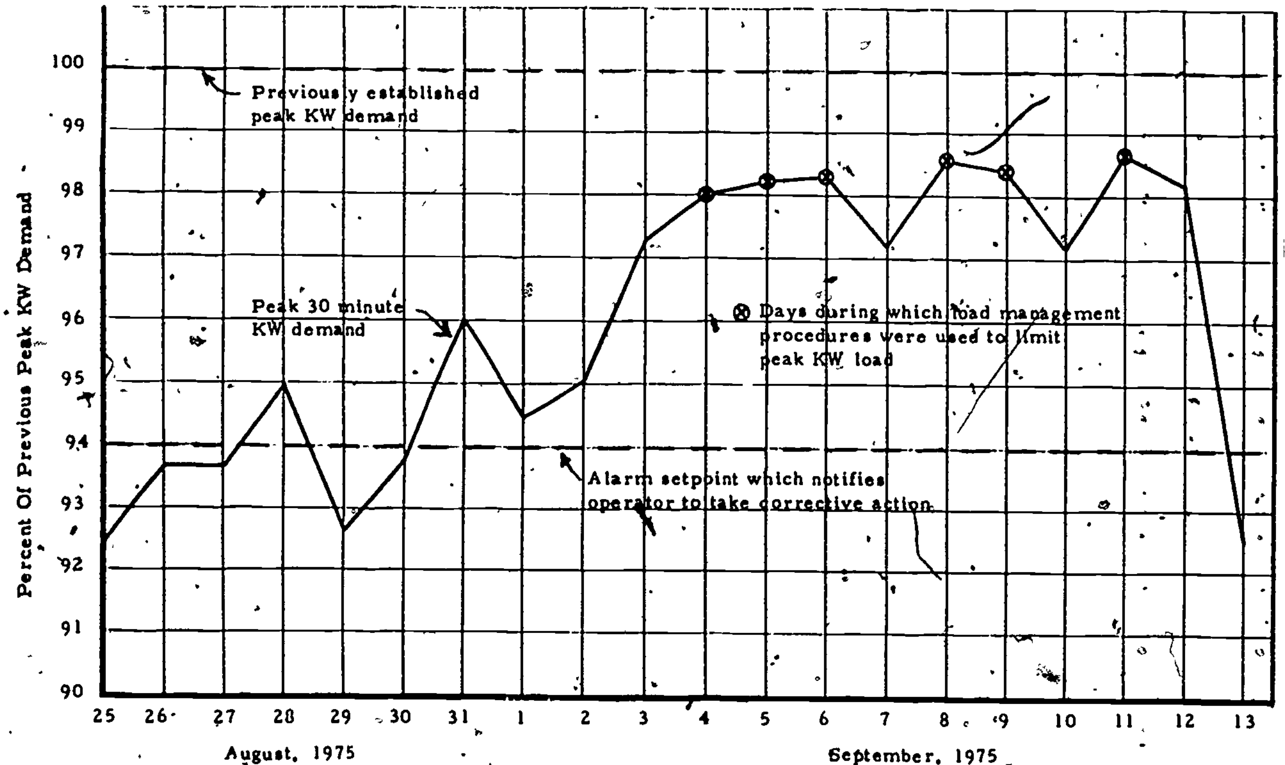
(2) Portatorque Analyzer Model PCM 2020, marketed by RFD Instrument Company, Inc., P.O. Box 548, Elgin, Texas 78621. 512/285-3385.

