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SERVICE PRICING IN A MEDICAL LIBRARY: A CONSTRAINED
GOAL PROGRAMMING APPROACH

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by

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Abstract

A service institution like a library provides a variety of related and interrelated services to a heterogeneous mix of users. These users belong to different institutions (members of the library system) with diverse characteristics and functions and which are assessed fees to support the annual operating budget.

The total operating costs of a library are described as having the following three components: direct costs for each service provided; variable support costs related to usage of services; and joint fixed support costs related to certain characteristics and functions of the institutions using the library.

In the present paper we explore the implications of an assessment policy where the direct and variable support costs of library operation are recovered through unit charges for the direct services provided, determined through construction and solution of a constrained goal programming model. We illustrate our procedures with an application to an independent medical library serving over 10,000 individuals in 22 academic, research and clinical institutions.

Introduction

A service institution like a library provides a variety of related and interrelated services to a heterogeneous mix of users. Moreover, there are many so-called support services which are necessary to the overall operation of the library. The need for these support services extends to most, if not all, of the direct services. In some instances a direct service may not even be available without the proper level of various support functions.

Together these direct services and support functions give rise to the costs that must be recovered somehow in maintaining the operation of the library. While constructing the library's budget may be a straightforward matter of adding together all proposed resource expenditures for the year, relating these costs, or more appropriately allocating these costs, to the services generating them is a very difficult administrative problem. Not only do the direct services interrelate and the support services get shared, but different users may create different demands even on the same service yielding higher or lower costs. The library's administration must deal with these issues either in justifying its budget or in monitoring its performance and establishing patterns of growth and expanding needs for resources.

Bres et al. (1979) and Rousseau (1985) distinguished two general categories of library users: (i) institutional or departmental users that are members of the library system and (ii) individual users (possibly of different types) within the institutions or departments. They suggested that an appropriate means for recovering costs on an annual basis (i.e., supporting the library's annual operating budget) is through assessments to the institutions housing the users.

Clearly, to justify the budget to the participating institutions and maintain cooperative support for the library, the fees assessed to the

institutions should reflect so far as possible the way in which costs are actually generated. Thus, institutional fees should be determined in a way that directly incorporates both individual user behavior and variation among institutions in informational requirements. However, the joint nature of many of the costs involved causes significant difficulties in any such assessment process.

While in principle there may be general agreement that separable user costs should somehow be incorporated in user charges, there is disagreement on how common fixed costs should be recovered. Rousseau (1985) looked at the implications of an assessment policy where the annual fixed costs of library operation are shared among the different institutions according to the "club principle" of Littlechild (1975). Using the techniques of linear programming and game theory it was possible to address such issues as the optimal library size and pattern of membership in the system, and to characterize the set of institutional fees that meet certain conditions of fairness and efficiency.

For ease of exposition and since the focus was on common costs, Rousseau proceeded as if user costs were charged for as incurred. The purpose of the present paper is to explore a means for recovering the variable cost components through unit charges for the direct services provided, determined via construction and solution of a constrained goal programming model. We illustrate the application by calculations based on the Houston Academy of Medicine - Texas Medical Center Library in 1976.

We began with a brief discussion of library operating costs and some preliminary considerations in model construction. This is followed by our mathematical model, application and presentation of results. A concluding section summarizes our procedures and findings and discusses some qualifications and extensions.

A Classification of Library Operating Costs

A reasonable division of the annual operating costs of a library distinguishes those attributable to each specific direct service provided (called direct costs) and those essential to general library operations as an integrated facility (called support costs). Direct costs arise from those direct activities in delivering services to the user. Thus, they are variable in nature, responding to the usage experience of each service.

The support costs, which may be relatively substantial in some libraries, are characteristically more complex to analyze than direct costs. A large portion of these costs are related to physical inputs, such as books and journals purchased or plant (space) and equipment leased. Also to be considered are those personnel and their activities that contribute to library operations overall, but at levels not determined by the quantity of direct library usage. For example, the technical services personnel and material costs are dependent upon the number and types of publications purchased and policies of processing and are, therefore, related to the programs of the institutions using the library rather than actual usage of the collection. One aspect of support costs, then, arises from the necessity to establish and maintain a basic facility with the requisite capacity to provide a predetermined set of services for its users. In a sense, these costs are relatively fixed with respect to usage once having defined the types of services to be offered.

Difficulties in dealing with these support costs enter when observing that qualitative considerations of service may require changes in supportive facilities and activities as usage varies. For example, the number of duplicates of various materials may increase if usage grows large enough as a means of easing accessibility; observe that the initial material acquisition may be considered fixed as a portion of the library's basic informational

configuration, while the duplication is a variable extension of this basic capacity to improve a service in response to its usage. Such quasi-variable aspects of support costs suggest a recovery method that depends on service usage shared among services since in most instances they benefit jointly.

