Goal Programming as a Solution Technique for the Acquisitions Allocation Problem

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Decisions influencing the allocation of acquisitions funds in academic libraries are often based on the influence of many conflicting expectations ranging from those of the university community, administrators, faculty, and students to those of the librarians themselves. Any effective allocation model must be capable of reflecting the librarian's judgment about the priority of desired goals within the constraints of the existing situation. Most allocation models fail to meet this requirement. This article demonstrates how goal programming techniques can be used to provide an optimal allocation solution within the context of conflicting and incommensurate goals. A goal programming model is developed and used to illustrate the solution of a library acquisition allocation problem.

Large increases in the number of scholarly monographs and journals published, combined with escalating prices in published materials over the last few years, have made it increasingly difficult for librarians to maintain current levels of collections (Daval, 1994; Kyrillidou, Rodriguez, & Stubbs, 1997). Many librarians are forced to cancel journal subscriptions and sacrifice monograph purchases to maintain core journal collections. Analysis has demonstrated that books and journals in scientific fields have increased in price faster than those in other subject disciplines (Alexander & Dingley, 1997), thereby forcing collection development librarians (particularly those working with science and technology) to select fewer monograph titles or to reduce serials collections to satisfy a pool of competing interests for limited funds.

To address this problem, librarians have developed various models for allocating acquisitions funds across subject disciplines. Research by Greaves (1974) has demonstrated that the majority of these models focus on a common set of

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eight factors that provide the variables for most acquisitions allocation formulas. These eight factors are:

- Number of faculty in an academic department;
- Number of students in an academic department or number of student credit hours generated within an academic department;
- Amount of research conducted in an academic department;
- Cost of library materials;
- Adequacy of the library collection in an academic discipline;
- Number and type of courses in an academic department;
- Circulation statistics tabulated by subject area; and
- Past record of a department in expending of allocated funds.

Subsequent research by Budd and Adams (1989) and by Tuten and Jones (1995) and later models formulated by Evans (1996), Sorgenfrei (1999), and Crotts (1999) confirm that the factors identified by Greaves (1974) continue to be the most commonly used in allocation formulas. This research also suggests that since the time of the Greaves survey, the output of published material has become an important variable in allocation formulae.

The models surveyed by Greaves (1974), Budd and Adams (1989), and Tuten and Jones (1995) vary considerably in their mathematical sophistication, function, methodology, purposes, subject, data, and so forth. The majority, however, attempt to reduce the degree of uncertainty by relying primarily on past trends or data.

The essential issue in allocating acquisitions funds does not end with operational efficiency but necessarily incorporates the purpose, function, and philosophy of each library and its parent institution. A library's allocation policies are based on the influence of many conflicting expectations ranging from those of the university community, administrators, faculty, and students, to those of the librarians themselves. Any effective model, therefore, must be capable of reflecting the librarian's judgment about the priority of desired goals within the constraints of the existing situation. Most allocation models fail to meet this requirement. Models using goal programming techniques, however, appear to offer the most appropriate approach to developing solutions that attain multiple, competitive, and often conflicting goals with varying priorities. The purpose of this article is to illustrate goal programming techniques that will allow librarians with responsibilities for allocating acquisitions funds in an academic library to achieve an optimum solution while prioritizing their funding objectives.

THE GOAL PROGRAMMING APPROACH

Goal programming is a special extension of linear programming (Charnes & Cooper, 1961; Ijiri, 1965) that is capable of handling decision problems that deal with a single goal with multiple subgoals as well as problems with multiple

goals with multiple subgoals (Ijiri, 1965). In conventional linear programming the objective function is unidimensional, intended either to maximize effectiveness or to minimize sacrifice. Goal programming techniques are capable of handling multiple goals in multiple dimensions and therefore have no dimensional limitation of the objective function.

Allocation goals set by collection development librarians are often achievable only at the expense of other goals; in many cases, these goals are incommensurable (i.e., measured in different units). Thus, there is a need to establish a hierarchy of importance among incompatible goals such that the achievement of the lower order goals are considered only after the higher order goals have been satisfied or have reached a point beyond which no further improvements are desirable. Goal programming techniques offer optimal solutions to the problem of conflicting or incommensurable goals if an ordinal ranking of goals in terms of their contributions or importance to the organization can be provided.

