This paper reviews the record of OR/MS applications to library management. Although libraries constitute a major factor in both the public and the private (not-for-profit) sectors, OR/MS has not fulfilled its potential in enhancing the cost effectiveness of library systems.
100,000 FTE jobs in the 4,593 academic libraries to the 9,060 public, 9,051 special, and 1,753 government libraries as well as the private sector corporate and institutional libraries it can be seen that we are talking about a large economic sector indeed.

The above figures are impressive in their magnitude. However, they merely represent one year's worth of transactions. Clearly they do not begin to address the worth of knowledge, wisdom, and fact repositied, nor the impact of same on the quality of life in, and the wealth of our nation.

**DISCUSSION**

For the purposes of this paper “Operations Research in Libraries,” will be considered by first defining in operationally meaningful terms, libraries on the one hand and Operations Research on the other. According to The American Heritage Dictionary of the English Language (p. 753), a library is “a repository for literary and artistic materials, such as books, periodicals, newspapers, pamphlets, and prints, kept for reading or reference.” This rather classical notion of a library does not recognize the fact that libraries are now a subset of the broader field known as information systems (IS). Nevertheless, we delimit the scope of this paper to institutions which can be defined as above, albeit with some leeway.

Both the definition and realm of operations research (OR) have been amply discussed elsewhere. Churchman, Ackoff and Arnoff (1957), Ackoff (1961), and Wagner (1969) represent some of the classic texts on the subject. For the purpose of this paper we considered only those contributions to knowledge and/or practice which were published in recognized Operations Research/Management Science/Industrial Engineering journals, co-authored by known operations researchers/systems analysts such as books, periodicals, newspapers, pamphlets, and prints, kept for reading or reference.” This rather classical notion of a library does not recognize the fact that libraries are now a subset of the broader field known as information systems (IS). Nevertheless, we delimit the scope of this paper to institutions which can be defined as above, albeit with some leeway.

The application of OR in libraries started in the 1960s (Leimkuhler and Cox 1964, Cox 1964, Morse 1968, Cook 1968) and peaked in the early 1970s. A comprehensive review of library operations research was done by Kantor (1979). In that review, Kantor summarized all of the previous review articles. Most noteworthy of these from the OR point of view are the bibliographies by Slamecka (1972) and Kraft and McDonald (1977), and the surveys and/or assessments by Churchman (1972), Morse (1972), Bommer (1975), Kraft and McDonald (1976), and Leimkuhler (1970, 1972, 1977a,b).

Another excellent review of OR in libraries appears in Chapter 4, “Library Models and Empirical Findings” of Library Planning and Decision-Making Systems by Hamburg et al. (1974). After introducing the concept of OR-type modeling and its role in both decision analysis and identifying what data need to be collected Hamburg et al. review the literature within each of the following categories:

- Provision of building area
  - Centralization versus decentralization
  - Branch location
- Hours
- Seating and space utilization
- Selection of documents
  - Choice of book subject matter and year
  - Number of copies
  - Theoretical foundation of journal selection
  - Journal selection
  - Selection effort
  - Acquisition of documents
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- Processing of documents
  - Processing work flow
  - Binding of serials
- Classification and cataloging of documents
  - Indexing
  - Original versus temporary cataloging
  - Dewey and Library of Congress (LC) correlation
  - Cataloging at the Library of Congress
  - Catalog use
- Control of location and use of documents
  - Selection of materials for compact storage
  - Storage of library materials
  - Load period
  - In-library use
- Security guards
  - Return of circulated library materials
- Facilitation of use of documents
  - Photo duplication
  - Maintenance and weeding of documents
    - Book relabeling
    - Book weeding
    - Journal weeding
- Aids for location of documents in other libraries
- Facilitation of access to other libraries
  - Interlibrary borrowing decision rules
  - Retrieval systems
  - Networks
  - Personal assistance
- Publications, advertisements and exhibits
  - Library initiative communication
  - Planning and administration
  - Library legislation
  - Library/user/funder analysis
  - Participative decision making
  - Data processing
  - Projecting library growth
  - Overall university library resource allocation
  - Overall public library resource allocation.

Literature on the utilization of OR in libraries has classified the field in several different ways. Hamburg et al. classify the literature in the detailed fashion outlined above. Kantor (1979) classifies papers and projects into five groups according to the purpose of the research: system description; modeling the system; parameter identification; optimization or multivaluation; and application; while Rowley and Rowley (1981) classify the work by the nature of the research (e.g., recurrent problems, on/off decisions). In this paper, we use a three-dimensional classification. In one of the dimensions, we adopt Rowley and Rowley's classification with slight modifications.