The total operating costs of a library might, therefore, be described as having the following three components: direct costs for each service provided; variable support costs related to usage of services; and fixed support costs related to certain characteristics and functions of the institutions using the library.

A reasonable and equitable charging mechanism, therefore, might recover the direct costs and variable portion of support costs through usage based fees, and the fixed support costs through institutionally based (or "membership") fees. Consequently, the fee assessed to an institutional member of a library system may be considered as having two components: one equal to the usage cost of all services by users of all types who are members of that institution and the other a fixed charge or membership fee representing a contribution to fixed support costs.

Rousseau (1985) presented a methodology for determining fair and efficient fixed charges based on the club principle of Littlechild (1975). The present paper describes a method for determining usage based fees using the technique of goal programming.

Preliminary Considerations in Model Construction

As has already been stated direct costs for services should definitely be recovered through charges for these services, while a variable portion of support costs exists that should be recovered in some fashion through the charges for all services. Several factors help establish a relationship, indeed a

partial hierarchy, in the magnitude of the costs to be recovered through the charges for each service: 1) differences in magnitude that reflect varying types and amount of resource requirements (i.e., professional and clerical personnel, equipment, etc.) for the services themselves, 2) differences indicating administrative charging policies that subsidize some services through nominal excess recovery in others (e.g., charging somewhat less for manual bibliographic searches by adding a few cents to the circulation charge), 3) differences based on historical precedents and consistent administrative practice (e.g., a fully self-sustaining service, such as user photocopying, may be specifically excluded from the cost recovery model since it places virtually no resource burden on the library, its availability enhances the library's service image, and it is not administratively desirable to have it subsidize other services).

Further, as seems outwardly reasonable, different users use the library in different ways and should, therefore, be charged in relation to both the quantity and quality of their use of each service. We recognize that a subset of the services offered by a library are used by different user types in varying intensities. This is not only because of varying information needs, but also because of policies of restriction of some services to specific types of users. For example, in some academic libraries telephone reference may be restricted to faculty members.

In addition, the same service (nominally) given to different individuals may differ in terms of costliness. For example, interlibrary borrows for a medical professional may require more time than those for a medical student. Similarly the most time consuming reference questions may be asked by a particular user group or conversely may seldom be asked by a particular group.

These differences suggest that charges for a specific service should not be the same for all users.

Finally, from a broader economic perspective there may be factors that influence the recovery strategy employed with respect to direct costs. Some services may show economies of scale. For example, in reshelving it should probably not take 100 times as much time to reshelve 100 books as it would 1 book because of batching books to be shelved. That is, the per unit time required would decrease with increased activity. Thus, charges based on average costs for such services would be inappropriate.

In sum, any cost recovery model for the direct costs and variable support costs must account for a wide variety of considerations -- technical, behavioral, economic, and managerial.

The Model

We deal with the case of a single time period of one year rather than a multiperiod model; in a concluding section we indicate how this model can be extended to multiple time periods.

Let there be m different services, denoted by subscript i , available to n different user types, denoted by subscript j , who are individual members of the q institutions, denoted by subscript k , within the library system. Further, let d_{ijk} denote the usage, or demand of service i by user type j at institution k . It will prove convenient to let d_{ij} ($\equiv \sum_{k=1}^q d_{ijk}$) represent the total usage of service i by all users of type j . This demand is the sole basis for recovering the entire variable portion of the library's operating budget. The relationship between this demand and the costs that accrue from any particular service may take on many different forms. A general algebraic expression representing this relationship may be written as

$$a_{ij}d_{ij}^{\alpha_i}$$

where a_{ij} can be considered, for now, merely a scaling factor and α_i is a value that can "bend" the shape away from a straight line (linear) one. It should be noted that the only limitation inherent in the algebraic statement given is a failure to account for any relationship that oscillates, a situation considered most unlikely. In fact, since we anticipate certain economies of scale for some services, we can expect the relevant values of α_i to fall in the range $0 < \alpha_i < 1$. To observe how choices for α_i change the shape see Figure 1, where it is clear that the smaller one chooses α_i , the more economies of scale are assumed present in the delivery of service i .

The relationship between usage and cost leads directly to an expression for unit charge:

$$a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}}$$

Thus, each user type j will pay to recover the costs allocated to service i in proportion to usage. Our intention, then, is to select values for the a_{ij} , given values for the other elements, so that one approaches the multiple goals of recovering direct costs as closely as possible. Mathematically, we can write

