The Economics of Information

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INTRODUCTION

Organizations that provide information services are coming under increasing pressure to justify their continued existence. Usually it is not a question of whether the organization is innately a good one, but rather, whether the service is adequate, given the cost of providing it. The problem is broader in scope than whether, for example, a single library or a single information retrieval system continues in existence. Rather, it is a question of whether the entire information storage, retrieval, and dissemination process is fulfilling its objectives of satisfying the information needs of users.

Research in the field of the economics of information represents an attempt to expand the scope of the field of information science and technology. The analysis is an attempt to examine in economic terms the entire chain of events that begins with the creation of new information by researchers and inventors; continues through the dissemination of information by educators, the communications media, computers and information services; and finally ends with the processing, or use, of information by individuals.

The analysis of the economics of information is concerned with the resources available to promote the process and the constraints that limit it. And since there is obviously competition for the use of funds, the economic analysis of information must consider how funds can best be allocated to maximize the overall benefit to society as well as the effectiveness to individual information producers and users.

1The author gratefully acknowledges the assistance of Janet G. Baxter and Ishrat S. Kadri in the preparation of this review.
This review begins with a brief presentation on micro-economics of information and proceeds to discuss the research currently being conducted on the ways in which individuals use and process information. The major part of the review concentrates on a description of the various institutions that produce and disseminate information, the resources and constraints affecting the production and distribution process, and the tools and methodologies available for making resource allocation decisions. Among the tools that are reviewed are welfare economics, cost-benefit analysis, demand analysis, marketing research, cost-effectiveness analysis, cost analysis, and operations research models.

A related framework for the analysis of the field of economics of information has been developed by Olsen (83). In this latest revision of an important bibliography, Olsen suggests that the information production and distribution process is influenced by social and economic forces. Within the field, supply and demand act to regulate the allocation of information to the users. Olsen's bibliography classifies the literature on the economics of information into 12 categories ranging from economic theory to operations research. Within each category are items of general interest and items specifically related to information science.

Another view of information economics is given by Lamberton (64) in the introduction to his set of readings on the subject. He sees the field as analyzing "...the processes by which information and knowledge is produced, diffused, stored, and used" (64, p.7). This encompasses the use of information in organizations, in planning, and in international trade. Also included is the analysis of the role of information in competitive markets and of the financial assessments on information producers.

MICRO-ECONOMICS OF INFORMATION

Micro-economics of information studies the information processing behavior of individuals. Marschak (70, 71) states the problem as that of analyzing the rational decision-making of an individual in terms of the information that the individual needs to make a decision. He mathematically formulates the problem in terms of the costs and delays involved in obtaining the necessary information. The model of information processing that is employed is characterized as a chain of events involving inquiring, communicating, and deciding. During the process, the cost and benefit of the information are calculated and are used by the individual to determine the value of the information.

In the latest book on the subject, Marschak & Radner (72) summarize much of what has been previously written in the field of micro-economics of information. They begin with a discussion of individual information
processing behavior as decision-making in a climate of uncertainty and
discuss the axioms of utility theory as they influence the decision process.
The cost and value of using various decision functions are discussed, and
the authors use a Bayesian model to describe the concept of "noisy"
information. The first part of the book concentrates on single-person
decision problems. In the second part of the monograph, the analysis is
extended to decision-making by a group of individuals (teams) and, in the
final section, to decision-making by networks of teams, or organizations.

INFORMATION PRODUCERS

An overall picture of the scope of information science from an
economic view must include an analysis of how information is initially
created and disseminated, as well as how users process information. In the
previous section a review of some of the work in the field of
micro-economics of information was presented. Attention now turns to an
analysis of the producers and disseminators of information.

The pioneering work in the description of the scope and size of the
information industry in the United States was performed by Machlup (68)
using 1958 data. Machlup defined the information sector of the United
States economy as composed of the education, research and development,
communications, information machines (e.g., computers), and information
services industry.

In this section of the review, a description of each of the major
information-production sectors is presented. Because of the nature of the
review, more emphasis is placed on the information science-type producers
(such as printing, publishing, and libraries) than on education or research
and development.

Education

A principal means by which information is disseminated is through the
education process. Considerable data are available to characterize the
expenditures for formal education, such as elementary, secondary, and
higher education in both public and private schools (Harris, 50; Simon &
Grant, 113). Projections of these statistics are also available (U.S. Office of
Education, 132) indicating expected enrollment in elementary and
secondary schools as well as colleges and universities. Projections of total
expenditures in education and staff needs are also made.