Based on the type of problems being tackled, the application areas are grouped as involving operational or recurrent problems, such as book storage problems; strategies or on/off decisions, such as library location problems; and control/design problems, such as loan policy problems (Rowley and Rowley). The application of OR in libraries can also be classified according to the type of OR techniques used:

1. Queueing models. Given the average book circulation time \( \left( \frac{1}{\mu} \right) \) and the mean number of persons who borrow the book \( (\lambda) \), the expected circulation rate of that particular book is derived using queueing theory (Morse 1968).

2. Simulation. With the number of staff, the volumes of various jobs (e.g., users' requests, new issues, overdue fees) and the job processing times specified, simulation is used to estimate the delays, processing times, and utilization of each member of the staff and the whole facility (Thomas and Robertson 1975).

3. Facility location algorithms. The library facilities and relocation problems are discussed by Min (1988).

4. Mathematical programming. If there are two types of information services, both of which share the same set of resources (e.g., staff time in scanning, indexing, abstracting), and each of them has a different "unit profit," a linear programming problem is used to find out how many services of each type to produce in order to maximize the total profit (Rowley and Rowley, pp. 58-64).

5. Network flow models. Given the heights and thicknesses of a given collection of books and the cost of different shelf heights, a network model is developed to determine the optimal number of shelf heights for minimizing shelving costs through finding the shortest path in a directed network (Gupta and Ravindram 1974).

6. Decision theory. A decision regarding whether or not to install a library security system is addressed given the installation cost and the probabilities of success and failure (Rowley and Rowley, pp. 91-92).

7. Search theory. Patterns of browsing in libraries are addressed in Morse (1970).


9. Inventory control theory. An EOQ model is used to determine the optimal order quantity for the stock of a certain library supply (Rowley and Rowley, pp. 111-116).

10. Probability and statistics. Library book circulation and individual book popularities are considered as probabilistic processes by Gelman and
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*Grounded Research.

Logico Deductive Research.

*This reference concisely presents a number of OR methodologies in a textbook format. It could therefore justify being placed in several rows in the above matrix.
Sichel (1987) who demonstrated the superiority of beta over negative binomial distribution.

11. **Benefit cost analysis.** Library planning is addressed by Leimkuhler and Cooper (1971).

Each of these categories, in turn, could be characterized further by whether or not the research work was *grounded*, e.g., based on "real-world" library systems involving real data and/or bonafide librarians in the study as opposed to models which were basically what might be called *logico/deductive*.

Table I provides a taxonomic summary of a representative bulk of the literature in the field. As can be seen from the above delineation and from Table I, the utilization of OR in libraries is far from achieving its full potential. This is especially true in the "grounded" studies category. Except for simulation and probability and statistics based applications, the bulk of the literature is not particularly grounded in real-life settings. The literature reflects the gap between the complex mathematical models in OR and the not very quantitatively educated library workers (Stueart and Moran 1987). Moreover, Churchman (1972) is critical of OR analysts for idealizing the existing library systems, gathering data, and building models on faulty bases. To enhance the application of OR in libraries, Bommer (1975) suggests a closer working relationship between operations researchers and library managers.

**CONCLUSION**

We are living in an information age. The classical notion of a library is very much part of it. It will serve as a worthwhile contributor to enhancing our quality of life and of knowledge for the foreseeable future. Yet, libraries compete for the dwindling resources, respectively, in the public and the private sectors. They can downsize acquisitions, reduce services provided, and/or become more cost effective. If done correctly, OR/MS can help library managers to better cope with the opposing goals of service enhancements and cost containments. There is much to be done, as indicated by the empty cells of Table I and by revisiting the categories of work that had been attempted. The payoffs to society are great. Yet, the recent record of accomplishment in this area is especially sparse. This then presents a challenge to those in the OR/MS community who are not satisfied by just creating a new or enhancing an old algorithm.

**NOTE**

1. The literature search included the use of: ABI/ inform CD ROM: (ERIC); the CWRU online library catalogue (EUCLID PLUS); Library and Information Sciences Abstract (LISA); Bowker Annual of Library and Book Trade Almanac; American Library Directory (R. R. Bowker Publishers); and searching in the relevant literature by following up on references cited (cycling).

**ACKNOWLEDGMENT**

This paper is an expanded version of a chapter in the forthcoming Encyclopedia of Operations Research and Management Science, S. L. Gass and C. M. Harris (eds.), 1994.

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