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BSTRACT

Two measures of effectiveness for university libraries are constructed. The Primary Measure of Effectiveness, defined over the total population of users, considers the number of material and information items desired by the users, the number of satisfactorily answered inquiries, and the number of users. For the Secondary Measure of Effectiveness the total population is classified into subsets according to similarity of users' needs. A measure is defined for each subset and is a function of the number of individuals in the subset. (Author)

MEASURES OF EFFECTIVENESS FOR A UNIVERSITY LIBRARY*

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Two measures of effectiveness for university libraries are constructed. The Primary Measure of Effectiveness, defined over the total population of users, considers the number of material and information items desired by the users, the number of satisfactorily answered inquiries, and the number of users. For the Secondary Measure of Effectiveness, the total population is classified into subsets according to similarity of user needs. A measure is defined for each subset and is a function of the number of individuals in the subset.

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Previous papers have argued that in order to describe, design, or evaluate a university library system, it is not sufficient to consider the library as a separate entity. The behavior and utility of a university library is constrained and influenced by actions of the funders and users of the library. Several specific studies have been reported including the development of a conceptual systems model (2), the construction and analysis of an industrial dynamics simulation model of university departmental libraries (3,10), and the formulation and analysis of mathematical models of optimal user search behavior (1). However, to this point no adequate measures of effectiveness exist which could be utilized by university libraries in evaluating on-going programs or in determining the impact of proposed programs.

The purpose of this paper is to propose two such measures and to discuss, in detail, the properties of each measure. A large number of user studies have been conducted (5) and the conclusion can be drawn that a measure of effectiveness must adequately reflect satisfaction of user needs. The "primary measure of effectiveness" is constructed to accomplish precisely this aspect.

A recent empirical study (12) conducted at Purdue University demonstrates that the total population of potential library users can be classified into subsets--faculty, graduate students, and undergraduate students--according to similarity of needs. A "secondary measure of effectiveness" is defined which is appropriate for each subset and which considers number of actual users and number of repeat users.

Library Goals and User Needs

The primary goals of the library are defined to be:

1. Maximize user need satisfaction.
2. Minimize the time loss (opportunity cost) to the user.

In addition, the university seeks to serve as many users as feasible. Thus, a secondary goal is:

3. Increase the number of actual users.

These goals serve as foundations for both measures of effectiveness.

Despite work by Bourne, et al (4) and Meier (8), adequate methodologies for collecting data on time loss do not exist. However, their results suggest that time loss can be accounted for indirectly through consideration of the increase (decrease) of the number of users and of the increase (decrease) in the use of library materials.

A questionnaire designed by Dean R. B. Downs, the Dean of Library Administration at the University of Illinois and by Dr. Warren Seibert of the Purdue Libraries was recently administered at Purdue University (6). Question 5 asked users to identify their "primary reason for coming to the library" from a list of 11 possible reasons including "do something else (not mentioned above)." The major reasons cited are:

1. Find and read material required for a course.
2. Read material for self improvement.
3. Read for pleasure or fun.
4. Borrow library material for further reading.
5. Do research for a term paper.
6. Do research for graduate exams or thesis work.
7. Do research for a publishable paper or book.
8. Get some material copied (Xerox).
9. Return materials (books) to the library.
10. Do homework with own books.
11. Seek information which does not require borrowing of library materials (questions answered by reference librarians).

Statistical methodologies for measuring library usage, e.g., re-shelving and browsing statistics, have been investigated in depth by Jain (7). These approaches could be utilized to obtain information on reasons 1-7. The number of persons

getting material copied, and the number of copies reproduced, are routinely kept now by many libraries. The only difficulty likely to be encountered relative to item 9 is the identification of users who came to the library only for the purpose of returning material. Sampling studies would be necessary to accomplish this identification and to collect information on item 10. The total number of requests for information could be easily recorded by the reference librarians. A much more difficult item to obtain is whether the inquiry was satisfactorily answered. This may be a purely perceptual aspect which can be provided only by the user or by some panel of experts. Regardless, the assumption is that data relative to user need satisfaction can be collected for the evaluation of implemented programs.

