

# A Multiobjective Model for Managing Faculty Resources

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## Abstract

*During the past 20 years, many state institutions of higher education have faced stringent financial constraints. As a result of these constraints, administrators, legislators and the general public are looking for more critical approaches in evaluating the operational efficiency of higher education institutions. It has become a necessity for higher education institutions to develop planning models for efficient resource allocation for their own survival. The purpose of this article is to present a model for faculty resource allocation at higher education institutions.*

## Introduction

It is becoming painfully clear that state institutions of higher education are facing tremendous challenges in acquiring funds. Lee and Clayton (1972) cited several, among the following, reasons for this situation including the overall poor health of the economy, change in the federal government role regarding higher education, an increase in the rate of higher education expenditures, and a switch in national priorities to more critical social issues that mandate the immediate attention of the government.

According to Zemsky and Stine (1989), higher education in America is facing real problems. These problems, however, stem more from changes than failure. The authors argued that the agenda for higher education for the remainder of this century consists of three main issues: costs, quality of teaching, and making higher education more inclusive. McPherson et al. (1989) noted that the higher education price index has increased by more than 8 percent over the consumer price index for the period between 1978 and 1986. This situation was exacerbated by the federal and state government cut backs of their support to academia. With the largest portion of higher education costs in faculty and staff compensation and in light of these financial pressures, the efficient utilization of the resources in state colleges and universities becomes extremely critical. Institutions must explore more effective methods of doing more with less.

In this article we will introduce an analytical technique that could be used for resource allocation in higher education institutions. The technique, known as goal programming, will be applied to a case study to show the potential application to institutions of higher education.

## Goal Programming

Goal programming is a decision-making tool that is capable of handling problem situations that involve multiple and often conflicting goals with varying degrees of importance. In order for goal programming to be used, the decision maker must be able to rank these goals in terms of their importance to the organization. Unlike linear programming which focuses on obtaining the optimal solution for one objective, goal programming identifies the point that best satisfies the stated goals. Goal programming attempts to minimize the deviations from these goals with consideration given to the hierarchy of the stated goals.

One of the advantages of goal programming is that it allows the decision maker to incorporate environmental, organizational, and managerial considerations in the model through the process of ranking or prioritizing the goals. However, some may argue that this allows for subjectivity to enter the analysis, and may see subjectivity as a hindrance in that results are less than "scientific". Other difficulties are described by Turban and Meredith (1994). These difficulties are common to all multiple criteria decision making techniques. They include the inability to express certain goals in quantitative terms, obtaining an explicit statement of the goals of the organization, and the decision maker may change the relative importance assigned to certain goals as time passes.

Goal programming has been widely used in various business and non-business areas. Despite the increasingly growing applications of goal programming in general, its use in higher education, however, has been limited. In addition to the study by Lee and Clayton (1972), there has been only two other studies by Schroeder (1974) and Diminnie and Kwak (1986). The application

of goal programming in the area of faculty resource allocations is almost non-existent. This article is an attempt to contribute to fill that gap.

## An Application

The model presented in this paper is an application of goal programming to the allocation of faculty resources at the University of Southern Indiana. From its beginning in 1965, the University has followed an orderly plan of development. One of the primary goals in this plan is strengthening faculty resources. Strengthening and allocating faculty resources often results in conflicting goals. The University of course would like to hire the best, most qualified faculty members in order to satisfy the goal of providing quality education to its students. But the University must also operate within the realm of its financial constraints and satisfy the goal of minimizing costs. These goals are basically at the opposite ends of the spectrum of options, but both must be considered in the allocation of faculty resources. Goal programming can be applied to this situation to obtain a solution that results in minimum deviations from the stated goals of the institution.

The model can be designed to analyze a particular unit of the university; for example, the entire academic affairs area, a particular school within the university, or a particular department within a school. The narrower the scope of the analysis, the more fine tuned the results become. Particularly in the area of faculty resource allocation, it is better to analyze each department within a school individually so items that are indicative of the department can be addressed and do not run the risk of being absorbed into the larger picture.