The economics of education is an important discipline in its own right,
and there is considerable literature about the subject. Blaug (9) provides an

2It appears that this study will soon be updated. See (78).
excellent synthesis of the issues. He describes the economics of education as a subfield of a larger field called the "economics of human resources," and he suggests that decisions about allocation of resources to education should consider the value of education and the contribution of education to economic growth. Blaug notes that one possible way to view the educational investment decision is to see education as building human capital—the more education individuals have, the more they earn over their lifetimes. Economics of education, he notes, is concerned with a broad range of issues including the attempt to establish relationships between the economic growth of a nation and the level of education of the members of the country. The discipline is also concerned with educational planning as an aid to effective resource allocation, analysis of manpower needs to determine the demand for various skills, and the value of education to individuals, as well as the financing of education.

Research and Development

One way in which information is created is through research and development. In the United States, support for this industry comes from three sectors: Government, universities and other non-profit organizations, and industries. The pattern of Federal funding for research and development has been traced by the U.S. National Science Foundation (130). The study shows the proportion of all Federal funds spent for research and development in space research, defense, health, education, commerce, transportation, natural resources, agriculture, and housing. An important conclusion is that between 1960 and 1972 total Federal expenditure increased 7.8% per year while Federal research and development expenditure increased only 6.6% per year. The study reports that the ratio of total research and development expenditure to total Federal budget outlays has been decreasing since 1965. Information about expenditures for research and development in other countries is tabulated by UNESCO (126).

Since more than half of the funding for the U.S. research and development industry comes from the Federal Government, Federal policy towards research funding is an important influence on the industry. Science magazine's analysis of the 1973-1974 budget (22) indicates that there will be a 6.25% increase in Federal funding for research and development over 1972-1973. Plant (90) predicts that the total expenditure for research in 1973 will be $31 billion, which represents an approximate 7% increase over 1972. Plant sees governmental agencies as supplying 54% of all research and development funds, industry as supplying 40%, and universities and other non-profit organizations as supplying 6%. He further projects that for 1973
industry will spend 70% of all research and development funds; universities and other non-profit organizations, 17%; and government will spend 13%.

As part of a continuing series on the cost of research, Milton (74) presents the latest calculations of an index of the cost of maintaining a technical researcher for one year. The index is designed to help in planning and budgeting the cost of performing research and is based on a survey of 15 research organizations taken every five years. With 1950 as a base year (with the cost-of-research index at 100), the 1970 value of the index is put at 342, with an average annual 6% increase since 1950.

Communications Industry

The communications industry is engaged in the distribution of information via media such as books, periodicals, newspapers, telephones, telegraph, radio, television, movies, theater, and postal service. In the strictest sense, the communications media do not generate new information but only serve to disseminate existing information.

A rather complete statistical picture of the communications industry in the United States in 1971 is given by the U.S. Bureau of the Census (127). Data on the magnitude of the telephone, postal, telegraph, radio, television, newspaper, and book industries are provided. Pierce (89) has prepared a useful summary of the evolution and technological growth of the communications industry. His analysis traces the development of communications channels and their growth in capacity and outlines the exponential increase over time in the usage of telephone and postal services.

One aspect of the communications industry that is relevant to information science is that of printing and publishing. Measures of output of the book industry are given by Grannis (46, 47). Sales figures are subdivided by type of material, and comparisons are made between book prices and the Consumer Price Index. Brown (18) presents an annual tabulation of the price index for periodicals, and Brown & Huff (19) give the same information for serial services. Matarazzo (73) reports on a sample of 20 physics journals and analyzes the changes in library subscription rates, cost to library per page, and page charges for the period 1959 to 1969. For the ten-year period, an 82% increase in the number of issues of the journals occurred, as well as a 147% increase in the number of pages published and a 202% increase in subscription prices.

Two economic analyses of the printing and publishing industry have been reported: one by Ernst and Ernst Management Consulting Service (40) and the other by Berg & Campion (6). The Ernst and Ernst Management Consulting Service study is a statistical and economic analysis of the
English- and French-language book publishing and manufacturing industry in Canada. The report analyzes consumption of books by language, revenues from book sales, size and characteristics of publishers, management capabilities, and market structure. The analysis finds that the publishing and manufacturing industry contributes only 0.08% of the Gross National Product (GNP) in Canada, while in the United States the industry output contributes 0.22% of GNP. Ernst and Ernst Management Consulting Service sees the potential for a growth of three or four times in the Canadian industry.