Goal programming techniques focus on minimizing the deviations between the goals themselves and what can be achieved within the given set of constraints rather than trying to maximize or minimize the objective criterion directly. These deviational variables are two dimensional, represented as both positive and negative deviations from each goal. In the solution, the objective function minimizes these deviations based on the relative importance or preemptive priority weights assigned to them. The objective function may also include real variables with ordinary or preemptive weights in addition to the deviational variables.

The primary characteristic of goal programming techniques is that they allow for ordinal solutions. In other words, the librarian may not be able to obtain information on the cost or value of a goal but may be able to establish an upper or lower limit for each goal. In goal programming, this judgment is expressed as a priority of the desired attainment of each goal ranked in ordinal sequence. In the allocation of scarce resources it is not always possible to achieve every goal to the extent desired by the decision makers. Thus, with or without goal programming, librarians attach a certain priority to the achievement of a certain goal. The true value of goal programming as applied to a library's materials budget is the solution of problems involving multiple, conflicting local goals ranked according to a priority structure set by the library.

A commonly used generalized model for goal programming (Charnes & Cooper, 1977) requires minimizing

$$Z = \sum_{i=1}^{m} w_i P_i(\eta_i + \rho_i)$$

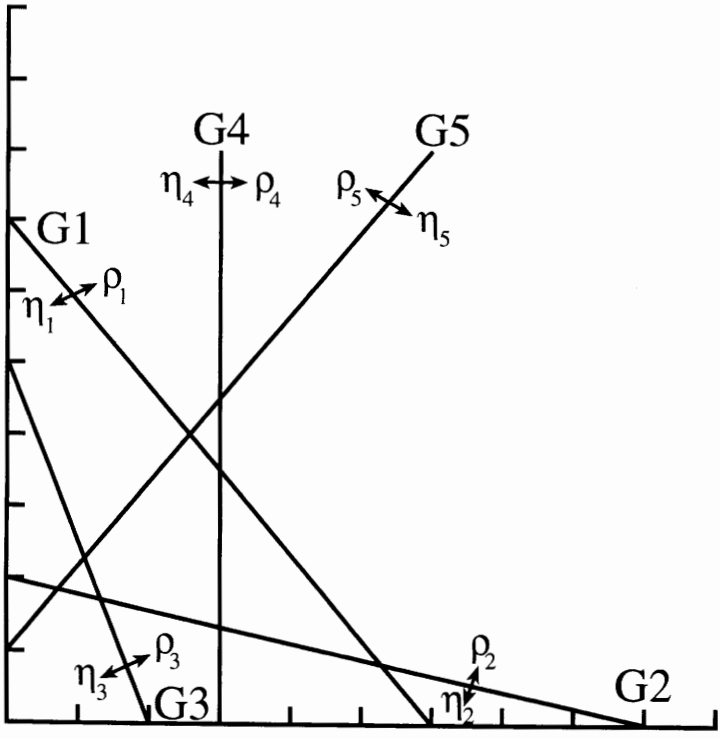
subject to

$$\sum_{j=1}^{n} a_{ij}x_{ij} + \eta_i - \rho_i = b_i \quad (i = 1, 2, \ldots, m),\ x_{ij},\ \eta_i,\ \rho_i \geq 0$$

where m goals are expressed by an m component column vector b ($b_1, b_2, \ldots, b_m$), and where each a_{ij} represents the decision variable coefficients expressing the relationship between goals, each x_{ij} represents the decision variables involved in the goals, and η and ρ are m-component vectors for the variable representing deviations from the goals. P_i is the priority level assigned to each relevant goal in rank order (i.e., $P_1 > P_2 > \ldots > P_n$), and w_i are non-negative constants representing the relative weights assigned with a priority level to the deviational variables, η_i and ρ_i, for each jth corresponding goal, b_i.