In addition, the model must have a defined time period. This time period, referred to as the planning horizon, can vary. As with the choice of the institutional unit to analyze, the planning horizon should also be limited. Of course the model can be extended for a longer planning horizon or for larger institutional units by introducing the appropriate variables and parameters.

## The Model

The basic data used in this model was obtained from the School of Education and Human Services' Department of Teacher Education. The model's scope is limited to one year to enhance understanding and provide a clearer presentation of the methodology involved. The Department has five goals. The first goal will be assigned the first priority ( $P_1$ ), the second goal will be given the second priority ( $P_2$ ), etc... In this model the goals are ranked as follows: (1) To assure coverage of the required course hours, (2) To maintain a faculty split of 80 percent full-time and 20 percent part-time,

(3) To maintain a 65 percent terminal degree coverage rate of full-time faculty, (4) To attain a desired distribution of faculty with respect to rank, and (5) To minimize cost.

The first and foremost goal is to provide coverage of the required number of course hours each year. The required course hours are calculated by multiplying the number of sections offered each year by three, the average number of credit hours per course. The department must have the faculty required to teach the courses offered. During the academic year used in this model, it is projected that a total of 456 course hours will be generated in the Department of Teacher Education.

A full time teaching load for full-time faculty is twenty-four course hours per year and twelve course hours or less per year for part-time faculty. Because of other duties such as administrative, student advising, counseling, etc., full-time faculty loads sometimes exceed and sometimes do not reach the full-time load level. The teaching load of each faculty member is determined by (1) the number of different preparations per week, (2) the number of students for which he or she is responsible, (3) the non-teaching responsibilities which he or she has, (4) the amount of personal attention each assignment requires, and (5) the experience of the faculty member. The total professional education load should be so distributed as to allow for reasonable specialization in the assignment of each faculty member.

The University of Southern Indiana has grown significantly in the past ten years. Overall, the University's enrollment has grown by 95 percent in this ten year period. In order to maintain accessibility and accommodate the enrollment increase, the University has had to significantly increase the reliance upon part-time faculty. The University has had to hire additional part-time instructors each biennium since 1980. This reliance on part-time faculty, who do not engage in advising, adds to the burden of full-time faculty and has diminished services to students. During the past ten years, the overall percentage of instruction delivered by full-time faculty members as part of their regular teaching assignment decreased from 74 percent to 58 percent. Currently in the Department of Teacher Education, the percentage of instruction delivered by full-time faculty members is 57 percent. Thus the second goal of the University is to reduce reliance on part-time faculty to a stable level of 20 percent.

It is important to establish a guideline regarding the percentage of faculty members required to possess terminal degrees. Of course each department would like for all faculty members to possess terminal degrees, but usually this is not feasible. Not only can costs be prohibitive, but also it is not always necessary for all faculty members to possess terminal degrees. Certain

courses do not require faculty with terminal degrees to teach them.

Currently in the Department of Teacher Education, ten of eleven full-time faculty possess terminal degrees. This is due in large part to turnover at the lower faculty ranks and very limited turnover in the upper faculty ranks. Distribution of faculty with respect to rank is also an important goal. It is necessary to impose some constraints on the distribution, otherwise the model would call for the most productive type of faculty in terms of teaching load, salary, etc. regardless of the actual distribution needs. In the Department of Teacher Education, no instructors are currently on staff. This is due in part to the experience requirements of the School of Education. Faculty are required to have a minimum of three years experience teaching in an elementary or secondary school and have completed their graduate studies. When these faculty are hired, they generally are hired as assistant professors. The rank of instructor is assigned to a person who has not completed a terminal degree.

Table 1 lists the various faculty ranks, teaching loads, desired proportion of faculty distribution by rank, and average salaries for each faculty rank. The final goal in this model is to minimize cost. Cost minimization is always a consideration, but in this particular scenario we want to know how much it will cost to satisfy the stated goals and whether or not the cost of making any changes will be prohibitive. In formulating the goal programming model, the decision variables and deviational variables must be defined.

