CHAPTER 1

A SYSTEMS APPROACH TO LIBRARY MANAGEMENT

1.1 Introduction

Three factors combine to produce major decision problems for society:

(1) A variety of needs exist in society.

(2) Ends may, in general, be met by a variety of means.

(3) Resources available for the satisfaction of needs are scarce, so that practically no needs can be fully satisfied.

The problems that arise are those of choosing the "best" ways of satisfying the needs of society. These problems are made considerably more difficult by the phenomena of growth and of changing perceptions of need priorities. For example, technology has worked to achieve a growing level of mass-production of motor vehicles through the development of efficient manufacturing systems. The rapid acceptance of the motor vehicle has led to, among others, the need for:

Extensive road systems.

Highly complex traffic control systems.

A huge vehicle maintenance system.

At the same time the need for more primitive means of transport has been considerably reduced, and certain natural resources are rapidly diminishing.

The 'systems' referred to each consist of a set of interacting components which are organized to achieve some purpose. The complexity of the interaction between a system and its environment (i.e., with other systems) is mirrored in the complex web of interactions among the system's components, or subsystems. Any approach which seeks to optimize the overall performance of a system should take account of this complex of interactions. It has become usual in recent years to refer to such an approach to design and management as the "systems approach".

Libraries have not been immune to the growing difficulty of management problems in a world of increasing demand and decreasing resources. The availability of options such as mechanization, centralization and computerization; the expansion in collections, activities, and services; the increased participation in library networks; the rapid increases in prices of labour, monographs and serials; and the recent failure of library budgets to grow in step with requirements (White, 1976), have all combined to present today's library management with difficult and pressing decision problems for the efficient and effective utilization of resources.

An inevitable result has been an increased interest, among librarians, in the application of the conceptual and quantitative principles of management science (Mackenzie, 1976). Strong evidence of this growing interest in Australia was the 1976 Lasie - sponsored conference in Sydney (Lasie, Vol. 7), which was addressed by C. West Churchman, a foundation figure in the philosophy and application of the systems approach.

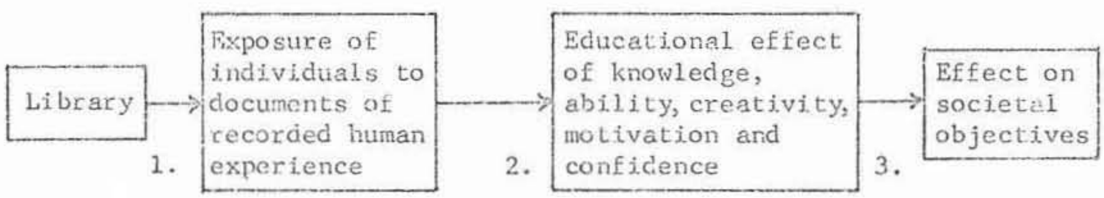
1.2 Formulation of Objectives

Central to the systems approach is the requirement that system objectives be formulated in a manner which can yield quantitative criteria for evaluating alternative policies (Hamburg et al., 1974). This is rarely an easy task for any organization and is almost always aggravated by the existence of conflicting objectives - a good example of which arises in the question of centralization versus decentralisation of a university library: ease of delivery of service may be otpimized at the expense of the provision of a more comprehensive collection and extended opening hours. In fact, special difficulties arise for the university library (Bryan, 1976) because its objectives must be determined in relation to its environment, the major component of which is the parent university.

That is, the university library must be seen for what it is: a component of a considerably larger system whose objectives often appear to be only vaguely defined and, furthermore, subject to rather rapid change (Bryan, 1976), reflected, for example, in the launching of new activities (e.g., wider subject coverage) and the recruitment of staff with new research interests. Such changes place immediate and considerable strain on the library subsystem, which must always strive to provide the best match between its output (governed by its own objectives) and the overall objectives of the university.

Clearly what is needed is a systems approach to the entire problem of university administration, in which due account is taken of the library's resources at any time and the real costs incurred in varying the profile of those resources. In the meantime, university library managers must formulate objectives on the basis of relatively stable components of university policy, and on information received through the formal, and many informal, networks which exist within the university. (One such stable component of policy is presumably the principle that university resources are divided equitably among the members of the university community. In fact, the equitable distribution of resources is a problem of particular interest to the university librarian, who may be required to reveal how purchasing funds are allocated to the different subject areas (e.g., departments) of the university. Nevertheless, this is a topic which receives little attention in the literature of library management (some examples are McGrath, 1975; Gold, 1975; Kohut and Walker, 1975; Clasquin, 1974).)

In a major study reported in Hamburg et al. (1974) and Hamburg et al. (1976) a basis for an operational statement of the library's objectives was arrived at by considering the steps through which information transfer contributes towards society's objectives.



Of the three stages involved, only stage 1 appears to be measurable, and so Hamburg et al. arrived at the lower-level concept of maximizing the exposure of individuals to documents of recorded human experience.

However, this statement is not explicit enough for direct application, so they considered three different explicit formulations:

(1) Exposure count: Each circulation, in-library use, and inter-library loan, is counted as one unit of exposure. Measurement is relatively easily accomplished for recorded exposures, but for unrecorded in-library use, sampling methods must be used to estimate the number of exposures per attendance. The use of exposure - counts as the overall objective to be maximized assumes

that different exposures yield the same benefit. This is clearly not the case.

(2) Item - use - days: A circulation involving exposure during X different days is counted as X item - use - days, rather than as one exposure. Each in - library use is counted as 1 item - use - day. An estimate of the average number of use-days per circulation may be obtained by questioning the user upon return. A typical difficulty with this objective is that browsing exposures to ten different documents in an hour results in ten item - use - days whereas an hour of concentrated exposure to one document results in only one item - use - day.

(3) Exposure time: For recorded exposures, there is a need to estimate, by questioning users, the average amount of time for each exposure type. For in - library (unrecorded) exposures, estimates are required of the average time spent in direct exposure to library materials, per visit.

Hamburg et al. appear to favour the third formulation, and give examples of computations of overall performance measures for the Free Library of Philadelphia.

Once the overall performance measure is chosen, conflicting objectives within the system are resolved by expressing them in terms of the overall objective.

The library is a typical complex system, in that it consists of a number of subsystems, each subject to feed-back control, and each with its own problems of definition of objective and measures of performance.

For example, the classification and cataloguing subsystem receives accessioned material from the acquisition subsystem, and is allocated a man- hour budget for the task of classifying and labelling materials, and generating index material. Conflicting objectives exist: process material as quickly as possible; classify material as accurately and consistently as possible. Accuracy of classification contributes to increased document exposure time by reducing the search - time in the document delivery process; rapid processing, on the other hand, increases exposure time by reducing losses due to delays in the system. The decision model which allocates resources between the two subsystem objectives requires estimates of the marginal rates of exposure-time-increase for each.