Exactly the same information would be required in order to evaluate benefits likely to accrue from proposed programs. If pilot programs were conducted, then the same methodologies could be utilized. Otherwise, subjective estimates would be required. Specific approaches are not defined; however, research is underway investigating the applicability of procedures such as those suggested by Moore and Baker (9).

A Primary Measure of Effectiveness

In order to specify a primary measure of effectiveness, three specific measures will be constructed and integrated. The three measures are concerned with 1) the total number of users and the total number of material items used, 2) the total number of non-material information items sought and the total number supplied and 3) the total number of users who are studying with their own materials or who are at the library for social purposes.

The following definitions will be utilized in the development of a Primary Measure of Effectiveness:

N = total population of users of the university library, e.g., all students, faculty, alumni, and staff associated with the university.

n = total number of users from N who use the library facilities per time period. Note that $n \leq N$.

r_1 = total number of non-material information items sought per time period, e.g., the total number of questions asked of reference librarians.

r_2 = total number of acceptable non-material information items supplied per time period, e.g., the total number of questions answered satisfactorily by reference librarians.

s = total number of users per time period who are studying with their own materials or who are there for social purposes.

m = total number of material items used (reshelved) per time period, e.g., the material used in order to satisfy the needs underlying items 1-8.

Effectiveness Term For m And n

The material items accessed during a time period are selected because of their potential, as perceived by the user, to satisfy some underlying need. Effectiveness of the library operation is a function of the total number of items accessed (m_1) and the total number which actually contributed to need satisfaction (m_2), e.g., m_2 should be maximized and (m_1-m_2) should be minimized subject to the constraint that $m_1 \geq m_2$. An effectiveness term such as $m_2\left(\frac{m_2}{m_1}\right)$ would accomplish the above; an increase in $m_2\left(\frac{m_2}{m_1}\right)$ indicates that m_2 is increasing or that (m_1-m_2) is decreasing $\left(\frac{m_2}{m_1} \rightarrow 1\right)$.

In light of the difficulty inherent in measuring m_2, a simplifying assumption is made. Assume that any item which is removed from its shelf location during a time period, and hence reshelved, is sufficiently relevant to contribute to need satisfaction. The total number of items reshelved is denoted by m and, as m increases, the effectiveness of the library increases.

The secondary goal suggested in the previous section is to increase the number of actual users. The total number of actual users is denoted by n and as n increases, the library's effectiveness increases. The relative impact of both m and n should be related to N, the total population of potential library users.

The following term for measuring the effectiveness of the library relative to satisfying user material needs and to the number of actual users is proposed:

$$e_1 = \frac{m}{N}\left(1 + \frac{n}{N}\right) . \qquad (1)$$

Table 1 summarizes the properties of e_1 under various possible conditions of change resulting from modifications in the library's operations.

In summary, given e_1 as defined, the following conclusions can be drawn:

1. As the number of material items used during a time period increases (decreases), e_1 increases (decreases).
2. As the number of users during a time period increases (decreases), e_1 increases (decreases).
3. If the number of material items used is less (greater) than the sum of the total population plus the number of users, then increasing the number of material uses is more (less) desirable than increasing the number of users.
4. If no material items are being used, e_1 is equal to zero regardless of the number of users. If the users are coming for some need not related to accessing library material, the effectiveness term for r_1 and r_2, or the the term for s, will measure the associated contribution to library effectiveness.

If e_1 is accepted, then the above conditions follow; conversely, if the above conditions are acceptable, then e_1 is an acceptable effectiveness term for relating the number of material items used with the number of users.