The decision variables for the model are defined as follows:

- $x_1$  = # of professors with terminal degrees
- $x_2$  = # of associate professors with terminal degrees
- $x_3$  = # of assistant professors with terminal degrees
- $x_4$  = # of professors without terminal degrees
- $x_5$  = # of associate professors without terminal degrees
- $x_6$  = # of assistant professors without terminal degrees
- $x_7$  = # of instructors without terminal degrees
- $x_8$  = # of part-time faculty

The deviational variables are defined as follows:

- $d_1^-$  = The underachievement of coverage of required course hours
- $d_1^+$  = The overachievement of coverage of required course hours
- $d_2^-$  = The underachievement of maintaining a faculty split of 80 percent full-time and 20 percent part time
- $d_2^+$  = The overachievement of maintaining a faculty split of 80 percent full-time and 20 percent part time
- $d_3^-$  = The underachievement of maintaining a 65 percent terminal degree coverage rate for full-time faculty
- $d_3^+$  = The overachievement of maintaining a 65 percent terminal degree coverage rate for full-time faculty
- $d_4^-$  = The underachievement of attaining a 29 percent distribution in the professor with terminal degree rank

**Table 1**

<u>Faculty Rank</u>	<u>Teaching Load</u>	<u>Desired Proportion</u>	<u>Average Salary</u>
<b>With Terminal Degrees</b>			
Professor	24	29%	\$47,000
Associate Professor	24	23%	\$41,000
Assistant Professor	24	17%	\$34,000
<b>Without Terminal Degrees</b>			
Professor	24	0%	\$47,000
Associate Professor	24	0%	\$41,000
Assistant Professor	24	11%	\$34,000
Instructor	24	0%	\$30,000
Part-Time Faculty	12	20%	\$ 6,400

- $d_4^+$  = The overachievement of attaining a 29 percent distribution in the professor with terminal degree rank
- $d_5^-$  = The underachievement of attaining a 23 percent distribution in the associate professor with terminal degree rank
- $d_5^+$  = The overachievement of attaining a 23 percent distribution in the associate professor with terminal degree rank
- $d_6^-$  = The underachievement of attaining a 17 percent distribution in the assistant professor with terminal degree rank
- $d_6^+$  = The overachievement of attaining a 17 percent distribution in the assistant professor with terminal degree rank
- $d_7^-$  = The underachievement of attaining a 0 percent distribution in the professor without terminal degree rank
- $d_7^+$  = The overachievement of attaining a 0 percent distribution in the professor without terminal degree rank
- $d_8^-$  = The underachievement of attaining a 0 percent distribution in the associate professor without terminal degree rank
- $d_8^+$  = The overachievement of attaining a 0 percent distribution in the associate professor without terminal degree rank
- $d_9^-$  = The underachievement of attaining an 11 percent distribution in the assistant professor without terminal degree rank
- $d_9^+$  = The overachievement of attaining an 11 percent distribution in the assistant professor without terminal degree rank
- $d_{10}^-$  = The underachievement of attaining a 0 percent distribution in the instructor without terminal degree rank
- $d_{10}^+$  = The overachievement of attaining a 0 percent distribution in the instructor without terminal degree rank
- $d_{11}^-$  = The underachievement of attaining a 20 percent distribution in the part-time faculty rank
- $d_{11}^+$  = The overachievement of attaining a 20 percent distribution in the part-time faculty rank
- $d_{12}^-$  = The underachievement of minimizing cost
- $d_{12}^+$  = The overachievement of minimizing cost

Once the decision and deviational variables are defined, the constraints and the objective function may be formulated. When formulating the constraints and the objective function, deviational variables must be added to reflect the amount by which a goal is underachieved ( $d^-$ ) or overachieved ( $d^+$ ). Each goal must be analyzed to determine if deviation is acceptable. If overachievement of the goal is acceptable, then only  $d^-$  appears in the objective function. If underachievement is acceptable, only  $d^+$  appears. It is impossible to have both overachievement and underachievement of a goal. If the goal is to be achieved exactly, both deviational

variables will equal zero and both  $d^-$  and  $d^+$  will appear in the objective function. Both deviational variables are included in the goal constraints since it is possible that the ultimate solution may result in either overachievement or underachievement of a particular goal.