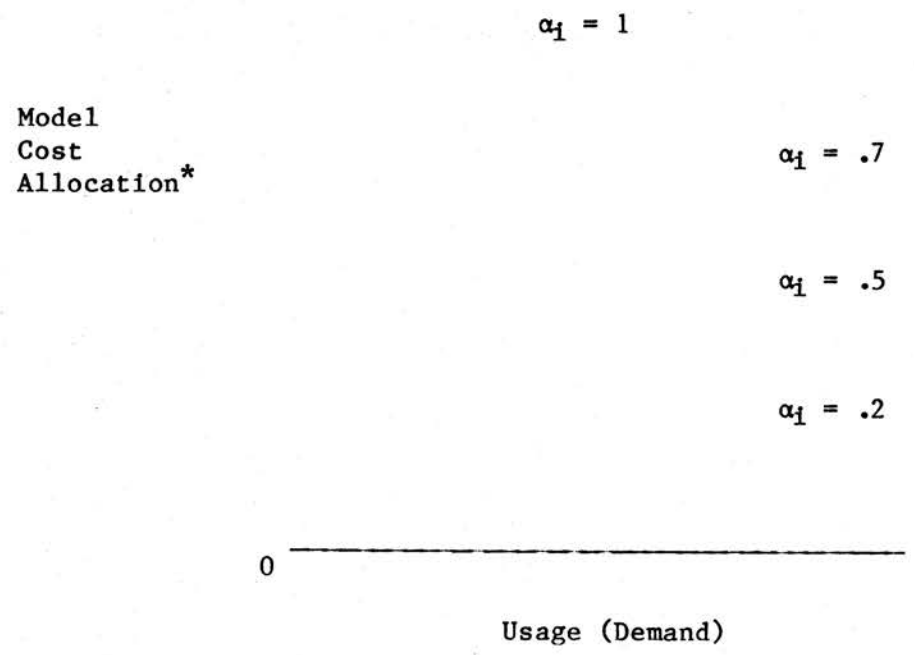
$$\min \sum_{i=1}^m \left| \sum_{j=1}^n a_{ij}d_{ij}^{\alpha_i} - C_i \right|$$

where C_i denotes the direct costs attributable to service i , and the absolute value merely permits some services to undercollect while others overcollect their respective direct costs but accounts for these discrepancies equally. Additionally, we require that the $a_{ij} > 0$ since other values are impractical and unrealistic.

We can rewrite our mathematical expression in a linear programming model explicitly containing the deviations of allocated recovery from cost.

Figure 1

Economies of Scale in Service Cost



*This axis corresponds to values of $a_{ij}d_{ij}^{\alpha_1}$

Version 1

$$\text{Min } \sum_{i=1}^m g_i^+ + \sum_{i=1}^m g_i^-$$

subject to:

$$\sum_{j=1}^n a_{ij} d_{ij} \alpha_i - g_i^+ + g_i^- = C_i, \quad i=1, \dots, m.$$

$$a_{ij}, g_i^+, g_i^- > 0, \quad i=1, \dots, m; \quad j=1, \dots, n.$$

where g_i^+ represents the excess of allocated recovery over direct costs (i.e., over collection)

g_i^- represents the shortfall of allocated recovery below direct costs (i.e., under collection)

Three immediate observations can be made from this model formulation:

- 1) since the objective is merely to recover overall direct costs as closely as possible and all services are treated the same with regard to deviations, nothing prevents an allocation in which one service subsidizes the costs, or some part of them, for one or more of the others
- 2) while the a_{ij} derived from the model have a direct impact on the relative charge structure between services, nothing in the model reflects any predisposed ordering or other relationships in this structure
- 3) The model does not account for the recovery of the variable support costs that are to be included as part of the service charges

Adjusting the model to accommodate the implied deficiencies in these observations is done in various different ways.

At the discretion of the decision maker differential weights or penalties can be imposed on the deviations representing varying priority associated with

over collection and/or under collection for each service. Moreover, with respect to over collection specifically, some unpenalized slack can even be accommodated by dividing the over collection deviation variable into two parts, one weighted in the objective and the other not even present. Such a modification encourages over collection for some services up to a prespecified limit. Incorporating these changes in the preceding model yields:

Version 2

$$\text{Min} \quad \sum_{i=1}^m w_i^+ g_i^+ + \sum_{i=1}^m w_i^- g_i^-$$

subject to:

$$\sum_{j=1}^n a_{ij} d_{ij}^{\alpha_i} - g_i^+ - s_i + g_i^- = C_i, \quad i=1, \dots, m$$

$$s_i < B_i, \quad i=1, \dots, m$$

$$a_{ij}, g_i^+, s_i, g_i^- > 0, \quad i=1, \dots, m; \quad j=1, \dots, n$$

where s_i represents the unpenalized over collection potential for service i ,

B_i represents the prespecified limit for over collection that is unpenalized,

w_i^+ , w_i^- represent the weights or penalties assigned over collection/under collection for service i , and all other elements are defined as before.

Note that for some services B_i , and hence s_i , may be equal to zero.

We can further modify the model to reflect various structural relationships between the service charges by introducing more constraints. These relationships may arise through a variety of administrative policies, some established by historical precedent.

