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ABSTRACT

The application of systems engineering and operations research to the problems of libraries has developed quite strongly during the past five years. The purpose of this paper is to draw attention to this relatively new area. There are serious problems of applying systems engineering to libraries. This is to be expected in the case of a non-profit-making situation where the end product is an intellectual rather than a physical one. Furthermore, although librarians do commonly have an academic orientation, this is usually in the humanities rather than science or engineering. This is quite clearly reflected in library research which commonly includes substantial data collection but no models or hypotheses. Nevertheless, the past few years have seen a significant development in the application of systems engineering to library problems. The achievement, though real, is still quite limited--especially where the behavioral aspects of library use are concerned. There is, in library systems engineering, a need and a challenge. (Author/SJ)

LIBRARY SYSTEMS ENGINEERING: AN INTRODUCTION

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The application of systems engineering and operations research to the problems of libraries has developed quite strongly during the past five years or so. The purpose of this paper is to draw attention to this relatively new area. Some examples of recent work will be used as illustrations.

Research and development has developed rather unevenly in librarianship. The traditional emphasis of research by librarians has not, in fact, been on libraries at all but on books. There is a significant difference. Enormous amounts of very scholarly work have been done on bibliographical matters: the history of printing, of book production and the analysis of literary texts. This can, and has, been accompanied by a neglect of libraries as systems.

However, some of the areas of investigation have been approached and regarded as systems. For example, the systematic organization of knowledge—the classification and arrangements of subjects—has been of interest at least since medieval times. The Dewey Decimal Classification scheme is a well-known nineteenth century specimen of this.

Another example of a system in this area is the dynamic interaction between authors as evidenced by the way they cite and refer to each other's publications. The popularity of this bibliometric analysis may stem in part from the convenient availability of the raw data: the citations at the ends of books, reports and papers. The study of the history of science and of communications has drawn heavily on statistical analysis and network studies of this kind.

The problems of organizing, controlling, updating, and monitoring encyclopedias and library catalogs are, in a significant sense, systems problems.(1)

One further area, sometimes referred to as "systems work" is the introduction of computer-based data processing to help handle the very considerable amount of record processing involved in running a library: order records for book purchasing; catalog records of the collections; circulation records of borrowings; and so on. This is an active area with a substantial literature.(2)

Visionaries have even foreseen libraries without books—an electronic "pro-cognitive system" whereby the individual researcher can communicate with all

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LI 003 906

recorded wisdom from his or her desk-top console.(3) Such advanced systems are very unrealistic in the near or medium future. The problems lie not in the computer hardware but in the sheer intellectual problems of handling subject concepts and the interrelationships between concepts—both of which are often difficult to define in binary terms. This is a problem which is shared with Machine Translations research. In practice successful computerization has been in the humbler areas of handling libraries' administrative records.

Much of the professional training and daily activities of librarians is concerned with the design, creation, and manipulation of files of one kind or another, but this is only one aspect of the provision and use of library services. In this paper we wish to restrict our attention to the direct study of libraries as systems. That is to say, taking the library service and users, in the broadest sense, and examining the planning and managerial problems arising from the interactions between books, journals, space, facilities, library staff and the users with their often vague or conflicting requirements.

Library systems engineering in this broader sense has been slow in developing for a variety of reasons.