Feedback occurs in this subsystem, as information on items previously classified is retrieved from the index as a guide to help settle classification problems (mainly in the interests of consistency). There are numerous examples of such loops within other subsystems. However the library system, as a whole, is dominated by the two major feedback loops illustrated in Figure 1.1.

This diagram illustrates the two major components of library activity:

(1) The labour-intensive service component.

(2) The capital-intensive document provision component.

A major decision problem is to find the best way to divide the total resources between these two components, so as to maximize the overall performance measure.

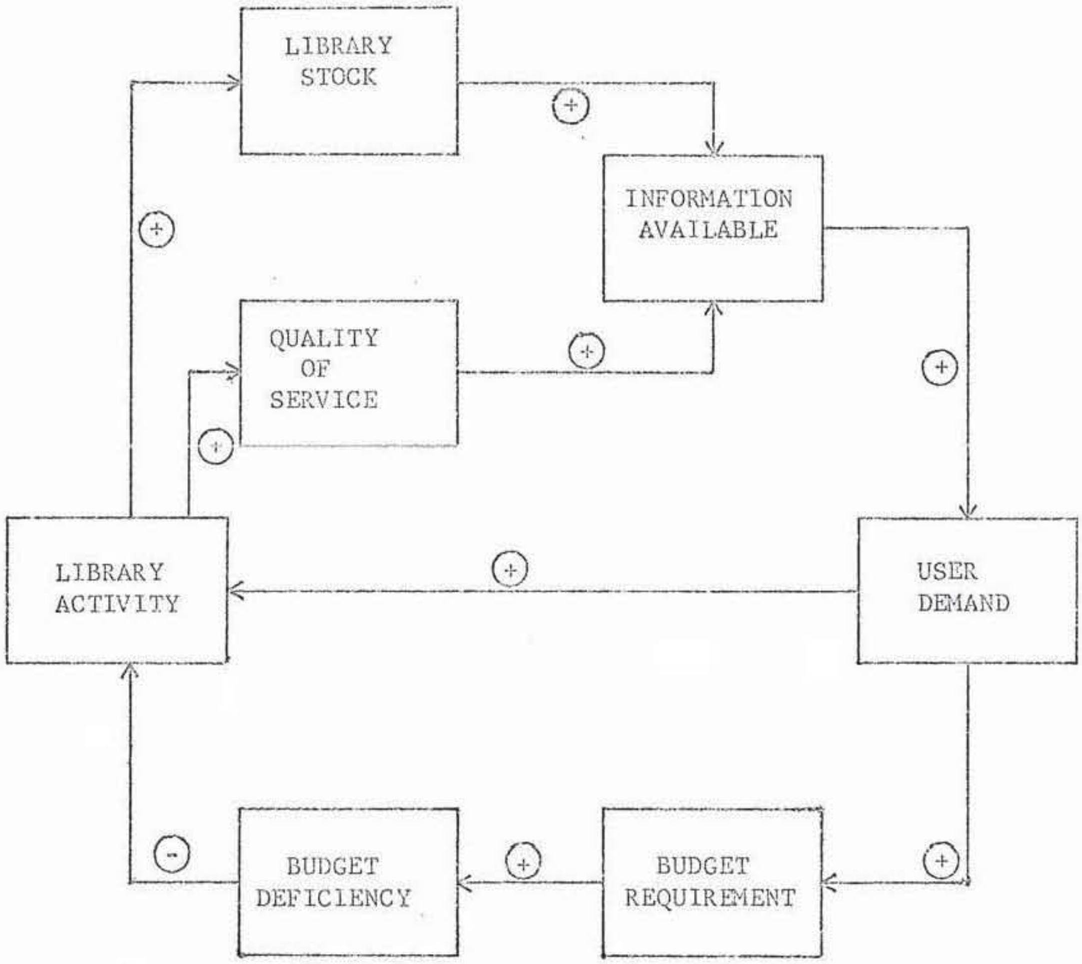


Fig. 1.1

Major Feedback Loops

The diagram also serves to indicate why the proportion of user demand satisfied is not, in general, an appropriate measure of overall performance, although it has in fact been used by many authors (e.g., Morse, 1968; Buckland et al., 1970; Kraft and Hill, 1973). The level of user demand is itself indirectly determined by library activity; hence the proportion of that demand which is satisfied does not in itself provide a suitable basis for the optimal planning of that activity. To quote Routh (1976) - "If a library is providing a minimal service, it may well have a minimal demand, and evaluation based on that demand would allow it to run on in the same stagnant old way.". Thus a library which receives only one (easily satisfied) request per year, because its stock and service are so poor, is 100% effective on this basis, although its operations are evidently far from optimal.

In fact, the actual user demand that is realized is only part of a larger volume of potential user demand that can be defined, at least in principle, by the users' interests and the relevant body of published material. The volume of potential demand is not easily measured from use-studies, although many such studies have been made from which demand patterns have been inferred (Line and Sandison, 1974; Ford, 1973; McGrath, 1975; Jenks, 1976; Urquhart and Schofield, 1972). Such studies are subject to bias determined by the information sources or channels available - readers will often not ask for material which they think the library does not hold (Line and Sandison, 1974) and which are not thought to be relevant enough to justify an inter - library - loan request.

Another performance measure which has received considerable attention is the average document (or information) delivery-time

(Hamburg et al., 1974, p. 19; Holland, 1976). This is clearly a function of both components of the system diagram, and provides some basis for the resolution of conflict, but is in fact too narrow a measure to be appropriate, since it must be supported by additional information regarding those requests which prove impossible to satisfy (such requests would lead to infinite delivery times).

The above discussion seems to support the use of exposure (or usage) counts, or exposure time measurement, to provide an evaluation of overall system performance. They depend on both components of the system diagram, and represent, in fact, the proportion of potential user demand that is realized and then satisfied by library activity.

1.3 System Analysis

The formulation of a useful performance measure and objective function, crucial as it is, merely provides a starting point for an iterative program of system modelling, evaluation and design. The aim is to transform the simple system diagram given above into a useful comprehensive model of the library system.

There are two stages in this procedure. The first involves the traditional methods of industrial engineering, at a fairly low level of sophistication. Subsystem operations are evaluated by costing, work measurement and work study methods (Mackenzie, 1976; Burkhalter, 1968; Turner et al., 1975; Clements, 1975). These studies seek 'tactical' (rather than 'strategic') optimization, and provide input data which are necessary for the application of more sophisticated techniques.