This technique can be demonstrated graphically as in Figure 1 where hypothetical goals G1–G5, ranked in priority order, are represented as linear equations plotted on a graph. In academic libraries, acquisitions allocation objectives are often stated in the form of inequalities by using such phrases as "acquire at least," "maintain a level of," "do not exceed," and "achieve a maximum." Since the solution procedure used in solving goal programming models requires a set of simultaneous linear equations, all goals must be converted into equations through the addition of goal deviation variables represented by the

FIGURE 1
Graphic Representation of Hypothetical Goal Programming Model

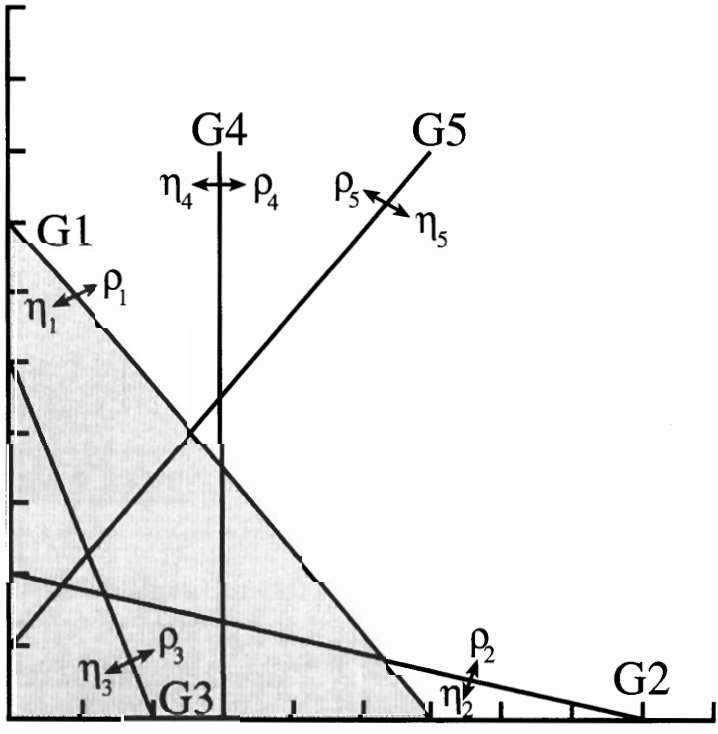


ηs and ρs on the graph. Goal programming seeks a solution that serves to "minimize" all unwanted deviations. Deviation variables reflect either the under-achievement (denoted as η) or over-achievement (denoted as ρ) for each objective statement.

The solution technique involves first determining the solution space for the highest priority goals (G1 in Figure 1) while minimizing the effect of an increase in any deviation variable η or ρ as reflected by the arrows perpendicular to each goal line. After finding a solution to the highest priority goals, the process moves to the set of goals having the next highest priority and determines the "best" solution space for this set of goals, where this "best" solution cannot degrade the achievement values already obtained for higher priority goals. The process repeats these steps until it converges to a single point or all priority levels have been evaluated.

Figure 2 illustrates the solution space after the process has moved through the highest priority goal (G1) where the objective function minimizes the over-achievement deviation variable. The solution space is shown by the shaded area bounded by the line representing G1.

FIGURE 2
Solution Space after the Highest Priority Goal



Similarly, Figure 3 illustrates the solution space after the process has moved through the next highest priority goal (G2) assuming the objective function minimizes the under-achievement of the deviation variable. The solution space at this point is shown by the shaded area between the lines G1 and G2.

This process is repeated until goals G3 through G5 have been satisfied or the solution space is such that no further compromise can be achieved. In this example the final solution space would appear as the shaded area in Figure 4, assuming the objective function is minimizing the under-achievement of G3 and the over-achievement of G4 and G5. Where the goals are incommensurate, the space between the plotted lines normally shrinks until reaching a compromise solution space.

Each of the goals considered in the model must be analyzed in terms of whether over- or under-achievement of the goal is satisfactory. If over-achievement is acceptable, η can be eliminated from the objective function. On the other hand, if under-achievement is satisfactory, ρ should be excluded from the