Figure 1


BEARING
VOLTAGE
CURRENT
METER DISK
BRIGHT SPOT
PHOTOCELL
LENS
RELAY
R
CLOCK
LIGHT
BEARING
A
B



$$SLOPE = \frac{RISE}{RUN} = \frac{KWH}{H} = KW$$



PROFILE OF PEAK KW DEMAND AT FII SHELBY SOUTH SUBSTATION

Figure 2

Figure 3

Types of Control Schemes

Category	Controller Cost Only	Installed Cost Per Control Point	Max. No. of Output Control Points	Program Changes By	Features	Typical Vendors	Remarks
I Manual Surveillance	$1,000 to 4,000	$1,000 to 4,000	1 (If the alarm point is used)	None Available	Alarm and Hard Copy Monitoring of KWD Load	Dynalco Corp. Ferranti Process Systems Scientific Columbus	Rely on proper action by the operator
II Hardwired	$3,000 to 15,000	$ 300 to $1,000	16 to 48	Operating Personnel Using Plugs or Switches	Alarms KWD Control KWH Consv. Cycling	Allen Bradley Cutler Hammer Dynalco Corp. ITE, PTI Process Systems Sangamo, Square D Scientific Columbus	Shed and Restore Sequence and Priority can be Changed Easily by The Operator
III Minicomputer	$20,000 to 80,000	$ 200 to 800	48 to 640	Operating Personnel Using TTY, CRT Console, Paper Tape or Function Keys	Alarms KWD Control KWH Consv. Cycling Optimization Trend Charts Logs Graphics	DEC, Fisher Foxboro Honeywell, IBM Process Systems Robertshaw Solid State Systems Taylor Westinghouse	The Featured Programs are limited only by Memory Size. (Some are harder to program than others!)
IV Total Energy Control System	$100,000 to 400,000	$ 100 to 600	Several Thousand	Operating Personnel Using TTY, CRT Console, Paper Tape, or Function Keys	All of Category III above Plus Complete Monitoring and Control	Fisher, Foxboro Honeywell Johnson Control Powers Regulator Robertshaw Taylor	This system performs continuous monitoring and Optimization Functions and Includes Potential Labor Savings

Figure 4

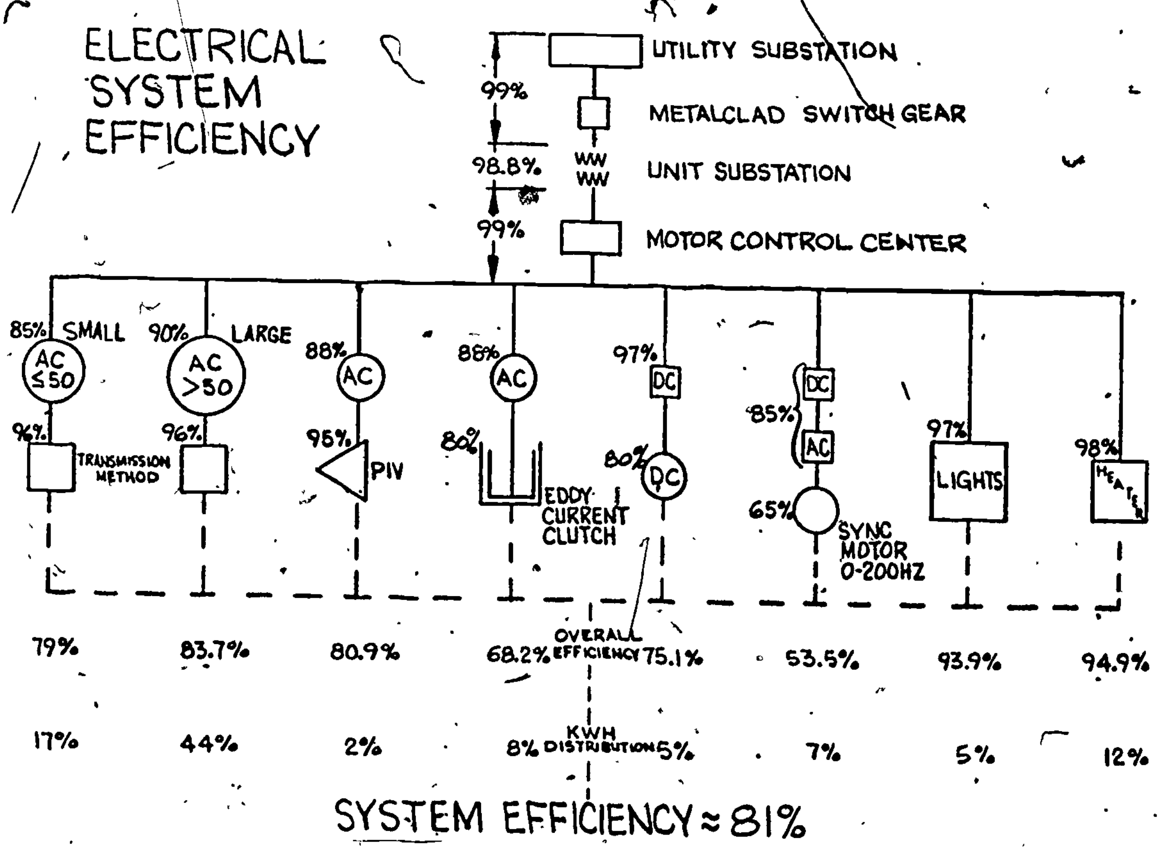
DESCRIPTION & EQUIPMENT NO.	OWNERSHIP	CONNECTED KVA	RUNNING KVA	RUNNING KW	CUBICLE	OPER. COST PER DAY	ESTIMATE OF TIME OFF	CONDITIONS UNDER WHICH DEVICE CAN BE DOWN	REMARKS (UTILIZATION, SPARES, ETC)
SUPPLY FAN K-7801.05		100			1D		10 MIN	FOR KWD	Consider As
RETURN AIR FAN K-7801.06A		25			2C		OFF, 50	CONTROL, OR AS PART OF	One Load To
RETURN AIR FAN K-7801.06B		25			2D		MIN ON	CYCLING FOR KWH REDUCTION	Be Shed
ELEVATOR		75			2E		0 MIN	NONE	Not Available
AIR HANDLING UNIT FOR S-3	S3	7 1/2			3D		5 MIN OFF 55 MIN ON	KWD CONTROL ONLY	EFFECTS YARN QUALITY
SERVICE PANEL K-15		30			3BL		0 MIN.	NONE	NOT AVAILABLE
LIGHTING PANEL K-78		30			3AR		0 MIN	NONE	REVIEW NEED FOR PHOTO CELLS ON SOME LIGHTING CIRCUITS