The second stage uses more advanced O.R. techniques such as linear and integer programming (Buckland et al., 1970; Kraft and Hill, 1973; Sinha and Clelland, 1976; Glover and Klingman, 1972); statistical and probabilistic analyses (Morse, 1968; Brookes, 1968; Line and Sandison, 1974); model-building and computer simulation (Buckland et al., 1970; Shaw, 1976; Reed, 1976; Thomas and Robertson, 1975). An extensive review of models and techniques which have been used in such studies is given in Hamburg et al. (1974).

Computer simulation models of industrial organizations are becoming increasingly comprehensive and effective as strategic planning tools (Naylor and Schauland, 1976; Faus, 1974).

Similar attempts are now being made to simulate library systems. For example, Thomas and Robertson (1975) described a GPSS program which performs a discrete simulation of the flow of items through various waiting - line processes. Specified parameters include the number of staff, the volumes of various inputs to the different procedures (e.g., users' requests, new books, issues, overdues, etc.), the individual operations, and the processing times involved. The program reports system performance in terms of delays, queue contents and the average utilization of each member of staff and of each storage facility. Thus their model is concerned only with the mechanics of library operations and is therefore essentially a tool for tactical decision making. There is no attempt reported, at this stage, to compute an overall system performance measure, relative to any stated objective.

1.4 Scope of Succeeding Chapters

In Chapter 2 of the present report, a schematic model of an academic library system is presented, with the aim of illustrating the key decisions and constraints, and some of the interactions among subsystems. Also shown are the likely paths of functional dependence among system parameters and variables.

A major problem in the design of the document-provision component of the library system is that of document selection. The document selection problem has received considerable attention in the literature (see Hamburg et al., 1974, ch. 4, for a review), and some quantitative models have been proposed, for the optimal selection of periodicals (e.g., Glover and Klingman, 1972). This problem has become especially critical in recent years, as "price increases in the serials and journals area have been an alarming and unknown quantity, consistently taking a greater than budgeted portion of funds dedicated to all reading material in a library" (Clasquin, 1974; White, 1976; Kraft and Hill, 1973; Wootton, 1976; Holland, 1976).

White has found that a combination of higher prices, the natural reluctance of librarians to cancel established subscriptions, and the tremendous growth of the volume of periodical literature has resulted in increased spending on serials, and a "drastic reduction in the level of acquisition for books". However, this expedient of shifting spending from books to serials so that decisions regarding the cancellation of subscriptions are avoided, must be temporary. The full impact of budget limitations must eventually hit the serials budget, and librarians will be forced to employ some forms of rational periodical-selection procedures.

This will be a difficult process for those academic librarians who, to quote White, tend "to rate completeness and continuity of collection above actual information use".

In Chapter 3, the subsystem model for serials acquisition is considered in more detail. A simple model of the usage of serials literature is presented, followed by a brief review of current and proposed methods for journal selection. A new mathematical model for journal selection is formulated in Chapter 4, including explicit constraints for the equitable distribution of purchasing among departments. Data requirements for this model are considered in some detail.

In Chapter 5 it is first noted that the journal selection problem is not likely to be solved easily by conventional techniques, because of its size. Instead, advantage is taken of special features of the problem to design a simple heuristic algorithm which efficiently finds a good suboptimal solution. The effectiveness of the algorithm is evaluated by comparing the solutions obtained, with solutions of the relaxed problem in which the equity constraints are not considered. For this latter problem, a recently published algorithm (Nauss, 1976) is coded and found to be quite efficient. A sample problem involving 8 departments and 1320 journals is generated, using the Bradford-Zipf productivity distribution to reflect the main structural feature to be expected in a real data set.

Results are obtained for the performance of the algorithms on this sample problem.

CHAPTER 2

THE UNIVERSITY LIBRARY SYSTEM

2.1 The Library and Its Environment

The environment of an academic library comprises the rest of the university, the set of published material which is relevant to the objectives of the university, and a network of co-operating libraries. The university's objectives define the users' interests (or vice versa) and these, together with the body of published materials, determine a volume of potential demand. This potential demand is defined in terms of the set of all documents which the library might legitimately be called upon to supply to users in pursuit of the university's objectives.

Figure 2.1 illustrates the interaction of the library with its environment. Library activity, constrained by a budget, influences the realization of potential demand, and determines the level of satisfaction of that demand, resulting in a degree of document exposure which measures the overall performance of the system. At the same time, the volume and character of potential demand (to the extent that it can be ascertained) and of realized demand (to the extent that it can be measured) influences - in fact, should determine, within the budget limitation - the planning of library activity.

The management problem is to allocate the limited budget among the various library activities so that document exposure is maximized, subject to equity constraints.