The complete model is listed in Appendix 1 and will be discussed in the following paragraphs. The first goal of the model is to assure coverage of 456 course hours. A full-time load for full-time faculty is twenty-four course hours per year and twelve course hours or less per year for part-time faculty. In the objective function, this goal is to be achieved exactly. We need enough faculty to cover the course hours, but do not want idle faculty. Therefore, the deviational variables for priority one ( $P_1$ ) are  $d_1^-$  and  $d_1^+$ .

The next goal is to maintain a faculty split of 80 percent full-time and 20 percent part-time. This constraint is formulated as follows: the sum of all full-time variables equals to 80 percent of the summation of all variables. In the objective function, the underachievement is to be minimized. We do not want to underachieve the 80 percent full-time level. The deviational variable for priority two ( $P_2$ ) is  $d_2^-$ .

The third goal is to maintain a 65 percent terminal degree coverage rate of full-time faculty. The constraint is formulated as follows: the sum of all variables with terminal degrees equals to .65 of the summation of all variables. As in priority two, the underachievement is to be minimized and the deviational variable for priority three ( $P_3$ ) is  $d_3^-$ .

The fourth goal is to attain the desired distribution of faculty by rank. The desired proportions are assigned to each variable and are entered in the constraints. The constraints are formulated as follows: variable  $x_i$  equals to the desired percentage times the summation of all variables. The constraints for this goal are listed as equations 4 through 11 in Appendix 1. In priority four ( $P_4$ ), the deviational variables vary. For variables representing faculty with terminal degrees, the underachievement should be minimized and for variables representing faculty without terminal degrees, the overachievement should be minimized to help insure that the desired positions of faculty with terminal degrees are maximized. Since goal constraints seven, eight, and ten have a desired distribution values equal to zero, we want to achieve them exactly. Therefore, the deviational variables for these constraints are  $d_7^+$ ,  $d_7^-$ ,  $d_8^+$ ,  $d_8^-$ ,  $d_{10}^+$ , and  $d_{10}^-$ . The deviational variables for the remaining constraints in priority four are  $d_4^-$ ,  $d_5^-$ ,  $d_6^-$ ,  $d_9^+$ , and  $d_{11}^+$ .

The final goal is to minimize cost. If all the previous goals are satisfied, how much will it cost? The salary level for each rank,  $c_i$ , is multiplied by the value of the

corresponding variable,  $x_i$ , to determine the total cost. The right-hand side of the constraint is set to equal zero since that would force a solution with minimum cost. In priority five ( $P_5$ ), the overachievement must be minimized. We do not want to exceed the minimum cost. The deviational variable is  $d_{12}^+$ .

### Model Solution

The model was solved using Lee and Shim's (1990) microcomputer program. The solution reveals the following values for the decision variables:

<u>Variable</u>	<u>Value</u>
$x_1$ = # of professors with terminal degree	5.278
$x_2$ = # of associate professors with terminal degree	4.856
$x_3$ = # of assistant professors with terminal degree	3.589
$x_4$ = # of professors without terminal degree	0.000
$x_5$ = # of associate professors without terminal degree	0.000
$x_6$ = # of assistant professors without terminal degree	3.167
$x_7$ = # of instructors without terminal degree	0.000
$x_8$ = # of part-time faculty	<u>4.222</u>
	21.112

Technically, the solution values should be integers. This can be achieved through an integer goal programming model. For the scope of this study, however, rounding will be applied to determine the number of each faculty rank that satisfies an integer solution. Even though rounding may result in an infeasible solution or may not lead to the optimal solution, in this model we are seeking a solution that best satisfies our goals rather than one that is optimal. The noninteger solution values are the starting point for further computational analysis. The solution values, rounded to the nearest integer, are:

<u>Variable</u>	<u>Value</u>
$x_1$ = # of professors with terminal degree	5
$x_2$ = # of associate professors with terminal degree	5
$x_3$ = # of assistant professors with terminal degree	4
$x_4$ = # of professors without terminal degree	0
$x_5$ = # of associate professors without terminal degree	0
$x_6$ = # of assistant professors without terminal degree	3
$x_7$ = # of instructors without terminal degree	0
$x_8$ = # of part-time faculty	<u>4</u>
	21

Substituting these values in the model constraints yields the following:

The amount of credit hours covered equals 456.  
 The full-time faculty ratio is 81 percent.  
 The terminal degree coverage is 67 percent.  
 The distribution of faculty rank is as follows:  $x_1=.24$ ,  $x_2=.24$ ,  $x_3=.19$ ,  $x_4=.00$ ,  $x_5=.00$ ,  $x_6=.14$ ,  $x_7=.00$ ,  $x_8=.19$

The total cost for this solution is \$703,600. All goals

are satisfied with the exception of some of the desired distributions for goal four. However, this solution provides a distribution that is very close to the stated distribution. The desired distribution for variable  $x_1$  is slightly underachieved while that of variable  $x_6$  is slightly overachieved. The current distribution of faculty in the Department includes four professors, two associate professors, and four assistant professors. In addition, there is one assistant professor without a terminal degree and 18 part-time instructors. The results of this model were satisfactory to the Department's Chair and will be submitted to the Dean of the School of Education for the 1994-1996 biennial operating budget request.

The basic framework provided by this model can be enhanced through sensitivity analysis. Different priority structures can be assigned to the goals and the change in the values of the decision variables can be examined. This allows for analysis of various scenarios involving the prioritization of the goals. One of the greatest benefits of this approach is that it is flexible and can be customized to the user's requirements.

### Conclusion

The model developed in this article is intended to demonstrate the potential application of goal programming to the allocation of faculty resources. The constraints and objective function used in this model can be expanded to address a broader university unit base or a longer planning horizon. The model can also be used to measure the success of obtaining established goals. Bench mark data can be generated using the model. Actual performance can then be measured against the bench marks to monitor the progress of goal achievement. This can be especially useful as a department, school, etc. strives to build up its faculty resources to the desired level.

### Suggestions For Future Research

The model can be augmented to include all academic units in the university. The priority structure has to be modified to account for the additional goals and objectives. A more detailed process for ranking the goals has to be introduced and implemented. ■

### \*\*\*References\*\*\*

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APPENDIX 1

$$\text{Minimize } Z = P_1d_1^- + P_1d_1^+ + P_2d_2^- + P_3d_3^- + P_4(d_4^- + d_5^- + d_6^- + d_7^- + d_7^+ + d_8^+ + d_8^- + d_9^+ + d_{10}^+ + d_{10}^- + d_{11}^+) + P_5d_{12}^+$$

Subject to:

$$\left(\sum_{i=1}^7 24x_i\right) + 12x_8 + d_1^- - d_1^+ = 465 \dots (1)$$

$$\left(\sum_{i=1}^7 .2x_i\right) - .8x_8 + d_2^- - d_2^+ = 0 \dots (2)$$

$$\left(\sum_{i=1}^3 .35x_i\right) - \left(\sum_{i=4}^8 .65x_i\right) + d_3^- - d_3^+ = 0 \dots (3)$$

$$\left(\sum_{i=1}^8 .29x_i\right) - x_1 + d_4^- - d_4^+ = 0 \dots (4)$$

$$\left(\sum_{i=1}^8 .23x_i\right) - x_2 + d_5^- - d_5^+ = 0 \dots (5)$$

$$\left(\sum_{i=1}^8 .17x_i\right) - x_3 + d_6^- - d_6^+ = 0 \dots (6)$$

$$\left(\sum_{i=1}^8 .00x_i\right) - x_4 + d_7^- - d_7^+ = 0 \dots (7)$$

$$\left(\sum_{i=1}^8 .00x_i\right) - x_5 + d_8^- - d_8^+ = 0 \dots (8)$$

$$\left(\sum_{i=1}^8 .11x_i\right) - x_6 + d_9^- - d_9^+ = 0 \dots (9)$$

$$\left(\sum_{i=1}^8 .00x_i\right) - x_7 + d_{10}^- - d_{10}^+ = 0 \dots (10)$$

$$\left(\sum_{i=1}^8 .20x_i\right) - x_8 + d_{11}^- - d_{11}^+ = 0 \dots (11)$$

$$\sum_{i=1}^8 c_i x_i + d_{12}^- - d_{12}^+ = 0 \dots (12)$$