- (a) There may be prescribed lower and upper bounds on some service charges; that is, for service i

$$l_{ij} < a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} < u_{ij}, \quad i=1, \dots, m; \quad j=1, \dots, n$$

where l_{ij} and u_{ij} denote the lower and upper bounds, respectively, on the charge for service i to user type j .

- (b) Some services may be charged more than others; that is, for services i and p

$$a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} \begin{matrix} > \\ < \\ = \end{matrix} k_{ipj} a_{pj} \frac{d_{pj}^{\alpha_p}}{d_{pj}}, \quad j=1, \dots, n$$

where k_{ipj} represents a prespecified magnitude of difference between these charges for user type j , and only one of the three relations holds.

- (c) Some user types may be charged more for a given service to reflect differences in their quality of use; that is, for user types j and q

$$a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} \begin{matrix} > \\ < \\ = \end{matrix} h_{ijq} a_{iq} \frac{d_{iq}^{\alpha_i}}{d_{iq}}, \quad i=1, \dots, m$$

where h_{ijq} represents a prespecified magnitude of difference between these charges for service i , and only one of the three relations holds.

It should be emphasized that constraints of these types arise through non-economic considerations. However, the more stringent these conditions become (e.g., the tighter the bounds on service charges), the less freedom the model has to allocate costs across services and, hence, there are tradeoffs. Such tradeoffs are very difficult to quantify in advance.

It remains to incorporate the variable support costs. If T denotes the library's total annual operating budget, then $T - \sum_{i=1}^m C_i$ represents the total support costs. Some fraction of this total, say, f ($0 < f < 1$) should be recovered through the service charges since it represents qualitative

expenditures varying with services and their usages. However, by their nature, these costs are to be jointly borne by all services. We introduce this consideration by having the total net over collections from all services, that is, the excess of allocated recovery over direct costs, meet this cost requirement. Algebraically, we write

$$\sum_{i=1}^m g_i^+ + \sum_{i=1}^m s_i - \sum_{i=1}^m g_i^- = f \left(T - \sum_{i=1}^m C_i \right)$$

We can now write a final version of the model as follows:

Version 3

$$\text{Min} \quad \sum_{i=1}^m w_i^+ g_i^+ + \sum_{i=1}^m w_i^- g_i^-$$

subject to:

$$\sum_{j=1}^n a_{ij} d_{ij}^{\alpha_i} - g_i^+ - s_i + g_i^- = C_i, \quad i=1, \dots, m$$

$$s_i < B_i, \quad i=1, \dots, m$$

$$\sum_{i=1}^m g_i^+ + \sum_{i=1}^m s_i - \sum_{i=1}^m g_i^- = f \left(T - \sum_{i=1}^m C_i \right)$$

$$l_{ij} < a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} < u_{ij}, \quad i=1, \dots, m; \quad j=1, \dots, n.$$

$$a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} \begin{matrix} > \\ < \end{matrix} k_{ipj} a_{pj} \frac{d_{pj}^{\alpha_p}}{d_{pj}}, \quad i=1, \dots, m; \quad j=1, \dots, n. \\ p=1, \dots, m; \quad p \neq i.$$

$$a_{ij} \frac{d_{ij}^{\alpha_i}}{d_{ij}} \begin{matrix} > \\ < \end{matrix} h_{ijq} a_{iq} \frac{d_{iq}^{\alpha_i}}{d_{iq}}, \quad i=1, \dots, m; \quad j=1, \dots, n. \\ q=1, \dots, n; \quad q \neq j$$

$$a_{ij}, g_i^+, s_i, g_i^-, > 0, \quad i=1, \dots, m; \quad j=1, \dots, n.$$

The various parameter values in this model will reflect the operating environment of the library and its administrative policies and procedures. Finally, we repeat that the remaining budget not specified in the model above [i.e.,

the fixed support costs $(1 - f)(T - \sum_{i=1}^m C_i)$ is recovered through institutional fixed charges determined via a club principle in Rousseau (1985).

An Application to the HAM-TMC Library

The model described above was applied to the Houston Academy of Medicine - Texas Medical Center (HAM-TMC) Library, an independent medical library that jointly serves and is supported by 22 academic, research and clinical institutions. Serving over 10,000 individuals, the library ranked second in 1976 in total expenditures of all medical libraries in the U.S. and Canada with an annual budget in excess of \$1.27 million which is recovered through fees assessed to the supporting institutions.

Four different user types and eight services were considered (see Table 1). As can be seen, this listing is a selective collection of all possible users and services; however, it represents a useful basis for analysis, and could be expanded if needed.