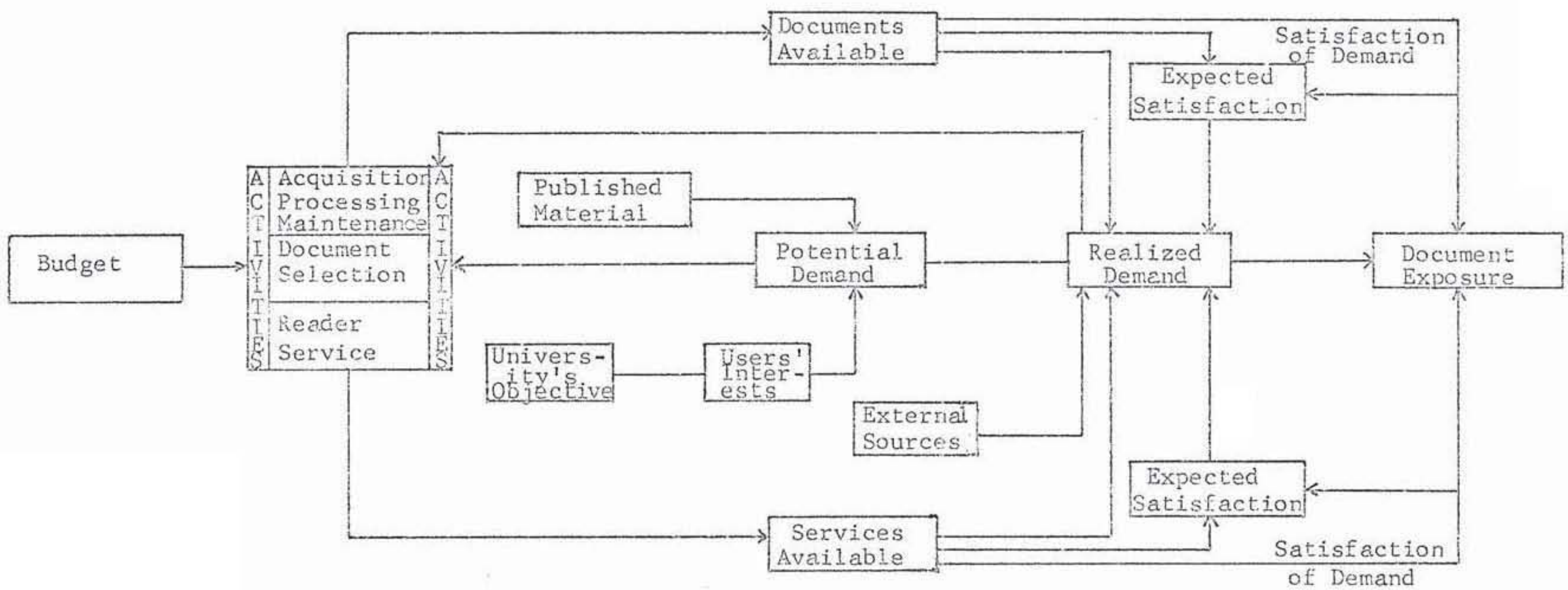


Fig. 2.1

The University Library System and Environment

The value of this conceptual model lies in its broad definition of paths which determine the ultimate contribution to document exposure, resulting from each activity. However, substantial and challenging measurement difficulties must be overcome before the model will become a useful tool for decision making.

Chief among these are:

(1) Measurement and characterization of potential demand (dependent on a definition of users' interests).

(2) Measurement of the level of "user initiative", as it contributes to the proportion of potential demand that is actually realized.

(3) Estimation of the importance of the marketing and promotion links (via "expected satisfaction"). That is, the extent to which users' knowledge of and past experience with the library's resources influence the realization of demand.

(4) Measuring the impact of personal service and attention in terms of the document exposure rate.

Also required are decision models which translate potential and realized demand into document selection policies.

Hamburg et al. (1974, p.60; 1976) subdivide library activity into seventeen non - overlapping functions, such as: provision of user furnishings; selection of documents and indexes; acquisition of documents and indexes; facilitation of access to documents in other libraries; personal assistance for document identification and location. They propose a Planning - Programming - Budgeting - System approach to determine the optimal allocation of resources to these functions. The functions must be mutually exclusive and exhaustive, and it must be possible to identify and isolate the input and output of each function. They present a program structure for an academic library, which they consider to meet these requirements. Diminishing returns apply to the benefit - cost curves of each of the n functions, and an optimal allocation is achieved when

$$\frac{\Delta E_1}{\Delta C_1} = \frac{\Delta E_2}{\Delta C_2} = \ldots = \frac{\Delta E_n}{\Delta C_n},$$

where ΔE_i is the increment in document exposure resulting from an increment ΔC_i in resources input to the ith function.

However there must be some doubt concerning the general ability to define functions which are truly independent, in the above sense. If increase in input to the ith program causes an increase in the overall efficiency of the jth program, the above condition on marginal return does not necessarily imply optimality. For example, the acquisition of a larger range of indexes could increase the efficiency of personal efforts to assist in document identification and location, and the efficiency of efforts to facilitate access to documents in other libraries.

An alternative approach would be to construct interlocking system models of different areas of library activity. In the following sections are presented schematic models of monograph acquisitions and processing; serials acquisitions, processing and binding; circulation, in - library use and housekeeping; inter - library loans. The information, planning and administration sub-systems are discussed in considerable detail in Hamburg et al. (1974), and are therefore not included here.

No claim is made for the completeness of these models. They are meant to provide only a starting point for a more detailed discussion.

2.2 Monograph Acquisition and Processing

This subsystem is represented in Figure 2.2, in which an arrow from A to B indicates that the value of B is at least partially determined by the value of A. Arrows passing through the diagram 'valves' such as the one labelled 'Order Placement Rate', represent flows of materials or information. In addition to the physical input of new books, the subsystem receives information inputs which are of two types:

(a) Inputs from outside the library system:

Potential demand;

Users' requests;

Awareness;

Ordering conditions imposed by suppliers;

Expected delivery delay (lead time);

Actual prices of items;

Currency exchange rates;

Level of original classification required;

(b) Direct output of managerial decisions:

Monograph selection policy (including serials back-sets);

Classification system to be used;

Monograph purchasing budget;

Staff budget allocation;