1. A library service shares several awkward features of non-profit-making support services. There is no convenient output—like profit. Instead, different classes of patrons with different needs and varying information-gathering habits use documents with obscure consequences and no payment. The whole area is bedevilled by uncertainties. There are practical problems of knowing what people actually do in libraries—or would do if information were not provided—and how library use fits in with alternative sources of information. There are also problems which derive from being a support service which has to adapt to the organization being served. Universities, in particular, can develop haphazardly and the librarian may find it difficult to learn what is happening; let alone relate his services to it. Changes in the range of subjects studied or in the methods of teaching have very important implications for library planning. For example, the trend from traditional lecturing to seminar, to audio-tutorial, or to project-oriented teaching is placing a substantial strain on library services. Furthermore there are likely to be unresolved conflicts of interest and priorities. The scientist may want more journals, the historian may want more archival materials and the student may want more generous provision of duplicate copies of heavily-used titles. It is clear that these complexities make library systems engineering a distinctly nontrivial area.
2. A second difficulty is that until recently very little operations research or systems engineering had been done. Systems Engineers and Operations Researchers do not seem to have shown much interest in the area and the orientations and training of librarians have not been conducive to this type of work. Recent papers have reviewed problems(4) and also progress.(5) Progress in this field is likely to be gradual.

### THREE EXAMPLES

Having discussed the reasons why library systems engineering has been slow to develop, we now propose to summarize three pieces of work by way of illustration.

#### Book Storage Models (6-9)

It is appropriate to start by drawing attention to the work conducted at Purdue in the Schools of Engineering under the direction of Professor F. F. Leimkuhler of the School of Industrial Engineering. One major element in this program has been to explore the economics of physically storing large collections of books and journals. The continuing exponential increase in publication makes this an important problem.

In particular Leimkuhler has examined the problem of two-stage storage systems in which there is an area of primary storage and also a secondary storage to which books are "retired." This needs to be planned with regard not only to the costs of storage which will be lower in the secondary store but also the cost of retrieval which will be higher in the secondary store.

The problem is at least two-fold:

- a. What proportion of the collection should be relegated to secondary storage?
- b. Upon what decision rules should titles be selected for secondary storage?

Some titles are used more frequently than others. Statistical analyses show quite regular patterns in the distribution of demand for books and journals.(10)

- i. There is a well-documented tendency for use to fall off with age—an exponential decay.
- ii. For any given topic, some of the relevant literature will be concentrated in a few key titles, some will be in related titles and some will be widely scattered over a very wide range of titles. This distribution of frequencies is known as Bradford's Law of scattering after the Librarian of the Science Museum in London who first noticed it in the library context. It is related to Zepf's law and other distributions.

The consequence of modeling these two aspects of the distribution of demand is that it permits an analysis of the storage system in terms of the amount of demand which would be effected by the transfer of given proportions of the documents to secondary storage by given decision rules.

This is a topic of major importance because libraries fall naturally into hierarchical structures. How far should research libraries attempt to maximize the range of titles held locally? How far should they plan to economize by maintaining relatively small and selective collections locally and rely on less accessible back-up facilities? In Great Britain the National Lending Library for Science and Technology is a national back-up resource for all scientific and technical libraries.

A related problem is that of compact storage whereby books are sorted by height, saving space at the expense of convenience. The main criticism of work on storage systems is that it is incomplete. The effect of reduced accessibility on users is a major factor and it is not yet understood.

#### Development of an Adaptive Loan and Duplication Policy for a University Library (11-13)

A leading center of library systems engineering is the University of Lancaster Library Research Unit at Lancaster, England. Towards the end of 1968, the Librarian was concerned because of complaints that library materials were often not available. He initiated a study and instructed the team to analyze the problem, to formulate alternative methods of increasing document availability, to evaluate these methods and, if possible, to make recommendations.

Two key variables were isolated:

- the length of loan periods for borrowing, and
- the policy concerning the purchase of additional copies.

The study team concentrated on these factors because they were known to be important and because they were more directly under the control of the librarian than other variables. The team was faced with numerous uncertainties about the importance of high availability, about conflicting opinions concerning the allocation of resources and about the development of the pattern of teaching and research in the university. There was a very urgent time constraint and so the aim was to produce an immediate remedy to the problem of low availability and also the basis for an adaptive collection control system such that the library's service would be more responsive to the changing influences upon it in the future.