FIGURE 3
Solution Space after Next Highest Priority Goal

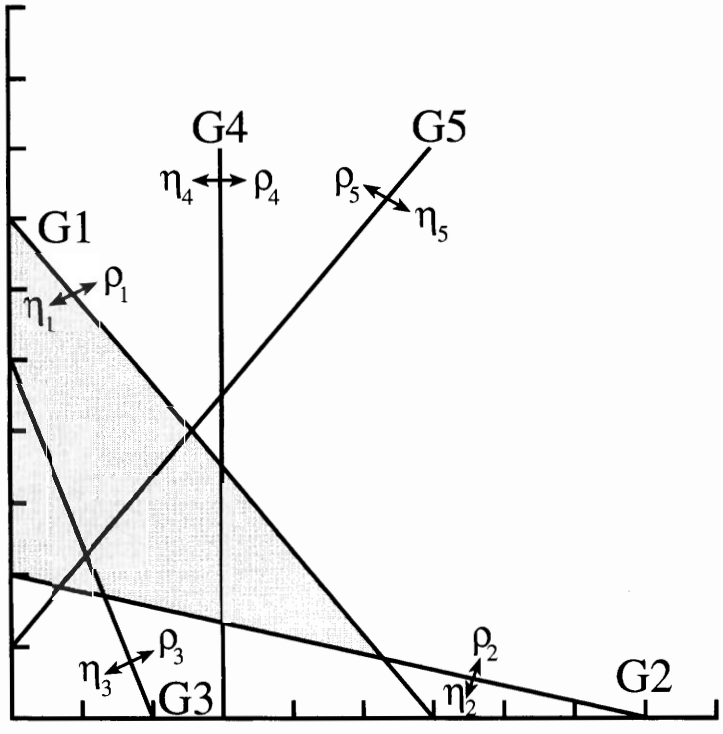
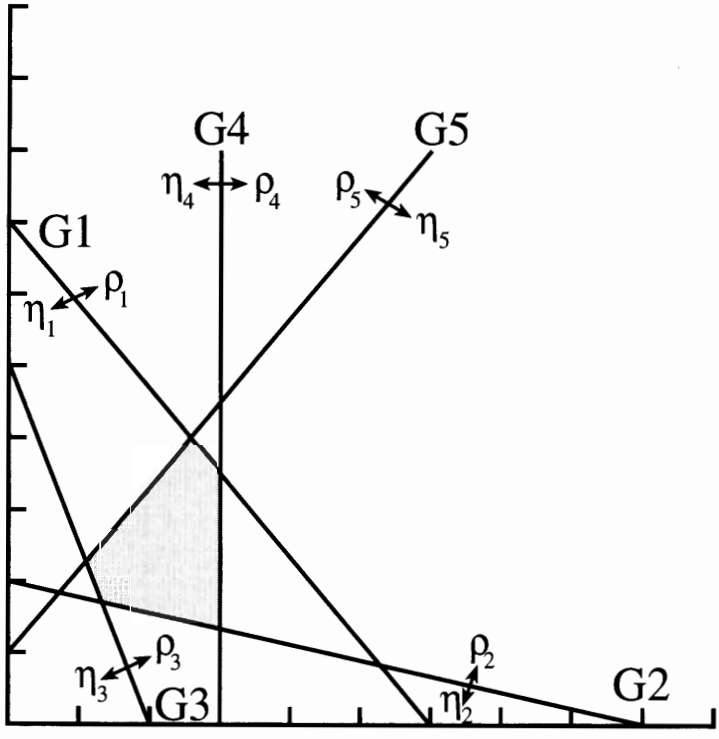


FIGURE 4
Final Solution Space



objective function. If the exact achievement of the goal is desired, both η and ρ must be represented in the objective function.

The deviational variables η and ρ must be ranked according to their preemptive priority weights, from the most important to the least important. In this way the lower order goals are considered only after the higher order goals are achieved as desired. If goals are classified in n ranks, the preemptive priority factor P_i $(i = 1, 2, \ldots, n)$ should be assigned to the deviational variables η and ρ, giving the priority factors the relationship of $P_1 > P_2 > \ldots > P_n$.

In the past, goal programming techniques have been applied sparingly to library management problems and few of these have addressed the acquisitions allocation situation. Gross and Talavage (1979) developed a mathematical planning model for information service managers to allocate scarce financial resources. Kraft and Hill (1973) used a zero-one linear programming model to address the problem of which journals a library should acquire given a particular demand pattern exhibited by the user and a set of limited resources available to the library. Glover and Klingman (1972) simplified the model devel-

oped by Kraft and Hill (1971) by substituting surrogate constraints and solving it using dynamic programming techniques. Using a similar methodology, Rothstein (1973) proposed a model for choosing an optimal periodical allocation based on a criterion to determine the maximum utility of the periodicals. Noting that each of these models accommodates only a single objective and ignores the journal cancellation problem, Schniederjans and Santhanam (1989) proposed a multi-objective approach to both the journal selection and journal cancellation problem using a zero-one programming technique.