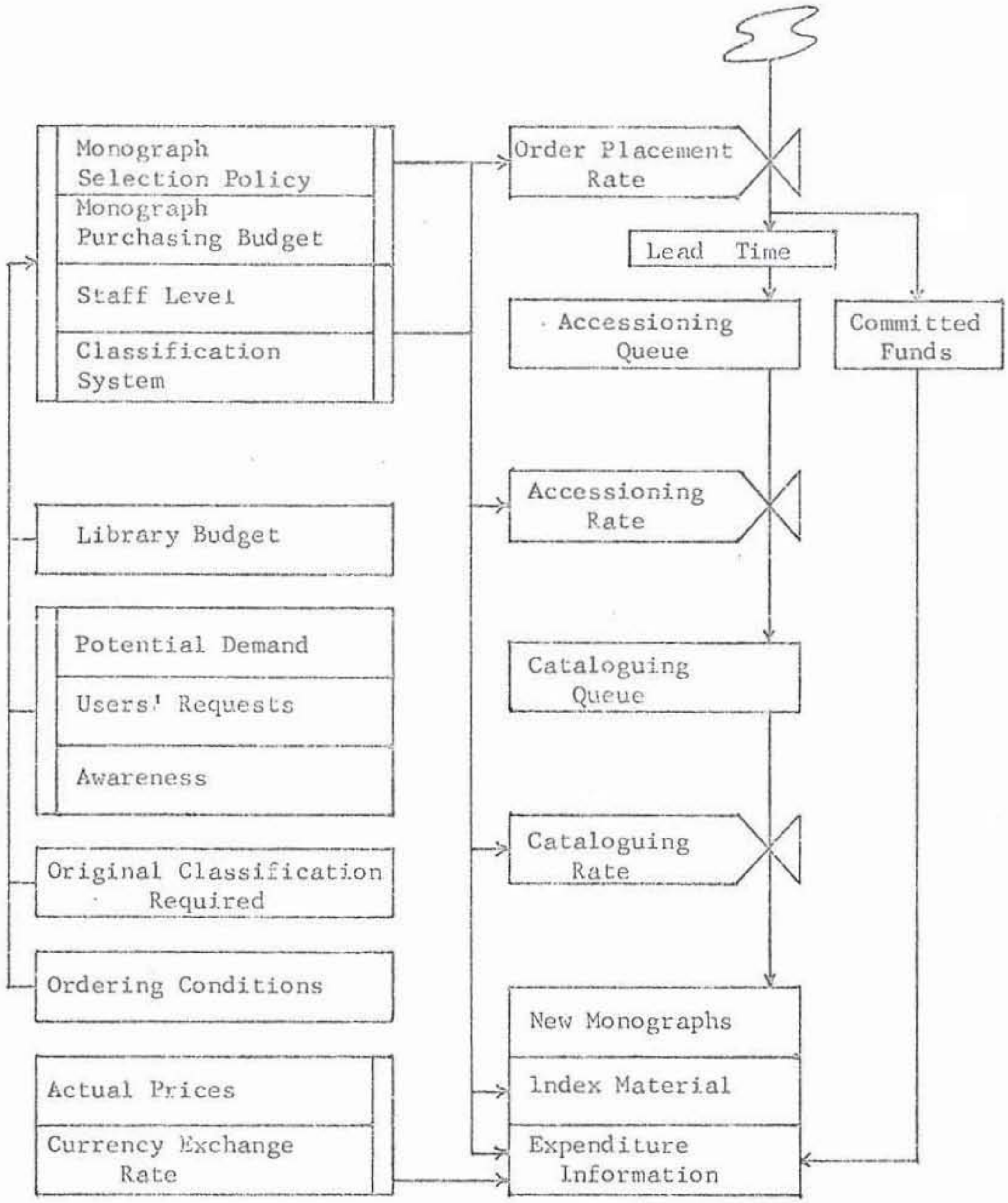


Fig. 2.2

Monograph Acquisition and Processing

Outputs of the subsystem are:

Processed books, sent to the monograph collection (or to Serials);

Index material;

Information regarding expenditure (staff and purchasing), price trends, etc.

2.3 Serials Acquisition, Processing and Binding

Major inputs to this subsystem, depicted in Figure 2.3, are:

(a) Information inputs from outside the library system:

Potential demand;

Users' requests;

Projected costs of serials subscriptions;

Actual subscription prices;

Currency exchange rates;

Conditions of agreements with suppliers;

(b) Information from other areas of the library:

Inter - library loan records;

Mutilation and loss information;

(c) Direct output of management decisions:

Serials subscription budget;

Serials selection policy;

Binding policy;

Staff budget allocation;

Bindery establishment.

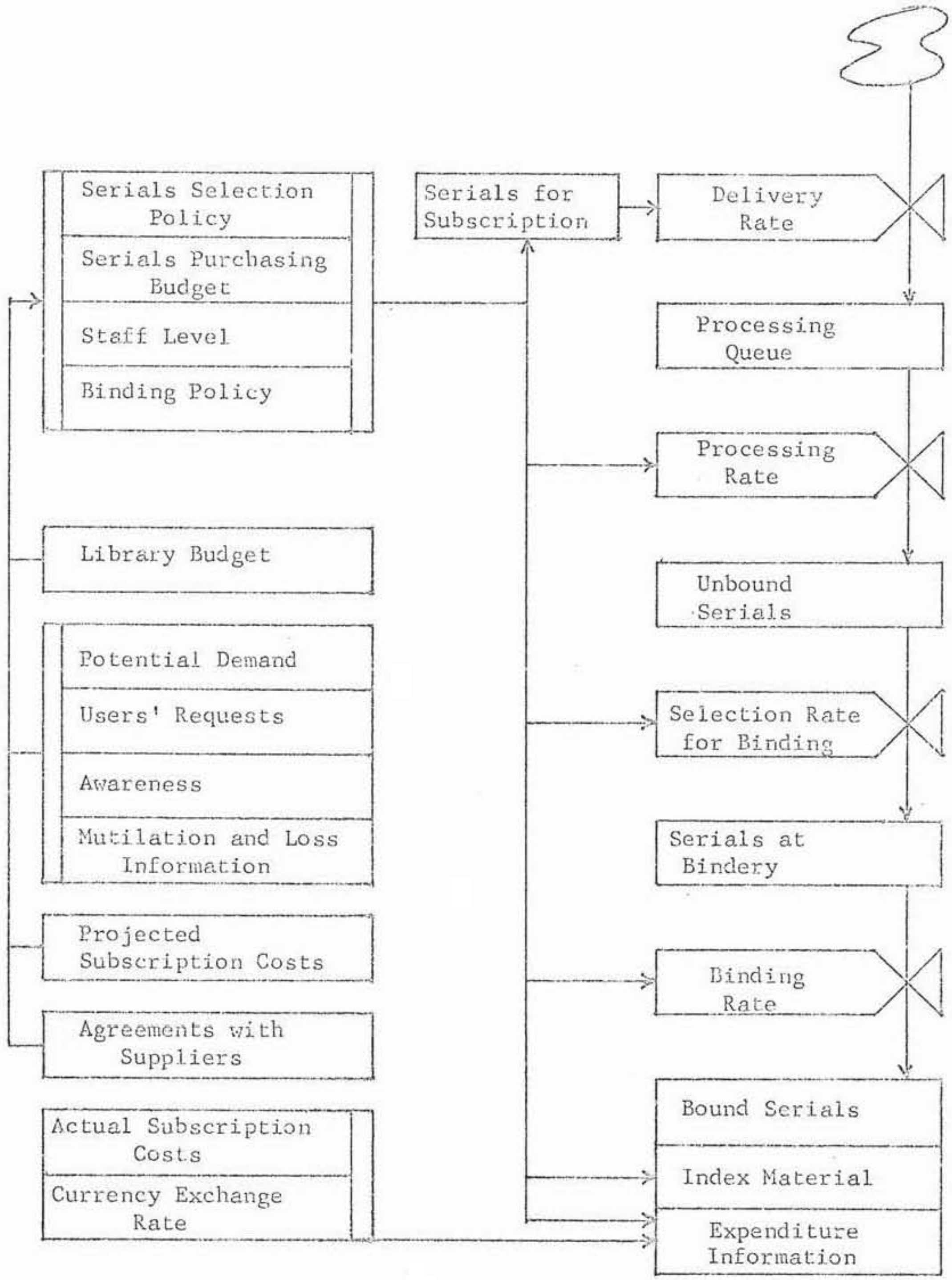


Fig. 2.3

Serials Acquisition, Processing and Binding

Outputs of the subsystem are:

Bound and unbound serials;

Index information;

Information regarding expenditure (Staff and Purchasing), price trends, etc.

2.4 Circulation, In - Library Use and Housekeeping

Figure 2.4 attempts to illustrate the three main factors involved in the direct satisfaction of demand:

(1) The contents of the collection (determined by document selection policies);

(2) The level of service provided by circulation staff in maintaining the flow of book materials in and out of the library;

(3) The effectiveness of housekeeping staff in maintaining order on the shelves, and a low proportion of unshelved books.

