

A TWO-PHASE METHOD FOR UNIVERSITY LIBRARY ACQUISITIONS ALLOCATION

G. GELDENHUYS, H. C. DE KOCK, E. BOTHA and L. HATTINGH

Department of Applied Mathematics, University of Stellenbosch,
7600 Stellenbosch, Republic of South Africa

ABSTRACT

A two-phase method for the allocation of funds for library materials to the various faculties and departments of a university is proposed. It consists of a first phase in which goal programming is used to allocate funds to the faculties, followed by a second phase in which a proportional formula is used for the allocation of funds to departments in the faculties. Sensitivity analyses of both phases are also discussed.

1. INTRODUCTION

An annual problem which has to be solved by the management of a university library is the allocation of its available funds for library materials to the various faculties and departments of the university. The allocation has to be made subject to a number of constraints and in a fair manner. We specifically consider allocation methods which are easy to implement, preferably on a microcomputer.

Five fairly recent surveys by Sellen [8], Werking [10], Budd and Adams [3], Packer [7] and Budd [2] give an excellent overview of the different methods that are used to solve the allocation problems of the libraries.

It is probably fair to say that amongst the quantitative methods the most popular are formula-based. The formulae usually take a number of attributes into account in a proportional way, as follows. For each department or faculty the attributes are weighted (multiplied by constants) and added. The allocation of funds to a department or faculty is proportional to its weighted sum.

Another approach favoured by some is based on mathematical programming. For example, Goyal [5] uses constraints on the budget, lower and upper bounds on acquisitions as well as the "importance" of a department (which could be based on student and staff numbers) in a linear programming formulation and solution of the problem. An important paper by Beilby and Mott [1] in this category is mentioned only in the latest of the five surveys mentioned above, the one by Budd [2]. Beilby and Mott consider the conflicting, multiple collection development goals which compound the problem of the allocation of library funds. They propose a lexicographic linear goal programming method to solve the problem and illustrate their method with a small example.

In some methods funds are allocated to the faculties. In these cases there is the (implicit) assumption that a faculty will be responsible for the further allocation of funds to the various departments in the faculty. However, this might not be a desirable procedure from the point of view of the library management. Academic staff are not trained to consider collection development goals in a professional way. Leaving the decisions on the allocation of faculty funds to departments in the hands of the dean of the faculty might inadvertently lead to an unbalanced collection. On the other hand, formula-based allocations to departments have the drawback that it is difficult to accommodate more global considerations in them, for example with respect to interdisciplinary co-operation. An advantage of formula-based methods is that they are very easy to implement, both at faculty and departmental levels. By contrast, a more sophisticated method such as Beilby and Mott's goal programming approach is attractive for the allocation to faculties but its extension to the allocation to the departments of a large or even medium-sized university would be very cumbersome.

We propose a two-phase method in which goal programming is used to allocate funds to the faculties, followed by a proportional formula for the allocation of funds to departments in the faculties. Our proposals

are based on our experience with the design of an allocation method for a university with ten faculties and approximately 130 departments. However, for purposes of illustration and comparison we use an example similar to the one of Beilby and Mott [1]. Since our purpose is to describe and discuss the two-phase method, we do not repeat the techniques of Beilby and Mott in detail.

2. ILLUSTRATIVE EXAMPLE

We consider a hypothetical university with four faculties, for Humanities, Social Sciences, Sciences, and Education [1]. The Science faculty has three departments and the others have four each. Table 1 gives information on the division of the faculties, the average price of books and periodicals as well as the present allocation (quantity) of book and periodical titles in the respective faculties. The same information is also provided for books and periodicals which can be regarded as interdisciplinary. As far as the departments are concerned, Table 1 gives the essential information about undergraduate and post-graduate full-time equivalent (FTE) students and about the collection range of each department. One FTE student takes all his or her courses in one department. Collection ranges and the significance of the weights in Table 1 are discussed more fully in the next section.

The main considerations in the allocation of library funds for the next year are as follows:

- A1 :The book and periodicals budget is \$200,000.
- A2 :The total quantity of acquisitions should be at least 7,500 and at most 10,500. (These constraints ensure a minimum growth and ensure that library staff will be able to cope with the processing of new materials.)
- A3 :Periodicals should account for approximately 60% of the total expenditure. (In times of rapid increases in periodical prices in particular there should be checks to ensure a sufficient growth in book holdings.)
- A4 :The allocation to a faculty should be proportional to its weighted FTE students.
- A5 :The allocation to a faculty should be proportional to its research output.