Goyal (1973) was perhaps the first to suggest a library fund allocation model using goal programming techniques when formulating a linear programming solution to the problem of allocating library funds to different departments of a university. Noting that Goyal's model considered only a single objective to be maximized (overall worth of acquiring journals), Hannan (1978) proposed a multiple-objective formulation for allocating funds between books and standing orders. Hannan (1978) deliberately excluded journals from his allocation model arguing that "if a journal has been purchased by a library, it behooves the library to continue subscribing for a moderate period of time in order for the journal holdings to be of any value" (p. 110). Nevertheless, as early as 1979 Fry and White (1979) had demonstrated through survey results that the vast majority of librarians were regularly canceling subscriptions because of declining interest by users. Since the time of their survey, librarians have increasingly cancelled journals because of funding problems (Kyrillidou, Rodriguez, & Stubbs, 1997).

Beilby and Mott (1983) were the first actually to formulate and solve a library acquisition allocation problem using goal programming. The Beilby and Mott formulation incorporated criteria relating to information access, user demand, circulation, and cost to determine the number of periodical titles and books to be purchased under subject disciplines. Although the solution was derived using proprietary computer programming written specifically for this problem, it nevertheless represents the first serious attempt by librarians to find mathematically an optimal solution within a context of conflicting and incommensurate fund allocation objectives. Furthermore, it offered the possibility of overcoming the primary limitation of traditional allocation formulations that simply treat factors linearly. Where the formula factors are incommensurable, the linear formulations make no provisions for comparability.

Nevertheless, goal programming has rarely been used as a working model for solving acquisitions allocation problems. Except in the case of the simplest problems, goal programming models require the speed and accuracy of computer assistance for the solutions to be economically feasible. This possibility was, until fairly recently, available only to individuals with access to computer programming written for solving specific, individual, goal programming problems. With the availability of commercial mainframe software capable of solving large matrices of equations, goal programming techniques can be readily applied to more general problems, and thus should become a more attractive tool for analyzing acquisitions allocations.

An informal survey of collection development officers indicates that perhaps a greater barrier to the widespread application of goal programming models to library allocations problems is the complexity of translating the acquisitions goals and objectives into mathematical statements. The necessary know-how to construct the mathematical statements and arrange them in meaningful matrix form is not common to collection development officers and their staffs. Consequently the task of applying the methodologies may be perceived by collection development officers to outweigh the benefits of the analysis.

With the advent of readily available goal programming software, these barriers in large measure can be overcome. Furthermore, as the following example will demonstrate, a goal programming model can be formulated that will allow librarians with responsibilities for allocating acquisitions funds to prioritize the irreducible plurality of funding objectives relative to the goals set. This model allows collection development officers to change both the mix of acquisitions goals and objectives and the priority ranking of these goals to observe the results under varying circumstances.

HYPOTHETICAL LIBRARY FUND ALLOCATION PROBLEM

To illustrate this application of goal programming technique, a hypothetical library fund allocation problem will be introduced. In this example the constraints used are selected for their abilities to demonstrate the potential of the mathematical methodology of goal programming rather than for any reflection they might have on the optimal mix of goal variables for a particular academic library. Goal statements (constraints) can be substituted or amended as necessary to meet the particular demands of the local library. For the development of this example, the following variables, constants, and constraints will be assumed.

Variables

x_i = the number of books to be purchased in subject i,
y_i = the number of periodicals to be purchased in subject i.

Constants

The subject disciplines are specified in Table 1 as:

circ_i = percentage of total circulation for subject i,
hours_i = percentage of total upper division undergraduate and graduate student credit hours associated with subject i,
pub_{bi} = percentage of book materials available in subject i,

pub_{pi} = percentage of periodical materials available in subject i,
low_{bi} = minimum acceptable percentage of book titles to be allocated in subject i,
low_{pi} = minimum acceptable percentage of periodical titles to be allocated in subject i,
up_{bi} = maximum acceptable percentage of book titles to be allocated in subject i,
up_{pi} = maximum acceptable percentage of periodical titles to be allocated in subject i.

Coefficients

c_{bi} = average cost of a book title in subject i,
c_{pi} = average cost of a periodical title in subject i.