Effectiveness Term For r_1 And r_2

The effectiveness of a university library should increase as the number of non-material information items supplied per time period (r_2) increases. The effectiveness should also increase, but to a lesser degree, as the number of non-material information items sought (r_1) increases. An increase in the number sought implies that the users perceive an improvement in the library's ability to satisfy non-material information needs. Over time, however, unless ability to

Table 1

Properties of e_1

Conditions of Change	Impact on $e_1 = \frac{m}{N} - \left(1 + \frac{n}{N}\right)$
1. $\Delta m \neq 0$, $\Delta n = 0$	$\Delta e_1 = \frac{\Delta m}{N}\left(1 + \frac{n}{N}\right)$
a) $\Delta m > 0$	$\Delta e_1 > 0$
b) $\Delta m < 0$	$\Delta e_1 < 0$
2. $\Delta m = 0$, $\Delta n \neq 0$	$\Delta e_1 = \frac{m(\Delta n)}{N^2}$
a) $\Delta n > 0$	$\Delta e_1 > 0$
b) $\Delta n < 0$	$\Delta e_1 < 0$
3. $\Delta m \neq 0$, $\Delta n \neq 0$	$\Delta e_1 = \frac{1}{N^2}\left[\Delta m(N) + \Delta m(n) + \Delta n(m) + \Delta n(\Delta m)\right]$
a) $\Delta m > 0$, $\Delta n > 0$	$\Delta e_1 > 0$
b) $\Delta m < 0$, $\Delta n < 0$	$\Delta e_1 < 0$
b-1) $\lvert\Delta n\rvert = n$	$\Delta e_1 = -e_1$ (and $\lvert\Delta m\rvert = m$)
b-2) $\lvert\Delta n\rvert < n, \lvert\Delta m\rvert = m$	$\Delta e_1 = -e_1$
c) $\Delta m > 0$, $\Delta n < 0$	$(-1)\frac{\Delta m}{\Delta n} > \frac{m+\Delta m}{N+n} \Rightarrow \Delta e_1 > 0$
c-1) $\Delta m = \lvert\Delta n\rvert$	$\Delta m < N+n - m \Rightarrow \Delta e_1 > 0$
d) $\Delta m < 0$, $\Delta n > 0$	$(-1)\frac{\Delta m}{\Delta n} < \frac{m + \Delta m}{N + n} \Rightarrow \Delta e_1 > 0$
d-1) $\Delta n = \lvert\Delta m\rvert$	$\Delta n < m-(N+n) \Rightarrow \Delta e_1 > 0$

In the above table, the following conditions hold:

i) $m > 0$, $0 < n < N$, $N > 0$.

ii) If $\Delta m < 0$, $\lvert\Delta m\rvert \leq m$

iii) If $\Delta n > 0$, $\Delta n \leq N-n$

iv) If $\Delta n < 0$, $\lvert\Delta n\rvert \leq n$.

satisfy these needs also improves, it is reasonable to expect the number of non-material information items sought to stablize or even decrease. Thus, r_2 should be the dominant consideration.

The recommended effectiveness term is:

$$e_2 = \frac{r_2}{N}\left(1 + \frac{r_1}{N}\right) \quad . \qquad (2)$$

Table 2 summarizes the properties of e_2 under various possible changes in r_1 and r_2.

As suggested in the above discussion, increase (decrease) in the number of non-material information items sought or increase (decrease) in items supplied produces an increase (decrease) in e_2. In addition, since $r_2 + \Delta r_2 \leq r_1 + \Delta r_1$, it is always advantageous to increase the number of items supplied, even if the number of items sought is undergoing an equal decrease. However, in the long-run, increase in r_2 would be expected to generate additional items sought, i.e., increase r_1.

Effectiveness Term For s

The effectiveness of the university library should increase (decrease) if its facilities are used by a greater (lesser) number of individuals for study or social purposes (s). In this case, the underlying user need is a need for space rather than a need for material or non-material information items. The following term exhibits the desired properties:

$$e_3 = \frac{s}{N^2} \qquad (3)$$

and $\Delta e_3 = \frac{\Delta s}{N^2}$. The denominator N^2 is suggested in order to have changes in s comparable to changes in n and r_1 since all three terms reflect the number of users utilizing the library. If the denominator were to be specified as N, then s would be considered as on the same level as n and r_2 both of which represent satisfaction of an information need.