Berg & Campion (6) have surveyed the primary journal market in the language sciences. The analysis is in terms of the participants (author, subscriber, editor, publisher, printer), the inducement to participate, and the contribution of each participant. Also developed in the paper is a functional analysis of the journal market. The authors see supply and demand for journals as being influenced by technology and user needs, respectively. Technology and information needs also influence the institutional arrangements for journal production which, in turn, influence the financial viability of the journal. They note that there does not seem to be any lasting balance between supply and demand for journals because there is increasing pressure to publish more pages in a journal so that additional authors may have a publishing outlet. Contributing to this trend is the fact that additional subscribers can support an increased number of journals.

Computing Equipment

Information processing is increasingly being aided by the use of computers. For example, computers are used in the education industry for administrative data processing purposes, in research as a laboratory tool, in communications to control printing and telephone equipment, and also in library automation and mechanized information retrieval systems. Since these devices play a significant role in information production and distribution, it is important to characterize the magnitude of, and future trends in, the computing industry.

Estimates of the value of worldwide shipments of computing equipment for 1972 are approximately $9.5 billion, and this is expected to reach $16.2 billion in 1976 (82). However, most of the usage of computers has taken place in manufacturing industries rather than in education, medicine, and other services that could be construed as being related to information production and distribution (82).

Detailed descriptions of the usage of computers in various sectors of the economy are relatively scarce, except for data on U.S. Federal and
educational usage. A survey of the number, location, and type of computers used in all agencies of the Federal Government is reported by the U.S. General Services Administration (129). They indicate that about 6,000 computers are employed and that more than 72% of these are owned by the Government, rather than leased. Hamblen (49) describes a survey of computers used in higher education institutions in the United States. He reports a census of less than 2,000 machines for fiscal year 1970.

The potential applications of computing equipment in the economy are numerous. Several important uses are relevant to the economics of information. For example, if computers as information processing tools are introduced into developing countries, the possibility exists that the rate of economic and social growth can be accelerated (Beltran, 3; United Nations, Department of Economic and Social Affairs, 125). This argument is advanced on the theory that differences in levels of technology cause major gaps between developing and developed countries. Through the use of computers in a myriad of applications, this gap can be narrowed.

Certain information science activities promise the possibility of increased use of computer equipment. They include facilities such as an information center in a library capable of providing custom tailored versions of machine-readable data for patrons (Watson & Briggs, 137).

There is every indication that the cost of obtaining computing equipment for information processing is declining and will continue to decline as technology advances. Bloch & Henle (10) show the increase in speed that computer logic has achieved in the past ten to fifteen years, along with declining costs. With Ware (136) predicting the possibility of a 1,000- to 10,000-fold increase in computing speed in future machines, and with Withington (144) projecting decreasing costs for all sizes of computers, the prospect of inexpensive computerized information processing seems a distinct possibility.

Information Services

In his 1962 study of the production and distribution of information, Machlup (68) defined information services as composed of professional services (legal, engineering, accounting, and medical); financial services (securities information, banking); services of wholesale traders (brokers, jobbers); and other services (business consultants, credit bureaus, employment agencies). The remainder of this review concentrates almost exclusively on the economics of information science (libraries and information retrieval systems) that Machlup (68) considers as part of the education industry. Primarily because of space limitations no discussion of
the information services industry, as defined by Machlup, is presented. The
next section characterizes the size, resources of, and constraints on
information services. Then the tools used to aid resource allocation
decisions are reviewed.

RESOURCES AND CONSTRAINTS ON INFORMATION SERVICES

The production and distribution of information is both aided and
inhibited by factors such as the political, psychological, and social
environment. This section considers a more limited set of resources and
constraints such as the availability of funds, taxation policies, and legal
structures (e.g., the patent and copyright systems) and outlines their
influences on the information science industry.

Funding

There are three major sources of funds for information science
institutions such as public libraries, school libraries, information analysis
centers, journal publishers, and special libraries. The first is funding from
Federal, state, and local governmental units; the second is funding through
direct user charges for information products and services; and the third is
funding through private financial arrangements such as corporate allocations
for company libraries, or capital supplied for the development of
information centers or new journals. It is beyond the scope of this chapter
to discuss the method and magnitude of private financial arrangements for
the support of information centers, but some attention will be focused on
financing public sector information activities.