Additional survey data and analysis (discussed in some detail in Bres et al. [1977, Part IV]) and extensive communication with library staff and administration yielded Tables 2 and 3. It should be noted that the second column in Table 2 shows that for some services various of the user types behaved identically in terms of usage. Hence, types were combined and treated the same where appropriate. In addition, for practical purposes values of α_i were estimated by informed individuals in the library rather than through

Table 1

User and Service CategoriesUsers:

1. Medical Professionals -- MD's, PhD's and associated personnel engaged in clinical practice, teaching, and research. Includes faculty, fellows, post doctorates, HAM members, and support staff, as research associates and assistants, secretaries, etc.
2. Nursing Professionals -- Nursing and allied health (including occupational therapy and physical therapy) faculty and practitioners, including associated personnel.
3. Medical Students -- Includes medical students, interns, residents, GSBS graduate students, UTSPH students, speech and hearing students, and all graduate students (including nursing, occupational therapy, physical therapy graduate students, etc.)
4. Nursing Students -- includes undergraduate nursing students, undergraduate allied health students, and high school students.

(Note: Personnel not from member institutions were considered "visitors" whose usage is supported indirectly by the members.)

Services:

1. Self service -- use of material in building, study space
2. Circulation
3. Interlibrary loans -- within TMC
4. Reference questions under ten minutes -- includes telephone holds, paging MD's, holds and rushes, and so on
5. Reference questions over ten minutes
6. Interlibrary borrowing
7. Manual bibliography searches
8. Computerized searches -- MEDLINE, SDILINE, SDC services and so on.

Table 2

User, Service and Cost Relations

<u>Service (i)</u>	<u>Number of Different User Types (r_i)</u>	<u>α_i</u>	<u>Direct Cost c_i</u>
(1) Self-service	1	.67	\$ 12650
(2) Circulation	1	.75	83350
(3) Interlibrary loans	1	.50	15700
(4) Reference questions under 10 minutes	4	1.00	44425
(5) Reference questions over 10 minutes	4	1.00	26060
(6) Interlibrary borrowing	3	.875	20200
(7) Manual Bibliography Searches	3	1.00	4810
(8) Computerized Searches	4	.875	36280

Table 3

USE OF LIBRARY SERVICES BY INSTITUTIONS (UNITS)

INSTITUTION	S.S.	SERVICE							MAN.BIB	COMP.S
		CIRC	ILL	REF<10	REF>10	ILB	MAN.BIB	COMP.S		
Baylor	125318	51360	0	4747	170	890	12	1021		
HAM	8296	3400	0	2114	94	69	43	426		
TWU	76091	31185	0	3113	120	83	0	162		
UTHSC	(94947)	(38094)	(492)	(3843)	(163)	(455)	(26)	(978)		
MS	45513	17835	0	1714	98	193	24	695		
GSBS	13906	5698	0	214	7	167	0	45		
SAH	3379	1385	0	67	0	0	0	0		
SHI	2545	1043	0	96	5	24	0	7		
UTSSN	16543	6780	0	934	41	7	0	14		
DB	5412	2218	264	228	0	12	0	29		
SPH	7649	3135	228	590	12	52	2	188		
UTMDA	7413	3038	2052	415	7	0	0	0		
PVAMUSN	4038	1655	0	120	2	0	0	2		
TIRR	1130	463	2268	142	2	0	0	57		
TRIMS	1398	573	1764	96	10	0	0	64		
I RELIGION	1459	598	0	53	0	10	0	19		
HCHD	2843	1165	0	74	2	0	0	19		
HERMANN	5453	2235	108	137	0	7	0	31		
METHODIST	5546	2273	0	238	7	7	0	26		
SL/TCH	4978	2040	468	226	19	7	0	60		
MEMORIAL	378	155	0	10	0	2	0	0		
ST. JOSEPH	434	178	0	29	2	0	0	0		
VA	1501	615	0	106	7	2	0	0		
TOTAL USAGE	341223	139027	7152	15463	605	1532	81	2865		

elaborate statistical analysis, but they suffice to illustrate our procedures here. Table 3 contains overall survey usage data by institution.¹

Further deliberations led to the following added specifications:

- (i) Services 1 and 2 were not permitted to under collect (they were the most heavily used services and most easily used as means of subsidizing other less frequently used services); mathematically, $\bar{g}_1 = \bar{g}_2 = 0$.
- (ii) Services 3 through 8 were permitted to under collect without penalty; mathematically, $\bar{w}_3 = \bar{w}_4 = \dots = \bar{w}_8 = 0$.
- (iii) It became convenient to define a mean unit charge for services with more than one user type as indicated in Table 2.

$$a_i = \frac{\sum_{j=1}^{r_i} a_{ij}(d_{ij})^{\alpha_i}}{\sum_{j=1}^{r_i} d_{ij}}, \quad i = 4, 5, 6, 7, 8$$

Then, lower bounds were specified on actual unit charges in the case of services 1, 2, 3 and mean unit charges in the case of services 4, ..., 8:

$$l_1 = 0, \quad l_2 = 1.0, \quad l_3 = 2.0, \quad l_4 = 2.5, \quad l_5 = 5.0, \quad l_6 = 7.0, \\ l_7 = 10.0, \quad l_8 = 11.0.$$