Table 2

Properties of e_2

Conditions of Change	Impact on $e_2 = \frac{r_2}{N}\left(1 + \frac{r_1}{N}\right)$
1. $\Delta r_2 \neq 0$, $\Delta r_1 = 0$	$\Delta e_2 \approx \frac{\Delta r_2}{N} + \frac{\Delta r_2 (r_1)}{N^2}$
a) $\Delta r_2 > 0$	$\Delta e_2 > 0$
b) $\Delta r_2 < 0$	$\Delta e_2 < 0$
2. $\Delta r_2 = 0$, $\Delta r_1 \neq 0$	$\Delta e_2 = \frac{\Delta r_1 (r_2)}{N^2}$
a) $\Delta r_1 > 0$	$\Delta e_2 > 0$
b) $\Delta r_1 < 0$	$\Delta e_2 < 0$
3. $\Delta r_2 \neq 0$, $\Delta r_1 \neq 0$	$\Delta e_2 = \frac{1}{N^2}[N(\Delta r_2) + r_2 (\Delta r_1) + r_1(\Delta r_2) + \Delta r_1(\Delta r_2)]$
a) $\Delta r_2 > 0$, $\Delta r_1 > 0$	$\Delta e_2 > 0$
b) $\Delta r_2 < 0$, $\Delta r_1 < 0$	$\Delta e_2 < 0$
c) $\Delta r_2 > 0$, $\Delta r_1 < 0$	(-1) $\frac{\Delta r_2}{\Delta r_1} > \frac{r_2 + \Delta r_2}{N + r_1} \Rightarrow \Delta e_2 > 0$
c-1) $\Delta r_2 = \lvert\Delta r_1\rvert$	$\Delta e_2 > 0$
d) $\Delta r_2 < 0$, $\Delta r_1 > 0$	(-1) $\frac{\Delta r_2}{\Delta r_1} < \frac{r_2 + \Delta r_2}{N + r_1} \Rightarrow \Delta e_2 > 0$
d-1) $\Delta r_1 = \lvert\Delta r_2\rvert$	$\Delta e_2 < 0$

In the above table, the following conditions hold:

i) $0 \leq r_2 \leq r_1$

ii) If $\Delta r_2 < 0, \lvert\Delta r_2\rvert \leq r_2$

iii) If $\Delta r_1 < 0, \lvert\Delta r_1\rvert \leq r_1$

iv) $r_2 + \Delta r_2 \leq r_1 + \Delta r_1$

The Primary Measure of Effectiveness

The primary measure of effectiveness, E, is defined as a weighted sum of e_1, e_2, and e_3. Specifically,

$$E = w_1 e_1 + w_2 e_2 + w_3 e_3 \qquad (4)$$

where w_1, w_2, and w_3 are the weighting factors.

The weighting factors allow the library administration to designate the relative importance of the contribution of each of the terms. Although there exist several approaches for determining w_1, w_2, and w_3 (e.g., 13), experience at Purdue University suggests another procedure which will be illustrated by the following example.

Suppose that the university library administrator states that an increase of 20 patrons studying in the library (Δs) is equivalent (in value) to an increase of 1 question answered properly (Δr_2) and that an increase of 3 material items (Δm) is also equivalent to $\Delta r_2 = 1$. Thus, it follows that

$$w_3(\Delta e_3) = \frac{w_3(\Delta s)}{N^2} = \frac{20\, w_3}{N^2} = \frac{w_2(N+r_1)}{N^2} = w_2 \left[\frac{\Delta r_2}{N} + \frac{\Delta r_2(r_1)}{N^2}\right] = w_2\ (\Delta e_2)$$

and that

$$w_1(\Delta e_1) = w_1 \left[\frac{\Delta m}{N}\ (1 + \frac{n}{N})\right] = \frac{3w_1(N + n)}{N^2} = \frac{w_2\ (N+r_1)}{N^2}\ .$$

If w_2 is arbitrarily set equal to 1, then

$$w_3 = \frac{N + r_1}{20} \quad \text{and} \quad w_1 = \frac{N + r_1}{3(N+n)}\ .$$

Note that if the administrator is consistent in stating his preference, then $\Delta m = 3$ is equivalent to $\Delta s = 20$.