UNIT SUBSTATION KL-8	MCC KL-8-1	DATE 7 7 77 (DAY MO. YR)	PREPARED BY WLS	L-5-4230-05 REF. DRAWING NUMBER; PAGE 1 OF 1	REV. Ø

Figure 5

EXACT LOCATION	TYPE OF ACTIVITY	AREA SIZE	ATMOS. COND.	SURFACE COLORS	FIXTURE TYPE	FIXTURE HT.	FIXTURE SIZE & NO.	AREA HEIGHT	MEASURED FOOT CANDLES	RECOM. FOOT CANDLES	REMARKS
CREEL	FORK TRUCK	100 x 200	CLEAN	GRAY LT. BLU GRAY	OPEN FL.	30'	36 2 x 8'	35'	31		MEAS. 30" OFF FLOOR
DRAWFRAME	TOW PROCESSING	30 x 100	MISTY	GRAY GRAY GRAY	OPEN FL.	10'	10 2 x 8'	15'	26		STEAM IN THE AIR
BALER	TOW BALING	50 x 200	FLYING FIBERS	WHITE YELLOW GRAY	Hg VAPOR	25'	15 @ 400 W	35'	36		MEAS TAKEN BEHIND BALER
CONVEYOR	TOW TO STORAGE	50 x 200	CLEAN	WHITE GRAY GRAY	HPS	40'	10 @ 250 W	50'	40		BALES STACKED 22' HIGH

PLANT	AREA	DATE / TIME	PREP. BY	PAGE	REVISION
PALMETTO PLANT	J STAPLE PROCESSING	7/7/77 TIME 1145	WLS	PAGE 1 OF 1	∅


ELECTRICAL SYSTEM EFFICIENCY
UTILITY SUBSTATION
METALCLAD SWITCH GEAR
UNIT SUBSTATION
MOTOR CONTROL CENTER
99%
98.8%
99%
85% SMALL
AC ≤50
90% LARGE
AC >50
88% AC
88% AC
97% DC
DC
85%
AC
97%
98%
96%
TRANSMISSION METHOD
96%
95%
PIV
80%
EDDY CURRENT CLUTCH
80% DC
65%
SYNC MOTOR 0-200HZ
LIGHTS
HEATER
79%
83.7%
80.9%
68.2%
OVERALL EFFICIENCY
75.1%
53.5%
93.9%
94.9%
17%
44%
2%
8%
KWH DISTRIBUTION
5%
7%
5%
12%
SYSTEM EFFICIENCY ≈ 81%

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