¹The abbreviations for the institutions are: Baylor Medical School (BAYLOR); Houston Academy of Medicine (HAM); Texas Women's University (TWU); University of Texas Health Science Center (UTHSC), consisting of the Medical School (MS), Graduate School of Biomedical Sciences (GSBS), School of Allied Health (SAH), Speech and Hearing Institute (SHI), School of Nursing (UTSSN), Dental Branch (DB), and School of Public Health (SPH); University of Texas Sytem Cancer Center M. D. Anderson Hospital and Tumor Institute (UTMDA); Prairie View A & M University School of Nursing (PVAMUSN); Texas Institute of Rehabilitation and Research (TIRR); Texas Research Institute of Mental Sciences (TRIMS); Institute of Religion (IRELIGION); Harris County Hospital District (HCHD); Hermann Hospital (HERMANN); Methodist Hospital (METHODIST); St. Luke's Episcopal/Texas Children's Hospital (SL/TCH); Memorial Hospital (MEMORIAL); St. Joseph Hospital (ST.JOSEPH); Veterans Administration Hospital (VA).

Thus, for example, the mean unit charge for a computerized search (service 8) had to at least be equal to \$11.00.

- (iv) No upper bounds were specified for any service charges, actual or mean.
- (v) A variety of relationships were developed between unit service charges (actual or mean). For example, the self service (service 1) unit charge was made the least expensive of all by including seven constraints of the type:

$$a_1 \frac{(d_1)^{\alpha_1}}{d_1} < \begin{cases} a_i \frac{(d_i)^{\alpha_i}}{d_i}, & i = 2, 3 \text{ (actual)} \\ a_i, & i = 4, \dots, 8 \text{ (mean)} \end{cases}$$

Note that the value of k_{1i} is 1 in the above relations meaning no explicit differential is required, only that service 1 is least expensive. Table 4 lists other constraints relating the other service charges.

- (vi) Relations on the charges within a specific service for each user type for the last five services were identified; recall that these types are listed in Table 1. As an example of such relationships, the following were formulated for the case of interlibrary borrowing (service 6):

$$a_{62} \frac{(d_{62})^{\alpha_6}}{d_{62}} < a_{61} \frac{(d_{61})^{\alpha_6}}{d_{61}} < 1.6a_{62} \frac{(d_{62})^{\alpha_6}}{d_{62}}$$

$$a_{62} \frac{(d_{62})^{\alpha_6}}{d_{62}} < a_{63} \frac{(d_{63})^{\alpha_6}}{d_{63}}$$

These relationships imply that nursing professionals will be assessed a unit charge for this service lower than or equal to that assessed either medical professionals or medical students.

Table 4

Relationships Between Unit Charges for All Services

<u>Algebraic Form</u>	<u>Interpretation</u>
$a_1 \frac{(d_1)^{\alpha_1}}{d_1} <$ $a_i \frac{(d_i)^{\alpha_i}}{d_i}, \quad i = 2, 3$ $a_i \quad i = 4, \dots, 8$	Self service (1) has smallest unit charge
$2a_4 < a_5$	Mean unit charge for reference questions under ten minutes (4) will be less than half that for those over ten minutes (5)
$2a_5 < a_8$	Mean unit charge for reference questions over ten minutes (5) will be less than half that for computerized searches (8)
$a_7 > a_8$	Manual bibliography searches (7) will be charged more than computerized searches (8)
$a_2 \frac{(d_2)^{\alpha_2}}{d_2} < a_7$	Circulation (2) will be charged less than manual bibliography searches (7)
$a_3 \frac{(d_3)^{\alpha_3}}{d_3} < a_7$	Interlibrary loans (3) will be charged less than manual bibliography searches (7)
$2a_3 \frac{(d_3)^{\alpha_3}}{d_3} < a_6$	Interlibrary loans (3) will be charged less than half of the mean amount for interlibrary borrowing (6)

However, the unit charge carried by the medical professionals cannot be more than 60% higher than that for the nursing professionals. There is no direct relationship between the unit charges for medical professionals and medical students. It should be noted that none of the inequalities forces an explicit set of values to occur; rather they maintain a limited ordering among the values including the possibility that all values for the unit charges will be equal to each other. Each of the other four services with different user types had similar constraints; the explicit formulations are not given here in the interest of brevity; however, their justification is discussed in somewhat greater detail in Bres et al. [1977, Part IV] where different users and their characteristics are analyzed.

- (vii) All services were permitted to over collect without penalty if the lower bounds on their unit charges caused them to recover in excess of their direct costs; beyond this point (i.e., if unit charges were made higher than their lower bounds and direct costs were already being exceeded) over collection was penalized, equally across services. The only exceptions to this policy were the first two services where they were permitted to over collect unpenalized all the way up to half the needed variable costs (total direct plus variable support) not otherwise recovered through other services; again the rationale was that the most heavily used services were the simplest, most effective means of subsidization. All these considerations were incorporated mathematically in the selection of the appropriate B_1 values.