A Secondary Measure of Effectiveness

The recognition of user subsets with dissimilar needs is considered important for the direction of program development, e.g., one type of program might benefit one subset and not contribute at all to another subset. Clearly, E could be utilized to study any given subset provided the input data is available. However, a measure is proposed which is different in form from E and is based on the number of users and the number of times the library is accessed by the users.

The division of the user population should be according to user needs. Rzasa and Moriarty (12) established one such division as faculty, graduate students, undergraduate students, and staff and others. Another division might be according to the formal organization structure, e.g., by the academic departments. The point is that the division is flexible and should be based on the specific environment under study. Let J be the number of subsets and let j be a subscript over the subsets, $j=1,2, \ldots, J$.

The secondary measure of effectiveness reflects the following properties:

1. As the number of individuals from a subset who use the library in a time period (n_j) increases, the measure should also increase.
2. As the number of times users from a subset use the library facilities within a time period (u_j) increases, the measure should also increase.
3. If the library is serving a large percentage of subset j, but the number of return visits is low, it is preferred that a lower percentage be served and that the users return more often.
4. If the library is serving a small percentage of subset j, but the number of return visits is high, it is preferred that a higher percentage be served even though the users return less often.

A secondary measure of the form below satisfies the above conditions:

$$\bar{E}_j = \left(\frac{A_j}{N_j}\right)\left(\frac{n_j}{N_j}\right) \qquad (5)$$

where $A_j = u_j - n_j$ and is defined as "activity" and N_j is the total population of subset j. $\bar{E}_j$ is proposed to measure changes in effectiveness relative to subset j and is not intended to compare effectiveness relative to subset j to effectiveness relative to some other subset j', i.e., a comparison of $\bar{E}_j$ to $\bar{E}_{j'}$ is not suggested.

It might be noted that a secondary measure of effectiveness, $\bar{E}$, can be related to the entire population which the library serves. $\bar{E}$ will give an indication of effectiveness based on the total number of users from the population, N, and the number of times the users return to the library during a given time period. The library administration will thus have an indication of how their facility rates as a source of need satisfaction by the users.

Specifically, the secondary measure of effectiveness should aid the administrator in evaluating programs aimed at a specific group. Table 3 summarizes the properties of $\bar{E}_j$ under various possible conditions of change resulting from modifications in the library's operation.

In summary, given $\bar{E}_j$ as defined, the following conclusions can be drawn:

1. If activity increases (decreases) while the number of users remains constant, effectiveness increases (decreases) since the number of users from group j are returning more (less) often.
2. Activity remaining constant while the number of users, n_j, increases is equivalent to saying that the new users are only coming once during a time period. Since the library is serving a larger proportion of the subpopulation, effectiveness increases.
3. If both activity and the number of users increase (decrease) then not only is a larger (smaller) proportion of group j using the facility but the return rate is increasing (decreasing), Therefore, effectiveness increases (decreases).