Inputs to this subsystem are:

(a) Physical inputs:

The collection and index;

Shelving accommodation;

Seating, etc.;

New books from cataloguing and processing;

Items returned from loan.

(b) Inputs from outside the library system:

Realized demand for borrowing material and for in - library use;

Default rate on loan returns;

Authority over borrowers (e.g., imposition of fines).

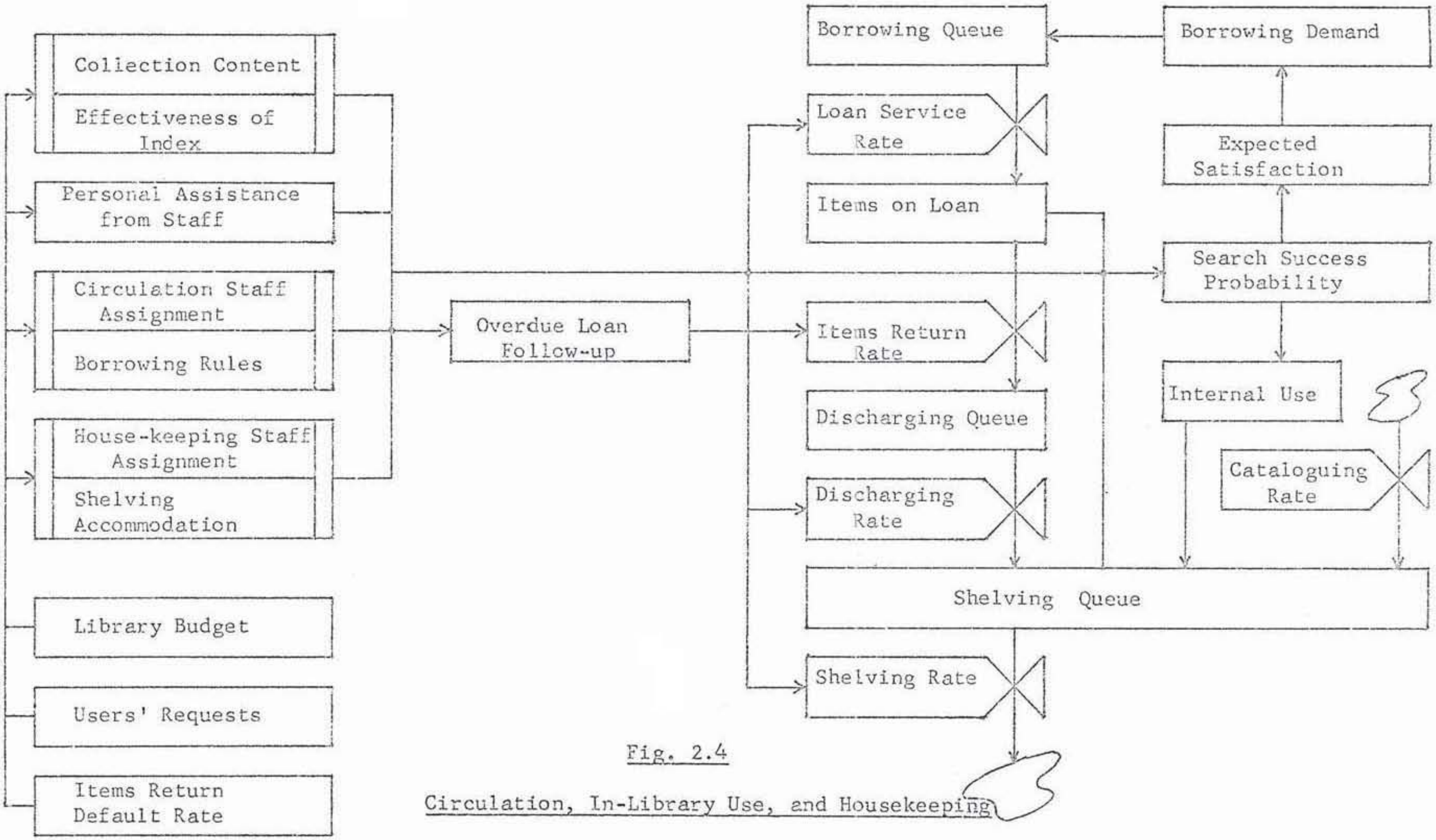


Fig. 2.4

Circulation, In-Library Use, and Housekeeping

(c) Output of management decisions:

Staff budget allocation;

Arrangement of stock and furniture;

Loan period and other borrowing regulations;

Assignment of housekeeping staff.

Each demand realized by the library implies a search for materials, the success of which depends on what the collection holds; on the effectiveness and efficiency of the index; on the availability of assistance from experienced staff; on the state of order of the shelves; on the proportion of books which are effectively unavailable because they are either on loan, unshelved or lost.

The realization of demand is influenced by the users' expectation of satisfaction, based on past experience (i.e., on the rate of satisfaction of demand) and by the users' awareness of library stocks.

Output of this subsystem are:

Document exposure;

Circulation and usage information;

Information regarding demand, the state of the collection (e.g., maintenance requirements), and expenditure (staff).

2.5 Inter - Library Loans

Of the total demand realized by the library system, a proportion cannot be satisfied directly, and may result in demands for inter - library borrowing. The translation of direct demand into inter - library demand depends on the expected importance of the item required, and on the users' expectation of satisfaction.

Quite often, an important feature of "satisfaction" is the speed with which the item can be obtained. Hence the probability of success is influenced by the rate at which I.L.L. staff can service requests (i.e., translate requests into orders placed elsewhere), and also by the response time of co-operating libraries. Other factors influencing the success rate are the resources of the I.L.L. subsystem (indexes, location guides, etc.) and the nature of the library network.

The subsystem is represented in Figure 2.5. Inputs to the system include:

(a) From outside the library system:

Demand which cannot be satisfied directly;

The library network and borrowing conditions;

(b) Output of management decisions:

Staff budget allocation;

Regulations for the use of inter - library loan materials;

(c) Physical:

Resources (determined by document selection policies).

Output of the subsystem include:

Document exposure;

Information regarding demand;

Information regarding expenditure (staff, communication, postage).