FACULTIES	Books Present Allocation (Quantity)	Average price \$	Periodicals Present Allocation (Quantity)	Average prices \$	DEPARTMENTS Weights	FTE Students		Research	Sum of Weighted FTEs and Research	Range	
						Pregrad 1	Postgrad 10			15	Books
Humanities	1270	13.01	250	37.64	English	193	90	1	1108	2.0	1.6
					Philosophy	75	15	1	240	1.7	1.5
					History	145	46	1	620	1.9	1.8
					Music	50	30	1	365	0.7	0.5
							TOTAL	2333			
Social Studies	2080	12.55	850	23.12	Psychology	536	67	8	1326	2.0	2.0
					Sociology	285	170	1	2000	1.1	0.9
					Anthropology	80	32	2	430	0.7	0.6
					Political Science	130	48	2	640	1.4	1.3
							TOTAL	4396			
Sciences	410	19.32	260	114.00	Physics	405	45	5	930	1.3	1.8
					Mathematics	562	40	1	977	1.6	2.0
					Chemistry	300	12	2	450	1.6	1.6
							TOTAL	2357			
Education	1270	10.53	730	24.18	Curriculum Studies	420	35	8	890	2.0	2.0
					History (Ed.)	280	46	6	830	0.8	0.9
					Psychology (Ed.)	355	68	7	1140	1.1	1.3
					Administration	244	40	1	659	0.5	0.6
							TOTAL	3519			
Interdisciplinary	450	13.10	820	35.00							

Table 1 : Details of Faculties and Departments

A6 :The fractions of the quantities allocated to the faculties should not deviate too much from the respective present fractions. (It is well known [7] that the introduction of mathematical models for library acquisitions allocation often results in allocations which differ significantly from those in previous years and that this might have a disruptive effect in the short run.)

A7 :Allowance should be made for retrospective acquisitions amounting to approximately 5% of the total quantity. (Important lost and damaged items should be replaced and classic works purchased in new teaching areas.)

3. THE FIRST PHASE

In the first phase of our proposed method we use goal programming to allocate funds for books and periodicals to the various faculties and the interdisciplinary group. Beilby and Mott [1] use the lexicographic linear goal programming method for this purpose. Our experience with larger examples has been that the lexicographic method is too restrictive for our purposes. Once the first few goals in the lexicographic method have been satisfied, the solution is fixed for all practical purposes and the addition of new goals have almost no effect on the solution. We have found it more useful to use the weighted goal programming approach in which the various goals are normalized and weighted and a single objective function is formed. In our illustrative example we use the following goals (taken from the list in the previous section) and respective weights : A3 (0.5), A4 (0.8), A5 (0.3), A6 (0.5), A7 (0.3). In practice these weights are determined in consultation with the library management. For example, in our real application FTE student numbers had been the major consideration in previous allocations (A4). On a second level of importance there was concern about the inroads that rising periodical costs had been making on book acquisitions (A3) and about the "political" effects of the introduction of a new method of allocation (A6). The other two goals (A5 and A7) were considered to be of less importance in the first application of the method. Various runs with different sets of weights can help the management to decide on final weights which satisfy the goals most important to them to an acceptable extent. The constraints of the problem are A1 and A2. A1 must be satisfied with equality. In times of strict budget controls and rising costs there can be little justification for overspending or underspending.

It should be emphasised that the selection of goals and constraints was made for illustrative purposes only. Beilby and Mott [1] show how almost all the goals and constraints mentioned above, as well as several others, may be formulated. We therefore discuss only one of the goals, A6, which differs from those in [1]. Let x_i (y_i) be the quantity of books (periodicals) that should be allocated to faculty or interdisciplinary group i and let b_i (p_i) be the fraction that books (periodicals) of faculty or group i constitute of the total quantity of books and periodicals in the present allocation of the university, $i = 1, 2, \dots, 5$. Then the two goals associated with A6 can be formulated as

$$x_i - b_i \sum_{j=1}^5 (x_j + y_j) + \eta_i - \rho_i = 0,$$

$$y_j - p_j \sum_{j=1}^5 (x_j + y_j) + \eta_{i+5} - \rho_{i+5} = 0,$$

for $i = 1, 2, \dots, 5$ and where the η_j and ρ_j are underachievement and overachievement variables that have to be minimized in the goal programming problem.