Table 3

Properties of $\bar{E}_j$

Conditions of Change	Impact on $\bar{E}_j = \left(\frac{A_j}{N_j}\right)\left(\frac{n_j}{N_j}\right)$ $\Delta\bar{E}_j = \left(\frac{\Delta A_j}{N_j}\right)\left(\frac{n_j}{N_j}\right)$
1. $\Delta A_j \neq 0 \quad \Delta n_j = 0$	
a) $\Delta A_j > 0$	$\Delta\bar{E}_j > 0$
b) $\Delta A_j < 0$	$\Delta\bar{E}_j < 0$
b-1) $\lvert\Delta A_j\rvert = A_j$	$\Delta\bar{E}_j = -\bar{E}_j$
2. $\Delta A_j = 0, \quad \Delta n_j \neq 0$	$\Delta\bar{E}_j = \left(\frac{A_j}{N_j}\right)\left(\frac{\Delta n_j}{N_j}\right)$
a) $\Delta n_j > 0$	$\Delta\bar{E}_j > 0$
b) $\Delta n_j < 0$	$\Delta\bar{E}_j < 0$
b-1) $\lvert\Delta n_j\rvert = n_j$	$\Delta\bar{E}_j = -\bar{E}_j$
3. $\Delta A_j \neq 0, \quad \Delta n_j \neq 0$	$\Delta\bar{E}_j = \frac{1}{(N_j)^2}\left[(\Delta A_j)(\Delta n_j) + A_j(\Delta n_j) + (\Delta A_j)n_j\right]$
a) $\Delta A_j > 0, \ \Delta n_j > 0$	$\Delta\bar{E}_j > 0$
b) $\Delta A_j < 0, \ \Delta n_j < 0$	$\Delta\bar{E}_j < 0$
c) $\Delta A_j > 0, \ \Delta n_j < 0$ Let $\hat{A}_j = A_j + \Delta A_j$ $\hat{n}_j = n_j + \Delta n_j$	$(\hat{A}_j)(\hat{n}_j) > (A_j)(n_j) \Rightarrow \Delta\bar{E}_j > 0$
d) $\Delta A_j < 0, \ \Delta n_j > 0$	$(\hat{A}_j)(\hat{n}_j) > (A_j)(n_j) \Rightarrow \Delta\bar{E}_j > 0$

In the above table, the following conditions hold

i) Since $A_j = u_j - n_j$, $A_j \geq 0$, i.e. $u_j \geq n_j$

ii) If $\Delta u_j < 0$, $\Delta n_j < 0$, and $\Delta A_j > 0$ (Case 3c)

then $\lvert\Delta u_j\rvert < \lvert\Delta n_j\rvert$

iii) If $\Delta u_j > 0$, $\Delta n_j > 0$ and $\Delta A_j < 0$ (Case 3d)

then $\Delta u_j < \Delta n_j$

4. The relationship between change in the number of users and change in effectiveness is influenced by the magnitude of the percentage of the group who use the facility.

   a. If the number of users decreases, then, in order for effectiveness to increase, activity must increase. The required level of activity increase is inversely related to the percentage using the facility.

   b. If the number of users increases, the effectiveness can increase even if activity decreases. The level of activity decrease is inversely related to the percentage using the facility.

Summary and Comments

Based upon the goals of a university library and conditions, which, if satisfied, led toward attainment of the goals, two measures of effectiveness were developed. The criteria established for the primary measure were 1) the number of material items utilized, 2) the number of actual users, 3) the number of informational items sought, 4) the number of satisfactory information items received, and 5) the amount of study space utilized. The total population served as a basis so that changes in the user population could be taken into account.

The criteria established for the secondary measure were 1) the number of actual users from a given subpopulation and 2) the return rate of these users. The subpopulation which the library served was used as a basis for the secondary measure.

The purpose of this paper was to develop an adequate measure of effectiveness for university libraries to evaluate on-going programs or in determining the impact of proposed programs. Inputs to the model for evaluation of present programs can be determined by the statistical methodologies mentioned. Inputs for the evaluation of proposed programs might be determined by the use of pilot studies, objective estimates by administrators or industrial dynamics models. Preferred programs could then be evaluated by using a cost-effectiveness analysis.

One final comment is needed. Although the measures developed satisfied the conditions which were specified, they are not unique. That is, as long as the model developed satisfied specific conditions which are directly related to the goals, the measure would be adequate.

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