Patterns of municipal funding of library service for the period 1950 to
1968 have been analyzed by Childers & Krevitt (26). They note that total
annual expenditures for all cities in the United States have increased from
$6 million to $30 million during the period under investigation. During
that time, expenditures for libraries have remained almost constant at
approximately 1% to 1.4% of total municipal expenditures. When library
expenditures are compared to most other public expenditures, one finds a
great deal of perturbation in all the other kinds of expenditures. The
authors conclude by noting that library spending is atypical in its stability.

The only difficulty in such a funding analysis comes when one sees that
cities in general are facing severe financial problems and that, even though
libraries will continue to receive their 1% of the funds, the total amount of
funds available in constant dollars may decrease or competition for the
available funds will increase to a point where libraries may not be able to
sustain their position. One trend that may prevent such a situation is the
passage of the State and Local Fiscal Assistance Act of 1972\(^3\) by the U.S. Congress. This revenue-sharing bill provides that $30.2 billion will be distributed to state and local governments over the next five years (42). While the act does give hope of a new source of funds, Schuchat (104) notes that libraries will have to compete with other departments within the government for a share.

No thoroughly adequate picture of the overall magnitude of funding for information service activities at all levels of government is available. The U.S. National Science Foundation prepared an analysis of scientific and technical information expenditures by the Federal Government during the period 1960 to 1970 with estimates for 1971 and 1972 (131). The report indicated 1970 expenditures of $387 million which represents a growth of 6.7% since 1969. Nearly 38% of the funds were spent for information activities of the Department of Defense, while 17% went to the Department of Health, Education and Welfare. Some recent financial information is also available regarding college and university libraries (Smith & Williams, 116, 117).

A discussion of a number of Federal statutes providing funds for information activities is given in *The Bowker Annual of Library and Book Trade Information* (15). Krettek & Cooke (62) report on the magnitude of Federal funds for libraries under a number of acts. Hughey (54) presents a detailed, state-by-state analysis of funds available under the Library Services and Construction Act. Phillips (88) discusses accomplishments of the Elementary and Secondary Education Act Title II. The Higher Education Act of 1965 is reviewed by Stevens (119), who examines the distribution of funds under Title II-A for acquisition of library material; Stevens & Hicks (120), who show the distribution of Title II-B training funds for librarianship; and Janaske (56), who discusses funding of library and information science research projects, also under Title II-B of the Higher Education Act.

**Taxation Regulations**

The tax system in the United States acts as an influence on private investment in the information industry. Perhaps the most important effect is the impetus given to private investment in research and development by relatively generous tax laws. Many tax provisions affecting this sector are described by Slitor (114). They include capital gains treatment of patent sales by individual inventors, deduction of expenses and losses of inventors, and tax exemption for professional scientific organizations. In addition, an

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\(^3\)State and Local Fiscal Assistance Act of 1972, Public Law 92-512, October 20, 1972.
important regulation allows research and experimental costs to be considered for tax purposes, either as an expense in the year in which they occurred, or capitalized and depreciated over the useful life of the asset.

The rules for depreciation of assets have been considerably liberalized in the past year. Under the Asset Depreciation Range system\(^4\) there is substantial flexibility in deciding asset life. Another current incentive to acquisition of capital assets is the investment credit.\(^5\) This provision allows, in addition to depreciation, the reduction of tax liability by approximately 7% of the value of the asset, spread over the life of the asset.

While these provisions of tax regulations are obviously not available to governmental information agencies, they are of considerable importance to commercial organizations engaged in information science research and development. Depreciation regulations affect lease-purchase decisions for computer software. Another major aspect of computer software taxation is the attempt by local governmental units to assess property tax on the software (27).

**Patent and Copyright Systems**

In order to encourage the production of information, statutes have been passed that give the creator of the information some exclusive rights to its distribution. This is done on the theory that there will be no incentive to produce information if there are high risks and little chance of any payoff (Silberston, 112).