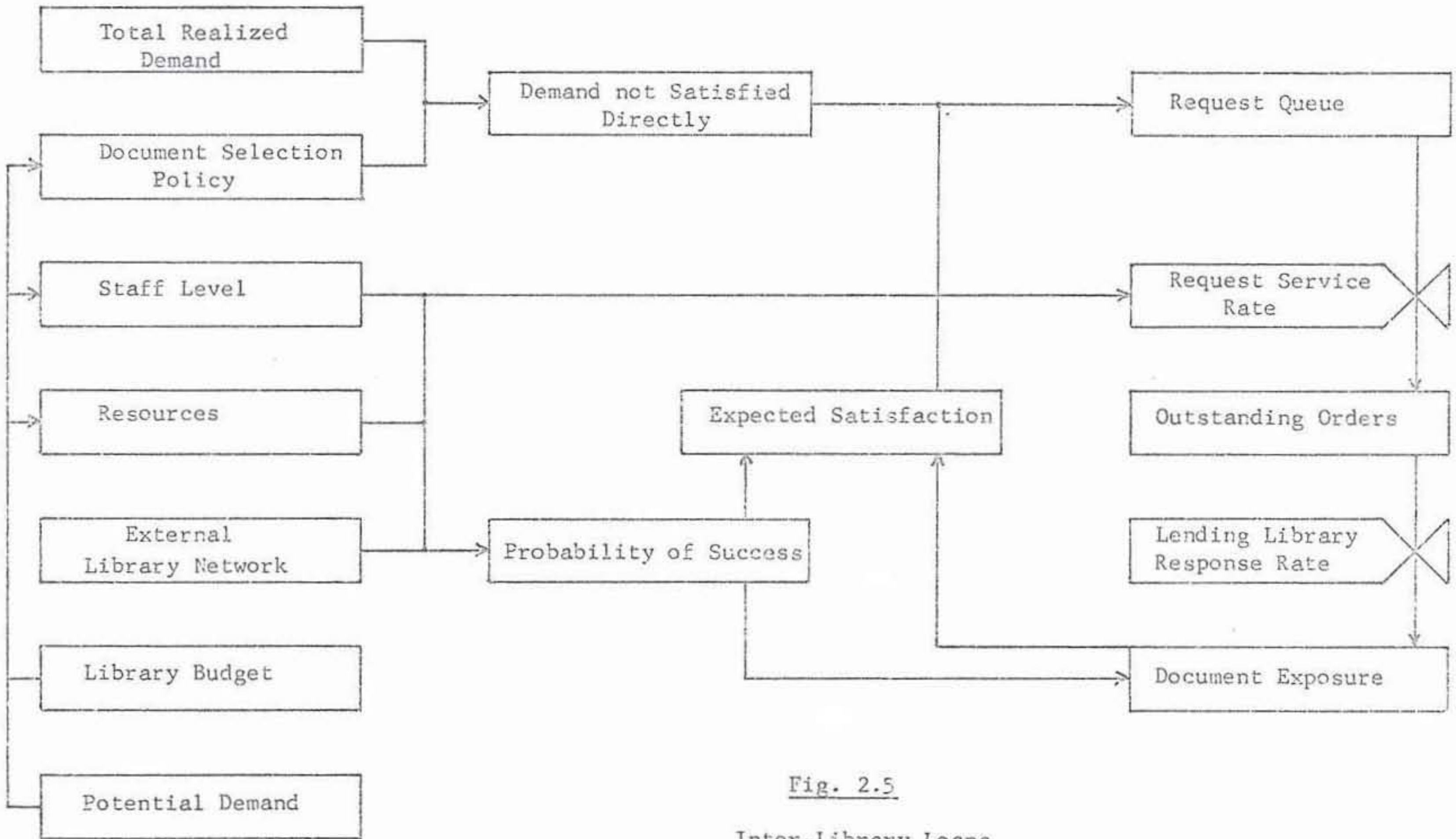


Fig. 2.5

Inter-Library Loans

Another function of this subsystem (not illustrated here) is to respond to requests from other libraries. The nature and level of this effort depends on external factors as well as on the library's holdings, and can vary widely between libraries.

2.6 Reference and Reader Service

The reference and general reader - service subsystem contributes to the document exposure rate in several ways:

(1) By assisting users in the search process, and instructing them in search techniques.

(2) Indirectly, by locating and communicating information in response to users' queries.

(3) By providing, maintaining, and supervising the use of special equipment such as photocopying machines and microform readers and printers.

Because of the highly personal nature of much of this work, finding ways to estimate the magnitude of these contributions in terms of document exposure presents a particularly difficult measurement problem. Of course, the area of the library - user interface has traditionally been a difficult one for library managers trying to develop measures of performance. It is not surprising that some authors (e.g. Hoos, 1976) see a fundamental limitation to the appropriateness of the techniques of systems analysis in the so - called 'soft' areas of social organizations.

However, there is no necessity for the systems analyst to abandon traditional approaches based on the intuition and experience of professional workers in the area of concern. And there is no fundamental reason why estimates and rules-of-thumb based on those approaches cannot be included even in highly sophisticated computer simulation models.

CHAPTER 3

SERIALS ACQUISITION

3.1 Introduction

Two decision problems are central to the design of the serials acquisition and processing subsystem (Figure 2.3):-

(1) The selection of the set of serials to be received, either by subscription, as gifts, or on exchange;

(2) The determination of a binding and discarding policy.

Subsidiary decisions are concerned with optimization of the subsystem operations, using whatever means are appropriate (e.g. costing, work study, simulation).

Decision making in the major areas is constrained by the following budget allocations:-

(a) Serials subscription budget. ('Subscription' is taken to include the cost to the library of items despatched in accordance with exchange agreements);

(b) Staff budget allocation to serials acquisition and processing (excluding bindery staff);

(c) The bindery equipment establishment;

(d) The staff budget allocated to the bindery;

(e) Storage.

So far as decision making within the acquisition subsystem is concerned, an overall budget may be taken as being prescribed, as a result of an overall strategy of decision making for the library system.

3.2 Simplified Model of Serials Usage

Referring to figure 2.1, the 'potential demand' at time t for exposure to serials literature is defined in terms of the set $R(t)$ of articles which the library can legitimately be called on to supply. An article belongs to this set if it achieves at least a minimum level of relevance to university objectives, as defined (in no very precise manner) by a subject interest profile.

At time t, the serials collection contains $n(t)$ articles which belong to $R(t)$. Each of these articles represents a potential contribution to document exposure which may be realized at some time in the future. There is no possibility of defining these contributions for individual articles. Furthermore, there are no grounds for believing that the average contribution per article would vary between subject areas. Therefore we consider an average value e for the contribution per article, a value which is assumed independent of time. Then the total potential document exposure time represented by the collection at time t is given by the product $en(t)$.

However the full potential of the collection will not be realized, because some articles become lost or mutilated, while others are transferred out of $R(t)$ before being accessed by any user, for reasons of 'obsolescence'.