(viii) The fraction f was selected as the ratio of total direct costs for all services to the total budget. Thus, the variable support cost fraction is determined in direct relationship to the total direct costs. They both increase or decrease together.

The estimated budget, broken down by line item expenditures, was \$1,274,428. Total direct costs were estimated to be \$243,475, leaving total support costs (including utilities and maintenance) at \$1,030,953. The variable portion of support costs to be recovered through service charges was thus estimated to be \$196,980.

The unit service charges are given in Table 5, ranging from 30 cents for self service to almost \$60 for a manual bibliography search, along with the dollar amount collected per service. As expected and administratively desirable the two most heavily used services (self service and circulation) are the source of subsidization for other less frequently used services such as reference questions and inter-library borrowing. On the other hand, inter-library loans, manual bibliographies and computer searches are charged almost break-even prices.

The consequent usage based assessments to each institution by service are obtained from the survey usage data of Table 3 and the unit service charges of Table 5: these assessments are given in Table 6.

The total institutional assessments are given in Table 7, where two alternative schedules of fair and efficient fixed charges derived from solution concepts in game theory are included for completeness. Determination of these fixed charge components is discussed in Rousseau (1985).

TABLE 5

UNIT CHARGES FOR LIBRARY SERVICES

	SERVICE							
	<u>S.S.</u>	<u>CIRC</u>	<u>ILL</u>	<u>REF<10</u>	<u>REF>10</u>	<u>ILB</u>	<u>MAN.BIB</u>	<u>COMP.S</u>
AVERAGE UNIT CHARGE	.30	1.70	2.19	2.50	5.00	7.00	59.36	12.33
TOTAL COLLECTED	102021.75	236189.25	15690.00	38657.50	2620.83	5144.56	4808.00	35323.11

TABLE 6

ASSESSMENTS TO INSTITUTIONS FOR USE OF LIBRARY SERVICES (DOLLARS)

INSTITUTION	SERVICE							TOTAL	
	S.S.	CIRC	ILL	REF<10	REF>10	ILLB	MAN.BIB		COMP.S
Baylor	37468.64	87254.13	0.00	11867.50	736.43	2988.68	712.30	12588.10	153615.77
HAM	2480.41	5776.17	0.00	5285.00	407.20	231.71	2552.40	5252.23	21985.11
TWU	22750.33	52979.36	0.00	7782.50	519.83	278.72	0.00	1997.33	86308.08
UTHSC	(28388.06)	(64716.88)	(1079.35)	(9607.50)	(706.11)	(1527.92)	(1543.31)	(12057.94)	(119627.06)
MS	13607.86	30299.40	0.00	4285.00	424.53	648.11	1424.59	8568.78	59258.28
GSBS	4157.73	9680.18	0.00	535.00	30.32	560.80	0.00	554.81	15518.85
SAH	1010.28	2352.94	0.00	167.50	0.00	0.00	0.00	0.00	3530.72
SHI	760.93	1771.92	0.00	240.00	21.66	80.59	0.00	86.30	2961.41
UTSSN	4946.17	11518.36	0.00	2335.00	177.61	23.51	0.00	172.61	19173.25
DB	1618.13	3768.10	579.16	570.00	0.00	40.30	0.00	357.55	6933.23
SPH	2286.96	5325.97	500.18	1475.00	51.98	174.62	118.72	2317.89	12251.32
UTMDA	2216.40	5161.18	4501.66	1037.50	30.32	0.00	0.00	0.00	12947.06
PVAMUSN	1207.32	2811.64	0.00	300.00	8.66	0.00	0.00	24.66	4352.27
TIRR	337.86	786.58	4975.52	355.00	8.66	0.00	0.00	702.76	7166.38
TRIMS	417.99	973.45	3869.85	240.00	43.32	0.00	0.00	789.07	6333.68
I RELIGION	436.22	1015.93	0.00	132.50	0.00	33.58	0.00	234.25	1852.49
HCHD	850.02	1979.19	0.00	185.00	8.66	0.00	0.00	234.25	3257.13
HERMANN	1630.38	3796.98	236.93	342.50	0.00	23.51	0.00	382.20	6412.51
METHODIST	1658.19	3861.54	0.00	595.00	30.32	23.51	0.00	320.56	6489.12
SL/TCH	1488.36	3465.70	1026.69	565.00	82.31	23.51	0.00	739.75	7391.33
MEMORIAL	113.02	263.33	0.00	25.00	0.00	6.72	0.00	0.00	408.06
ST. JOSEPH	129.76	302.40	0.00	72.50	8.66	0.00	0.00	0.00	513.32
VA	448.78	1044.81	0.00	265.00	30.32	6.72	0.00	0.00	1795.63
TOTALS	102021.75	236189.25	15690.00	38657.50	2620.83	5144.56	4808.00	35323.11	440455.00