The patent system provides that a new and useful process, machine, or composition of matter, or improvements on these, may receive a patent. An important patent decision handed down by the U.S. Supreme Court occurred in the case of *Gottschalk v. Benson*.\(^6\) The case concerned an attempt to patent a computer program. The court ruled that computer programs are ideas and cannot be patented. Computer hardware manufacturers opposed granting of the patent, as did the 1966 President's Commission on the Patent System. The Association of Data Processing Service Organizations was in favor of granting the patent, arguing that patents were necessary to protect the software developers. The computer hardware manufacturers argued that granting of patents would impede development of new software (Weaver, 138). Titus (123) and Duggan (37) both review the decision, and Duggan (37) speculates whether or not it will now be possible to obtain a patent on hardware devices that perform algorithmic processes.

\(^{4}\)The Asset Depreciation Range (ADR) System, Internal Revenue Regulation Section 1.167(a)-11.

\(^{5}\)Internal Revenue Code of 1954, Section 46 through 50.

\(^{6}\)Gottschalk v. Benson 34 L. Ed. 2nd. 74 (1972).
A copyright is "The exclusive, legally secured, right to publish and sell the substance and form of a literary, musical, or artistic work..." (Kent, 59, p.1). The purpose of copyright is to allow the recovery of costs and to provide an incentive for distribution of the material (Kent, 59). In the U.S. Court of Claims in 1972, a preliminary decision was made in the important copyright case of Williams & Wilkins Co. v. U.S. The court commissioner found that the U.S. National Institutes of Health and National Library of Medicine were guilty of infringing on the copyright of the publisher, Williams & Wilkins, by making photocopies of articles in medical journals published by the plaintiff and delivering them to scholars and researchers. North (81) discusses the case and notes that Williams & Wilkins could recover compensation for copyright infringement. In a critical analysis of the commissioner's report, Shaw (108) indicates that the scope of the suit was considerably expanded in the process of litigation, notes numerous technical errors in the plaintiff's case, and points to the ambiguous issue of what the magnitude of "reasonable royalties" should be. Should the court concur with the commissioner's ruling, the result will have a considerable financial impact on libraries and information centers. The copyright situation is in a state of flux at the moment, with the new copyright legislation pending and with the issue of the relation of cable television to copyright still to be resolved. The reader is referred to the chapter by Gannett in this volume of the Annual Review for further analysis of the copyright problem.

RESOURCE ALLOCATION

In any society, choices have to be made in allocating funds to competing projects. This section reviews some of the tools available that aid in resource allocation decisions, including welfare economics, cost-benefit analysis, demand analysis, cost-effectiveness analysis, and operations research techniques. Attention is focused on application of these methodologies to information service institutions such as libraries, and to information retrieval systems, rather than to the entire spectrum of the information industry.

Resource allocation tools have two major functions: they serve as external allocation aids and as internal allocation devices. External allocation refers to decisions made with respect to allocation of resources among competing institutions, while internal allocation tools aid in allocation within an industry or an organization. In some sense, all the tools that will be discussed are useful for both purposes. It then becomes a

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7 Williams & Wilkins Co. v. U.S. 40 U.S. Law Week 2550.
question of the level of detail with which a particular tool is applied to a specific situation.

Information as a Commodity

Information is used in many ways by many user groups, be they consumers, researchers, managers, or students. It is sometimes assumed that users have "perfect knowledge"—for example, that they know prices of all alternative commodities (Jerner, 57) or have precise data on alternative jobs in the labor market (Rees, 97). While the ideal situation would be to make sure every person had "perfect knowledge," it is economically infeasible. Some method must be devised to allocate a scarce resource (information) to alternative ends.

In most sectors of the economy, the usual method for allocating commodities to individuals is through the market mechanism. A price for the commodity is established and those persons willing to pay the price acquire the information. There are a number of problems in using this approach to allocate information. First, if it is assumed that equal access to information is a right, just as is freedom of speech, freedom of religion, and privacy, then a decision must be made whether the market mechanism is adequate for allocating information to individuals. It has been pointed out that, in economic terms (Stigler, 121) and philosophical terms (P. Wilson, 142) knowledge is power. Alternative institutional arrangements other than the price system may have to be made to insure the equality of the distribution.