Constraints

Budget. The survey by Tuten and Jones (1995) confirms the general impression that in an environment of limited financial resources, the cost of books and journals is a widely used factor in acquisitions allocation decisions. These costs, expressed as budget constraints, can be addressed as:

$$\sum_{i=1}^{7} (c_{bi}x_i + c_{pi}y_i) + \eta_i - \rho_i = p.$$

TABLE 1
Relation of Subject Disciplines and Variables

Subject Disciplines	*Books*	*Periodicals*
Humanities	x_1	y_1
Life Sciences	x_2	y_2
Physical Sciences	x_3	y_3
Social Sciences	x_4	y_4
Interdisciplinary Studies[a]	x_5	y_5
Business	x_6	y_6
Engineering and Technology	x_7	y_7

[a] In the context of this article, interdisciplinary studies refers to subject areas that span two or more of the subject disciplines listed. Examples may include women's studies, eithnic and area studies, urban and policy studies, or cognitive sciences in cases where they are not neatly circumscribed by humanities, social sciences, physical science, and so forth. Definitions for interdisciplinary studies tend to be site specific and vary from institution to institution.

where p represents the total amount of funds to be allocated across subject disciplines.

Lower Limit. Given the great disparity in the cost of materials across subject disciplines, it becomes necessary to impose some constraints on the minimum number of titles that will be acquired. To satisfy other constraints, the model may allocate a greater portion of titles to those subject areas with the most costly materials, thereby greatly reducing the growth of the collection. The lower limit constraint is:

$$\sum_{i=1}^{7} (x_i + y_i) + \eta_2 - \rho_2 = q$$

where q represents the lower limit of titles required by the allocation.

Upper Limit. Depending on the specifications of other constraints, the model may allocate more funds to subject areas having the least expensive items, thereby greatly increasing the number of items to be purchased. This constraint insures that the growth of the collection remains within the library's capability to acquire and process materials in a timely fashion. The upper limit constraint is:

$$\sum_{i=1}^{7} (x_i + y_i) + \eta_3 - \rho_3 = r$$

where r represents the upper limit of titles required by the allocation.

Published Volumes. Tuten and Jones (1995) show that while it is not the most widely used factor, an important determinant of fund distribution is the relative differentials in the volume of titles available for purchase in the individual subject disciplines. These differentials can be addressed by introducing the following set of constraints:

$$x_1 - \text{pub}_{b1} \sum_{i=1}^{7} x_i + \eta_4 - \rho_4 = 0$$

$$\vdots$$

$$y_7 - \text{pub}_{p7} \sum_{i=1}^{7} x_i + \eta_{17} - \rho_{17} = 0.$$

Credit Hours. Tuten and Jones (1995) corroborate the research by Greaves (1974) and Budd and Adams (1989) in showing that the number of stu-

dent credit hours assigned to an academic department is a commonly used variable in factoring fund allocations. The credit hour differentials are represented by the set of constraints:

$$x_1 - \text{hours}_1 \sum_{i=1}^{7} x_i + \eta_{18} - \rho_{18} = 0$$

$$\vdots$$

$$y_7 - \text{hours}_7 \sum_{i=7}^{7} x_i + \eta_{31} - \rho_{31} = 0.$$

Circulation. Research by Greaves (1974) and Budd and Adams (1989) and the survey by Tuten and Jones (1995) show that a matrix of circulation statistics tabulated by subject discipline is one of the most widely used factors in determining the desired allocation of acquisitions funds. The rationale for this factor is based on the assumption that past circulation use is a reliable predictor of future demand. Circulation is also seen as a measure of success in accurately selecting materials needed by users. The circulation statistics can be represented by the set of constraints:

$$x_1 - \text{circ}_1 \sum_{i=1}^{7} x_i + \eta_{32} - \rho_{32} = 0$$

$$\vdots$$

$$y_7 - \text{circ}_7 \sum_{i=1}^{7} x_i + \eta_{45} - \rho_{45} = 0$$

Minimum Allowance. Certain variables that librarians may want to factor into the allocation equation may be matters more of professional judgment than of hard mathematical data. Greaves (1974), for example, identified the "adequacy of the library collection in a subject discipline" as a major factor used in the majority of fund allocation models (p. 145). In addition, Packer (1988) and Niles (1989) have illustrated that the plethora of material and media available from which to choose is exacerbating a diversity of campus political pressures being placed on librarians. The constraints for minimum allowance insures that each fund receives a minimum proportion of the title allocation based on the professional judgment of the collection development librarian and the political pressure brought to bear by faculty and administrators. This is expressed as:

$$x_1 - \text{low}_{b1} \sum_{i=1}^{7} (x_i + y_i)\eta_{46} - \rho_{46} = 0$$

$$\vdots$$

$$y_7 - \text{low}_{p7} \sum_{i=1}^{7} (x_i + y_i)\eta_{59} - \rho_{59} = 0.$$

Maximum Allowance. This constraint reinforces and complements the flexibility introduced in the minimum allowance constraints by increasing funds for expanding subject areas and controlling expenses for waning ones. This constraint assures that each fund receives no more than its fair share of the titles based on the professional judgment of the collection development librarian by establishing maximum limits for each subject fund. This goal is represented by the set of constraints:

$$x_1 - \text{up}_{b1} \sum_{i=1}^{7} (x_i + y_i)\eta_{60} - \rho_{60} = 0$$

$$\vdots$$

$$y_7 - \text{up}_{p7} \sum_{i=1}^{7} (x_i + y_i)\eta_{73} - \rho_{73} = 0.$$

Periodical/Book Ratio. In an economy such that the escalating cost of periodicals threatens to consume a library's entire acquisitions budget, some mechanism is necessary to maintain a proper balance between the number of periodicals purchased relative to the number of books acquired. For purposes of this example, a 60/40 ratio of periodicals to books is assumed as desirable. This ratio is represented by the constraint:

$$\sum_{i=1}^{7} c_{pi}y_i - 0.6 \sum_{i=1}^{7} (c_{bi}x_i + c_{pi}y_i) + \eta_{74} - \rho_{74} = 0.$$

Assume that the collection development librarian provides the following priority structure for the acquisitions goals and information on constraints.

P_1 = Limit acquisitions expenditures to \$1.0 million;
P_2 = Acquire at least 9,000 titles and no more than 12,000;
P_3 = Maintain a 60%–40% ratio between periodicals and books;

TABLE 2
Values Determining Variable/Goal Relationships

Goals	Book Variables							Periodical Variables							Goal Criteria
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	y_1	y_2	y_3	y_4	y_5	y_6	y_7	
1. Cost [a]	37.50	83.45	86.83	40.40	38.34	45.95	76.48	51.44	312.67	538.38	153.18	102.31	94.37	216.23	$1,000,000
2. Acquire at least	1	1	1	1	1	1	1	1	1	1	1	1	1	1	9,000 titles
3. Acquire no more than	1	1	1	1	1	1	1	1	1	1	1	1	1	1	12,000 titles
4. Circulation	1							1							53.53%
		1							1						6.05%
			1							1					9.31%
				1							1				11.37%
					1							1			3.07%
						1							1		9.84%
							1							1	6.83%
5. Enrollment	1							1							25.25%
		1							1						5.30%
			1							1					8.56%
				1							1				14.16%
					1							1			3.69%
						1							1		26.87%
							1							1	16.17%
6. Published volumes [a]	1														44.83%
		1													10.34%
			1												13.79%
				1											15.52%

(*continued*)

TABLE 2
Continued

Goals	Book Variables							Periodical Variables							Goal Criteria
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	y_1	y_2	y_3	y_4	y_5	y_6	y_7	
					1										0.69%
						1									12.07%
							1								2.76%
								1							30.86%
									1						15.43%
										1					12.35%
											1				30.86%
												1			2.78%
													1		5.40%
														1	2.32%

Note: [a] Cost factors and percentages of published volumes are compliled from data in the 1996 *Bowker U.S. Periodicals Price Index* and "Output & Prices: Ups and Downs" in the March 20, 1995 *Publishers Weekly*.