The main variables and results of the first phase for the example are shown in Table 2. Numbers for the quantities of books and periodicals have been rounded to integers.

Faculty	BOOKS			PERIODICALS		
	Quantity	Amount(\$)		Quantity	Amount(\$)	
Humanities	x_1 892	11604.92		y_1 456	17163.84	
Social Studies	x_2 1649	20694.95		y_2 843	19490.16	
Sciences	x_3 878	16962.96		y_3 449	51186.00	
Education	x_4 1252	13183.56		y_4 640	15475.20	
Interdisciplinary	x_5 445	5829.50		y_5 813	28455.00	

Table 2 : Phase One Allocation to Faculties.

Because of the way in which we have simplified the example, range and interdisciplinary co-operation exert an influence on the next allocation by the way in which it is represented in the present allocation, that is, by way of historical precedent. Some of the goals in the example are clearly conflicting. For example, the present book allocation for the faculty of Sciences is approximately one third of that

for the faculty of Humanities whilst their weighted FTE students are roughly the same. In the solution goal A6 is the one which is met least satisfactorily.

4. THE SECOND PHASE

In the second phase of our method the funds allocated to the faculties are divided between the various departments by using a proportional formula. The form of our formulae is the same for books and periodicals, but the details differ for the two cases. In our formulae we take into account the undergraduate and post-graduate FTE students, the research output, the average prices of books and periodicals, and the collection range of each department. In the real problem on which we worked extensive investigations showed that these factors were the most appropriate for our particular problem. Other possibilities are discussed in [3].

It is obvious that the teaching of undergraduate and post-graduate students influence the acquisition of library materials in different ways. For this reason different weights are used for the respective groups of students. In practice the weights are determined by taking into account aspects such as circulation data (if available) and citations in reports, theses and research papers. In addition the research effort of a department also has an influence on its acquisitions. Therefore the number of research papers is weighted and added to the weighted sum for FTE students. This final sum for each department is multiplied by its range factor. The range factor gives an indication of the collection scope of a particular department. Some departments teach, research and collect in a very narrow field whilst others have much wider obligations. It would not be fair to treat the two types of departments as if they had the same range. Range is determined on professional grounds by library staff and is based on considerations such as publication lists of major publishers and the collection development goals of departments.

In real applications it would be possible to use a larger set of weights to account for finer differences between departments. For example, if a department uses books for post-graduate teaching to a far greater extent than the usual emphasis on periodicals, there could be a shift in the weights to account for this. Finer distinctions between various year groups can be made if suitable data are available. Also note that there

are different ranges for books and periodicals. Details of the weights and ranges for the example can be found in Table 1. The allocation of book and periodical funds to a department is proportional to its final sum for books and periodicals respectively. Table 3 shows the final allocation to the different departments in the example.

Departments	Books (Quantity)	Periodicals (Quantity)	Departments	Books (Quantity)	Periodicals (Quantity)
English	487	236	Physics	304	173
Philosophy	90	48	Mathematics	393	202
History	259	148	Chemistry	181	74
Music	56	24			
TOTAL	892	456	TOTAL	878	449
Psychology	723	403	Curriculum Studies	553	259
Sociology	600	274	History (Ed)	207	109
Anthropology	82	39	Psychology (Ed)	390	215
Political Science	244	127	Administration	102	57
TOTAL	1649	843	TOTAL	1252	640

Table 3 : Phase Two Allocation to Departments.

To simplify matters we have assumed that the average price in a faculty also applies to each department in the faculty, as shown in Table 1. In practice these prices would differ between departments. Equity would then demand that there should be comprehension for the differences. A department should not be penalised with regard to the quantity of its acquisitions simply because the average price of its library materials is very high. For this reason the previously mentioned sums (for books and periodicals) of a department could be multiplied by the average price of books and periodicals respectively before a final proportional allocation is made.