Second, if the market mechanism is used to aid the allocation of information, then there is the implication that a certain quantity of information is available at a stated price. Yet as Boulding (13) indicates, there is no accepted method to measure a unit of information.8

A third problem with the use of the market mechanism to allocate information has to do with the characteristics of information. A decision cannot be made as to the price to pay for the information until the information has been examined and evaluated (Shubik, 110). Thus, information about the information is required before a value can be assigned. Still another problem relates to the fact that, in the process of transferring information from one individual to another, the resource is not depleted (55). For example, if an automobile is exchanged between two parties, one person acquires the vehicle while the other loses it; but in the

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8Information is used here in the sense of a message that may eventually be used as a basis for acquiring knowledge. Boulding (14) uses the analogy that knowledge represents capital structure, and information represents income flow into the capital. The concept of information as used in information theory is not applicable to this discussion.
case of information, this is not necessarily true. When information is disseminated, both parties have the information and the person who transfers the information—for example, a school teacher—may gain information in the process (Boulding, 14). Thus there may be no economic incentive to engage in the transfer process. Given this situation, the methodology of welfare economics may be applicable to aid in the allocation process.

**Welfare Economics and Cost-Benefit Analysis**

Welfare economics provides one methodology for making aggregate resource allocation decisions. As Winch (143) notes, welfare economics is concerned with the extent to which the objectives of society as a whole are satisfied, rather than the individual objectives of its members. Decisions using the concepts of welfare economics are based on an evaluation of a social welfare function. This function is a translation into economic terms of the values that politicians and individuals place on social objectives. A welfare function states the priorities to be given to factors such as raising the standard of living, redistributing income among individuals, increasing national income, reducing unemployment, developing self-reliance of countries and individuals, and providing "merit goods" such as education (P. Dasgupta et al., 34). A merit good is one that is usually supplied by the public rather than by the private sector of the economy. This is done on the theory that, if the public sector supplies the good, the distribution will be more equitable.

Once the objectives of a system are established, cost-benefit analysis can be employed in aiding allocation decisions. The methodology involves comparison of the cost of a project with its benefit over time. Project costs include materials, labor, and other expenses. While under normal circumstances the cost of these factors of production can be inferred from market prices, there are situations in which market prices do not reflect the social cost (e.g., in the case where there is government subsidy of a product).

Benefits measure the added value of a project to society. There are a number of ways to measure benefits and one of these is by determining what the consumer is willing to pay for the output from the project (P. Dasgupta et al., 34). The problems with this approach are that there may be no clearly defined output and also that there may be value to society in excess of the value that an individual places on the output. (This latter concept is referred to as "externalities" and is discussed by Mishan [75] and Prest & Turvey [91].) For example, construction of a new library building will have direct benefit in that it will provide additional
service for patrons. But there will also be externalities (e.g., construction workers will be employed on the project or the building will be an aesthetically pleasing addition to the city's environment). A major deficiency in cost-benefit analysis is its inability to measure externalities adequately.

Once benefits and costs of a project are calculated for each year of the planning period, then one can use discounting methods to calculate an overall measure of project performance. (These methods are explained by Mishan [75].) Since the benefits and costs are spread over a long period of time, direct comparison of the total benefit and cost cannot be made by simply adding the two quantities and comparing their sums. Instead, today's value of a stream of future benefits and costs is determined by discounting each value to reflect its current worth.

Reduction of the benefit and cost values to their present value requires the use of a discount rate. There are a number of problems in selecting an appropriate discount rate, and they are reviewed by Prest & Turvey (91, pp.697-700). Basically, one must select a rate that reflects the increased social value that could be obtained by alternative investments in other projects. Obviously this is extremely difficult. Approximations are sometimes made by using current interest rates in the private capital market. The U.S. Office of Management and Budget recently announced that a 10% discount rate should be used for most Federal cost-benefit studies (128).

There are many mathematical formulations of the final calculation of project worth using cost-benefit analysis, but they all roughly synthesize into a comparison of the present value of the stream of benefits to the present value of the stream of costs. This comparison can be a calculation of either the ratio of the benefits to the costs or the difference between the benefits and the costs. If the discounted benefit stream exceeds the discounted cost stream, the project is considered as a candidate for implementation.

Further details on the theory of cost-benefit analysis and its applications to problems outside the area of information science may be found in texts by Mishan (75), A. Dasgupta & Pearce (33), and P. Dasgupta et al. (34). A classic survey of cost-benefit issues has been performed by Prest & Turvey (91). In a tutorial presentation at the American Society for Information Science Annual Meeting, Cooper (28) reviewed some of these concepts as they relate to information science.

A number of papers have applied cost-benefit analysis to information science activities. They include works by Goddard (45), Newhouse & Alexander (80), Herring et al. (52), the University of California's Library
Systems Development Program (24), Streeter (122), and Hayami & Peterson (51). These works are discussed in turn.