Firstly if one accepts the concept of obsolescence (Line and Sandison, 1974) due to progress in the subject, then a contribution to the obsolescence rate will exist which we can expect to vary between subject areas.

Secondly, the subject profile of the university is not static, so that some articles will become obsolescent to the library's users merely because of a change in their interests. This contribution to the obsolescence rate may be assumed to be the same for all subject areas. At the same time, such changes in interests will cause some articles to move into $R(t)$, hence tending to increase the potential of the collection.

Therefore the document exposure that actually occurs depends on the rate at which demand is realized, the overall obsolescence rate, and the length of time for which each article is held before being discarded.

The demand realization rate is dependent on a number of factors.

For example: The level of activity of users;

The effectiveness of 'awareness' services, including current awareness, indexing and abstracting tools;

Expectations of satisfaction;

The quantity of material placed in closed stacks.

In general, both the obsolescence rate and the demand realization rate are dependent on subject areas. As a result, the total realized document exposure time in a given subject area (i.e. for a given university department) will be reduced from its full potential by an 'exposure realization' factor which is characteristic of the department.

Values for 'obsolescence' rates have been inferred by a number of authors, from the results of usage studies (e.g., Sinha and Clelland, 1976). Many such results have been criticised by Line and Sandison (1975, 1974) for a lack of attention to the sampling difficulties involved. As discussed by Line and Sandison, severe problems are involved in identifying and separating the various factors that contribute to a decline in recorded usage with age. Synchronous studies, in which the usage of a set of items of varying ages is studied over a short period (e.g., one year) can be particularly misleading. Also, there is one obvious factor which does not seem to have been mentioned at all: once the information content of a journal volume has been extracted and studied by the limited number of users requiring it, that volume is unlikely to receive significant use again.

Defining the manner in which the various factors combine to influence the rate at which demand is realized remains a central problem in the management of these factors to achieve higher overall performance. The construction of a valid model of these processes will require intensive research into user behaviour. Such research can be very expensive and it will be necessary at the outset to try to assess the possible impact of the results, in relation to the costs involved. Such an assessment is beyond the scope of the present work.

3.3 Journal Selection

The journal selection problem requires the allocation of a limited budget over a candidate set of N journals, with the aim of maximizing the total expected document exposure time, subject to equity constraints.

The problem is a large one in terms of the number of decision variables. The candidate set ideally contains all scholarly and research journals in current production. The size of this set depends on how stringent are the criteria used to determine membership. For example, White (1976) identified 2459 U.S. journals in 1973 (in all subject areas), "a group smaller than earlier estimates", while 50,000 "worthwhile" titles in science and technology were estimated in 1975 by Wootton (1976). However, a large proportion of titles will not be relevant to a given university's interests, and will therefore not enter the candidate set. Nevertheless, a decision problem involving several thousand variables can be expected.

Models which have been proposed for the solution of the problem are summarized in Hamburg et al. (1974). Two steps are involved:

(1) Finding a measure of worth for each title;

(2) Formulating and solving the decision problem.

Measures of worth are almost always based on some idea of the productivity of a title in subject areas of relevance to the university's interests: i.e., the number of relevant articles published each year in each journal. A different, but related measure is total expected usage or demand (Kraft and Hill, 1973). The difficulties of measuring usage to provide input data have already been discussed.

Much of the theoretical work makes use of an early finding of Bradford (1948), elaborated since then by various authors (e.g. Brookes (1968), Leimkuhler (1967)), which defines the distribution of productivity among journals in a given subject area. Analytical representations of the distribution have been found, expressing, for example, the cumulative sum of articles, $R(n)$, in the n most productive journals. Use is also commonly made of an assumption of exponential decay of journal usage or demand, with time. The truth of this assumption has been seriously questioned by Line and Sandison.

Typical results are those of Cole (1963) and of Buckland et al. (1970, 1968). Cole represents unsatisfied demand as a function of the number of journals held, N (i.e., the first N journals of the Bradford ranked distribution), and the number of years they are retained (X). For a given space constraint on the number of journal volumes a library can hold, Cole determined the values of N and X that minimize unsatisfied demand. Buckland et al. extend Cole's work, and find the strategy that obtains the greatest number of useful references (demand satisfaction) per purchase and storage dollar. However some very restrictive assumptions are made. For example: there is only one subject field of interest (The Bradford distribution applies only to well-defined subject areas (Brookes, 1969)); titles do not differ significantly with respect to purchase price; binding policies are the same for all journals.

More recent work based on the ranking of journals is that of Robertson and Hensman (1975), who discuss productivity ranking, precision ranking (according to the proportion of all items in a journal that are relevant) and cost - effectiveness ranking (according to the number of relevant articles per unit cost).

None of the approaches discussed so far is capable of deriving an optimal policy, for a prescribed budget.

A more sophisticated approach has been formulated by Kraft and Hill (1973) and developed more fully by Glover and Klingman (1972). Journal selection is formulated as a Diophantine programming problem in zero - one variables.

The main feature of this approach is that it attempts to optimize decisions over a prescribed planning horizon of r subscription - periods. The decision variables are

$$X_{jpq}, \quad (j = 1, \ldots, N; \quad q = 0, 1, \ldots, r; \quad p = 0, 1, \ldots, q),$$

where $X_{jpq} = 1$ if the volume of journal j, published in period p, is acquired in period q; and $X_{jpq} = 0$ otherwise.
The constraint

$$\sum_{q \geqq p} X_{jpq} \leqq 1, \quad \text{all } j, p$$

is required to ensure that a journal volume is acquired only once. There are in addition several budget constraints, one for each of the r periods, in which subscription, processing, replacement, binding and storage costs are all lumped together. There is no attempt to take account of equity requirements. All journal volumes are assumed to be bound at some stage.

The major difficulty of this approach lies in the size of the problem in terms of the number of decision variables, and the number of data elements needed. For example, for the formulation of Kraft and Hill, a problem with N candidate journals and r subscription periods, would require $\frac{N(r+1)(r+2)}{2}$ decision variables and $\frac{N(r+1)^2(r+2)}{2}$ data elements (plus budget specifications). Thus, if $N = 2000$ and $r = 5$, there would be 42,000 decision variables and 252,000 data elements.

It seems clear that this formulation will be of value only for narrow selection problems involving small numbers of candidate journals. For example, the problem of distributing a budget increase, for the addition of new serials titles to an established collection.

Finally it should be noted that the foregoing work has been applicable only to the selection of 'primary' literature (i.e., articles, etc.). Although considerable work (e.g., Martyn, 1967) has been done on delineating the literature coverage provided by various 'secondary' publications (current awareness, indexing, and abstracting tools), no quantitative models are available for the optimal selection of secondary periodicals.