Analysis of the problem resulted in a Monte Carlo simulation of the way patrons use libraries. This gave a quantitative insight into the relationships for any given title between:

1. level of demand;
2. loan period;
3. number of copies held;
4. probability that a copy will be available when sought.

Meanwhile data collection from libraries with differing loan policies indicated that there is a very strong tendency for books to be returned or renewed at the expiration of the official loan period. Furthermore, the proportion of loans which are renewed at the end of the loan period varies little over a range of loan periods. These results implied that the librarian's ability to establish the length of the permitted borrowing period is an effective control device over the length of time books are absent from the shelves. The data also permitted the estimation from official loan policies of the actual borrowing patterns. They also imply that the use made of documents does not seem to increase proportionally with longer loan periods.

Since the development of a fully satisfactory single index of performance for a library system would be a complex and nearly impossible task, two simpler, proximate measures were used.

1. Satisfaction level: in a given time-period the proportion of demands on the library which could be immediately satisfied;
2. Collection bias: a measure of the suitability of the collection for browsing, based on the extent to which the collection available to the browser tends to be biased towards the less popular material since the more popular titles will tend to be on loan.

Subject to constraints, a good library will have high "satisfaction level" and a low "collection bias." Various policies were evaluated in these terms. They included:

- a. A single, but shorter, loan period
- b. Selective duplication of stock
- c. Different loan periods based on type of borrower
- d. Different loan periods based on book popularity
- e. Combined systems.

On the basis of the cost-effectiveness as estimated by the Monte Carlo simulation, a new loan and duplication policy was implemented. This was a three tier whereby individual books were ascribed to one of three loan periods according to the level of demand for them. The three loan periods were:

- a. Short loan            4 hours
- b. Popular loan        1 week
- c. Long loan            Until the end of term

Allocation of books to these loan categories and also signals for the acquisition of duplicate copies now derive from a new process of monitoring book usage—mainly on the basis of examining the number of dates on date-due labels. Because these decisions are based on actual usage, the library provision adapts continuously to maintain standards of service in the face of changing patterns of demand and far more feedback is available than before. (See Figure 1.)