TABLE 3
Allocation Results

Allocation Variables	*Number of Titles*	*Percent of Titles*	*Budget Allocation ($)*
Books			
Humanities	3481.798	44.83	130,567
Life Sciences	803.074	10.34	66,214
Physical Sciences	1071.024	13.79	92,997
Social Sciences	1205.387	15.52	48,698
Interdisciplinary Studies	53.590	00.69	2,055
Business	937.437	12.07	43,075
Engineering and Technology	214.360	02.76	16,394
Total	7766.670	100.00	400,000
Periodicals			
Humanities	970.252	30.86	49,910
Life Sciences	485.126	15.43	151,684
Physical Sciences	388.287	12.35	209,046
Social Sciences	970.252	30.86	148,623
Interdisciplinary Studies	87.407	02.78	8,943
Business	169.778	05.40	16,022
Engineering and Technology	72.942	02.32	15,772
Total	3144.044	100.00	600,000

P_4 = Allocate titles by subject according to publication volume;
P_5 = Allocate titles by subject according to circulation use and classroom credit hour demands; and
P_6 = Maintain minimum and maximum limits established for each subject fund.

Using goal programming, preemptive priorities can be assigned to these goals and an optimal solution be determined by finding x and y so as to minimize the objective function

$$Z = P_1(\eta_1) + P_2(\eta_2 + \rho_3) + P_3(\eta_{74}) + P_4(\eta_4 + \ldots + \eta_{17}) + P_5(\eta_{18} + \ldots + \eta_{45}) + P_6(\eta_{46} + \ldots + \eta_{59} + \rho_{60} + \ldots + \rho_{73})$$

such that all of the objective statements (1) through (74) are satisfied for x, y, η, and $\rho \geq 0$. Each element η or ρ in the achievement function corresponds to an unwanted goal deviation which the goal programming procedures attempt to minimize.

ANALYSIS OF RESULTS

This hypothetical problem was solved using the linear goal programming procedures of the System Application Software/Operations Research (SAS/OR)

programming code. The variables and constraint statements were configured on a VAX mainframe according to the matrix format outlined in Table 2. The matrix was subsequently solved using SAS/OR software. The program allocated the titles to meet the defined collection development goals as outlined above and in accordance with the stated priorities.

The results of the goal programming model are presented in Table 3, where the values represent minimum deviations achieved at the six priority levels and were produced by the sequential solution of the problem. In this example, all the rigid constraints are satisfied, implying that the solution is feasible. Goals P_1 through P_4 were fully achieved. For goals P_5, two of the subject funds in both books and periodicals were under-achieved according to both the circulation and enrollment criteria. A third book fund was under-achieved according to the circulation criteria. For goal P_6, six of the book and four of the periodical funds under-achieved the prescribed minimal level. Only one of the book and three of the periodical funds over-achieved the prescribed maximum level.

In any allocation problem where the acquisitions goals are conflicting, the best that can be achieved is an optimal solution. The success of the goal programming approach lies in its capacity to achieve the higher order priority goals while at the same time achieving partial success in reaching the lesser goals. In this example, the first four goals were fully achieved, but even for the fifth and sixth goals, which were not fully achieved, goal five failed full achievement on substantially fewer categories than did goal six.

CONCLUSION

The purpose of this article was to illustrate the use of linear goal programming in the allocation of acquisitions funds based on conflicting collection development goals in an academic library. While the example was limited in scope to only seven subject disciplines and two material types, the model can easily be modified to deal with the more complex real-world environment confronting collection development officers.

Goal programming models can be formulated to accommodate whatever goals and objectives a library's collection development officer deems most significant for their particular institution regardless of the incommensurability of the goals among themselves. Moreover, these models offer the flexibility both to change the mix of acquisitions goals and the priority rankings of these goals to permit the librarian to observe potential allocations under varying circumstances. In this example a collection development officer may wish to see the changes in allocations resulting from a shift from a 60/40 periodicals-to-book ratio to a 70/30 ratio, or the differentials that would result from shifting the circulation variables to a higher priority.

Goal programming can also be used to some extent as a forecasting tool. Because goals are stated in terms of constants and coefficients, the values of these

constants and coefficients can be adjusted to yield results for expected future conditions. In this example the changes in allocation distributions can be observed as the cost of periodicals is allowed to rise sharply vis-à-vis the cost of books while all else remains the same.

The ability of goal programming models to accommodate incommensurate goals as well as their flexibility in allowing changes in the mix of goals statements, the priority ranking, and the values assigned to the constants and coefficients suggest that linear goal programming can be an effective planning tool for collection development librarians faced with multiple conflicting goals and limited acquisitions funds.

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