5. SENSITIVITY ANALYSES

Sensitivity analyses can be provided for both phases of our method and are useful in final adjustments of the various weights and coefficients in the model. The well-known techniques of goal programming can be used for the sensitivity analysis for the first phase [6].

The second phase can also be subjected to sensitivity analyses. For example, consider the coefficients $c_1 = 1$, $c_2 = 10$ and $c_3 = 15$ which are used in the weighting of undergraduate FTE students, post-graduate FTE students and research output respectively. The quantity of books A_i allocated to department i in the faculty of Humanities can be represented as the function $A_i = f_i(c_1, c_2, c_3)$. Let N_{i1} , N_{i2} , N_{i3} and r_i be the number of undergraduate FTE students, post-graduate FTE students, research publications and the range respectively of department i in the faculty of Humanities. Then

$$f_i(c_1, c_2, c_3) = 892 \frac{\sum_{j=1}^3 r_i c_j N_{ij}}{\sum_{i=1}^4 r_i \sum_{j=1}^3 c_j N_{ij}} .$$

A normalized measure of the sensitivity of the allocation made to department i to changes in the coefficient c_j is [9]

$$S_{ij} = (c_j/f_i) \partial f_i / \partial c_j .$$

An analysis for the faculty of Humanities for the allocation in Table 3 shows that

$$-0.1487 \leq S_{ij} \leq 0.1095$$

for all i and j , with all the sensitivities other than the bounds being much smaller than the bounds. This indicates that the allocation is fairly stable with respect to small changes in the coefficients. Our experience indicates that the sensitivity is very much smaller in larger examples.

6. VALIDATION

The calibration of a model for library acquisitions allocation would almost certainly differ at different universities. The following suggestions for validation are based on our experience. In the first place there should be wide consultation with all interested parties. This should include close cooperation with library management as well as professional library staff, and initial discussions with faculty representatives who are informed users of library facilities. It is also important to provide many examples of allocations to illustrate the effects of a wide variety of combinations of weights and coefficients. All faculties and departments of the university should have the

opportunity to comment on the basic structure of the model before it is finalised.

Because of the presence of a goal of the form A6 the new method will be phased in gradually. There will therefore be the opportunity to incorporate changes in the model that are required in view of deficiencies that might become apparent as the model is implemented. In these ways it is possible at the very least to provide an acceptable level of face validation [4].

7. CONCLUSION

The two-phase method has the advantage that important global considerations of library management can be taken into account in the first phase and that more detailed aspects can be dealt with in the second phase. Both phases are easy to implement and can be subjected to suitable sensitivity analyses.

REFERENCES

- [1] M.H. BEILBY and T.H. MOTT, Academic library acquisitions allocation based on multiple collection development goals, *Computers & Operations Research*, 10, 335-343, (1983).
- [2] J.M. BUDD, Allocation formulas in the literature : A review, *Library Acquisitions : Practice & Theory*, 15, 95-107, (1991)
- [3] J.M. BUDD and K. ADAMS, Allocation formulas in practice, *Library Acquisitions : Practice & Theory*, 13, 381-389, (1989).
- [4] S.I. GASS, Decision-aiding models : Validation, assessment, and related issues for policy analysis, *Operations Research*, 31, 603-631, (1983).
- [5] S.K. GOYAL, Allocation of library funds to different departments of a university - An operational research approach, *College and Research Libraries*, 34, 219-222, (1973).
- [6] J.P. IGNIZIO, *Linear Programming in Single- and Multiple-Objective Systems*, Prentice-Hall, Englewood Cliffs, New Jersey, (1982).
- [7] D. PACKER, Acquisitions allocations : Equity, politics, and formulas, *The Journal of Academic Librarianship*, 14, 276-286, (1988).
- [8] M. SELLEN, Book budget formula allocations : A review essay, *Collection Management*, 9, 13-24, (1987).
- [9] P.J. VERMEULEN and D.C.J. DE JONGH, Parameter sensitivity of the 'Limits to Growth' world model, *Applied Mathematical Modelling*, 1, 29-32, (1976).
- [10] R.H. WERKING, Allocating the academic library's book budget : Historical perspectives and current issues, *The Journal of Academic Librarianship*, 14, 140-144, (1988).