TABLE 7

TOTAL ASSESSMENTS TO INSTITUTIONS (DOLLARS)

<u>INSTITUTION</u>	<u>USAGE ASSESSMENT</u>	<u>SHAPLEY VALUE BASED FIXED CHARGE</u>	<u>TOTAL ASSESSMENT</u>	<u>NUCLEOLUS BASED FIXED CHARGE</u>	<u>TOTAL ASSESSMENT</u>
Baylor	153615.77	316001.98	469617.75	293052.85	446668.62
HAM	21985.11	57678.98	79664.09	69459.69	91444.80
TWU	86308.08	21178.65	107486.73	29418.38	115726.46
UTHSC	(119627.06)	(400931.21)	(520558.27)	(379828.13)	(499455.19)
MS	59258.28	394228.98	453487.26	371279.85	430538.13
GSBS	15518.85	0.00	15518.85	0.00	15518.85
SAH	3530.72	0.00	3530.72	0.00	3530.72
SHI	2961.41	0.00	2961.41	0.00	2961.41
UTSSN	19173.25	0.00	19173.25	0.00	19173.25
DB	6933.23	3615.20	10548.43	4274.14	11207.37
SPH	12251.32	3087.03	15338.35	4274.14	16525.46
UTMDA	12947.06	17342.40	30289.46	29418.38	42365.44
PVAMUSN	4352.27	1700.22	6052.49	2981.42	7333.69
TIRR	7166.38	2133.89	9300.27	2981.42	10147.80
TRIMS	6333.68	1554.28	7887.96	2981.42	9315.10
I RELIGION	1852.49	2133.89	3986.38	2981.42	4833.91
HCHD	3257.13	2133.89	5391.02	2981.42	6238.55
HERMANN	6412.51	2133.89	8546.40	2981.42	9393.93
METHODIST	6489.12	2133.89	8623.01	2981.42	9470.54
SL/TCH	7391.33	2133.89	9525.22	2981.42	10372.75
MEMORIAL	408.06	2133.89	2541.95	2981.42	3389.48
ST. JOSEPH	513.32	2133.89	2647.21	2981.42	3494.74
VA	1795.63	514.28	2309.91	2981.42	4777.05
TOTALS	440455.00	833973.12	1274428.12	833973.05	1274428.05

Conclusions

This paper has been concerned with the problem of allocating the annual operating budget of a large independent medical library to the various diverse health-related institutions (members of the library system) that jointly support and are served by the library. To justify the budget to the participating institutions and maintain cooperative support for the library, the fees assessed to the institutions must be both equitable and efficient. We have argued that a reasonable and equitable charging mechanism, therefore, might recover the direct costs of services provided and the variable portion of support costs through usage based fees, determined through construction and solution of a constrained goal programming model, and the joint fixed support costs through institutionally based (or "membership") fees based on a club principle [see Rousseau (1985)].

The goal programming model developed in the present paper was applied to the Houston Academy of Medicine - Texas Medical Center Library using data from 1976. The data and assumptions used in the present application were at times approximate and an oversimplification, but they suffice to illustrate the principles involved. Many of the constraints in the model arose from non-economic considerations and were the result of the general operating environment of the library and its administrative policies and procedures.

The resulting unit service charges ranged from 30 cents for self service to almost \$60 for a manual bibliography search. Self service and circulation (the two most heavily used services) subsidized the less frequently used services such as reference questions and inter-library borrowing. Three services (inter-library loans, manual bibliographies and computer searches) were charged essentially break-even prices.

In principle, our model can be extended to include multiple time periods. For example, prospective planning might be useful for several years if significant capital expenditures were anticipated and their gradual inclusion in several years' budgets were desired. The effect of an expanding market (i.e., user population) or service capabilities would also prompt a broader analysis of the cost recovery process.

To adapt the preceding model to a dynamic, multiperiod context requires, initially, that all preceding variables and parameters be subscripted for time period, except for the a_{ij} which remains the constant allocational factors throughout. This process implies that values for all parameters will have to be estimated, or otherwise determined, for each time period in the planning horizon; of course, some values may remain unchanged as, for example, the fraction f which seems to be more a matter of policy and time invariant economic logic. Also, the number of constraints will increase to account for individual, period-by-period recovery of the various costs.

The most substantive change would be the addition of a series of constraints that effectively couple recovery overall in one time period with that in the next, since there may be beneficial tradeoffs in over collecting on total budget one period and using this excess subsequently. For example, such a situation may be desirable in order to smooth or level the service charges over time despite fluctuations in budget. Such extensions, however, are beyond the scope of the present paper.

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