## C O N S T R A I N T S

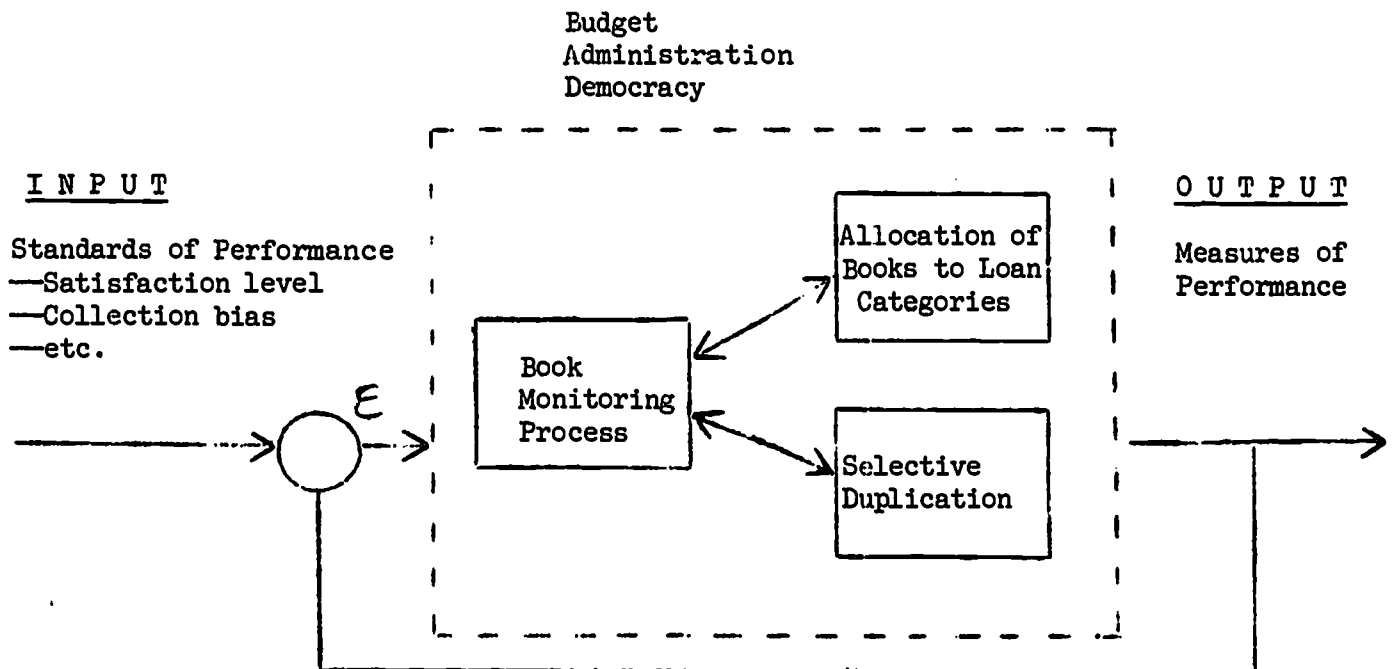


Figure 1. The Lancaster Loan and Duplication System

From Hindle and Buckland

The results of implementation were unexpected and dramatic. Borrowing increased dramatically and, after two years, has tripled. This was more than could be accounted for by the predicted increase in availability or by the increase in student numbers. It is possible that increased availability resulted in a perceived increase in success in use of the library and that this is a positive reinforcement for further use.

### A Library Management Game (14-15)

Reference has already been made to the complexity of library problems. Not only are there many uncertainties but there are many interactions which are poorly understood. These considerations encouraged the Lancaster Library Research Unit to experiment by using simulations of library systems to improve libraries in an indirect manner. In addition to attempting operational studies designed to tackle identified problems in specific libraries, they have developed a library management game based on the simulations mentioned in the previous example. The idea is to induce a more highly developed concept of the library as a complex interactive system into the training of professional librarians. The

rationale is that this would foster a more systems-oriented approach inside library administration.

In March 1972, a small group of senior library administrators and library educators were assembled in Morecambe, England. They were divided into small teams and given a quite specific task. They were told that they had just been appointed director of an imaginary library and that they had precisely thirty-six hours to prepare a five-year plan for the library including policies and budget. Any increase in budget would have to be justified in writing and verbally in terms of improved service to a skeptical library committee.

The range of policies was in fact limited to:

1. Loan policies;
2. Duplication policies;
3. Increases in range of titles held.

The participants were provided with data on their imaginary library and a selection of measures of performance were suggested:

- a. Amount of borrowing;
- b. Satisfaction level (previously defined);
- c. Collection bias (previously defined);
- d. Amount of reading;
- e. Costs.

Their task was:

- to grasp the structure of the problem both qualitatively and, as far as possible, quantitatively;
- to decide on the relative weighting to be given to the various different measures of performance;
- to determine the most effective combination of policies for improving the library service; and
- to describe and justify their chosen policies in terms of expected results.

A heavy stress was placed throughout on the idea of using a model and on the concept of management information. The initial reactions of the participants were uniformly favorable though it was clear that more development would be needed.

## CONCLUSION

The problems of applying a systems engineering approach to library problems are quite severe. This is to be expected in the case of a non-profit-making situation where the end product is an intellectual rather than a physical one. Furthermore, although librarians do commonly have an academic orientation, this is usually in the humanities rather than science or engineering. This is quite clearly reflected in library research which commonly includes substantial data collection but on models or hypotheses.



Nevertheless, the past few years have seen a significant development in the application of systems engineering to library problems. This has been reviewed elsewhere.(4) The achievement, though real, is still quite limited—especially where the behavioral aspects of library use are concerned. There is, in library systems engineering, a need and a challenge.

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