In assessing the benefits of public and school libraries, Goddard (45) suggests that benefits from library service can be divided into three categories: education, information, and recreation. With respect to education benefits, Goddard argues that 75% of public library circulation is accounted for by school-age children and, thus, education is a major function of public libraries. Since it is commonly accepted that there are externalities in education (i.e., there is benefit to more than just the person being educated), one accepts the importance of the public library in fulfilling this need. Goddard continues his analysis by noting that there is no clear evidence that there are externalities in supplying general information or providing recreation for library users. He suggests the possibility of measuring benefits of library use in terms of the socio-economic class and the political-cultural-business affiliation of the borrower.

An alternative approach to measuring the benefits of public library service has been taken by Newhouse & Alexander (80). Their objective is to determine which subject categories of library material provide the greatest benefit to the users. To estimate benefit, they conducted a survey to determine the proportion of the borrowers of a particular book who would have bought the book if the library did not own it. By tallying the responses by classes of books, they have an indication of the relative value of one particular class of materials over any other. The cost-benefit ratio for a particular class of books is a function of the present value of (a) the relative benefit obtained by a borrower of a book relative to the benefit derived by a purchaser, (b) the total benefit for the class of material, (c) the average price of the material, and (d) the average circulation of items in the subject area.

In a report to the National Science Foundation, Herring et al. (52) consider the problem of evaluating U.S. Government expenditures on information services. They note that while there was a cost of close to a billion dollars for information activities, little is known about the benefits received. To improve the situation, they suggest the use of two measures. One equates benefits in terms of market response to an information product or service—that is, how much a person would be willing to pay for the information. The second measure equates benefits with the amount of time a person is willing to spend at information-gathering activities.

One method for measuring the benefits of a library automation program is to look at the existing manual system and see the degree to which the performance of particular components of the system is affected by automation. This approach has been suggested by Hirsch (53) and the
University of California (24). The University of California's Library Systems Development Program (24) conducted an extensive cost analysis of both the existing manual library system and a proposed automated system. (Related documentation for this study is contained in references [23] and [25].) Judgments were made as to which costs in the manual system would be eliminated, and what the costs of an automated replacement would be. Consideration was also given to projected workload growth over a ten-year period and projected unit costs for operations over the same time period. Then, using various discount rates, the authors calculated the total costs versus benefits over the planning period.

An interesting cost-benefit evaluation of a scientific computing service was performed by Streeter (122). The methodology involved measuring the job turnaround time relative to the degree to which the computer system was fully used. The relative value of the system to the users as a function of turnaround time was developed, based on information obtained via interviews with, and questionnaires to, system users. The value (as a function of utilization) was computed, through a combination of the two previous functions, and compared to the capacity (turnaround time versus utilization) of the system. The analysis was made for both batch-processing and time-sharing systems, and it was concluded that users place the highest relative value on an interactive system versus a high-speed or low-speed batch system.

Hayami & Peterson (51) have attempted to assess the benefit of improved-quality farm commodity information. The purpose of their research is to improve the accuracy of statistical reporting so that farmers can make better production decisions. They distinguish between two models of the production process: one in which production of a commodity cannot be easily altered in response to output projections, but in which an inventory can be accumulated; and one in which production can be changed in response to new information. Using each of the models, they tabulate, for a variety of commodities, the cost of conducting a survey to determine the quantity of the commodity produced and the sampling errors, given the survey size. Next they calculate the trade-off between the size of the sampling error and the total social loss in value of the commodity given the sampling error. When the social loss is compared to the survey cost, a measure of the benefit to cost for each sampling error is calculated.

**Demand Analysis**

*General research.* Accurate assessments of the usage of information services could be a great help to one who is determining which service
should receive funding, and what the magnitude of the investment in the activity should be. This section reviews current work in developing models to predict demand for information services and examines the role of marketing research and pricing policy in demand analysis.

The purpose of demand analysis is to arrive at a relationship between price and quantity. In the case of information, the hope is to develop a function that describes the quantity of information to be supplied at a given price. As has been noted previously, and as Arrow (1) indicates, the value of the information to the purchaser is not known until the purchaser has the information. Arrow also notes that if any particular piece of information has a different value for different individuals, then pricing of information will lead to "... a nonoptimal purchase of information at any given price and also to a nonoptimal allocation of the information purchased" (Arrow, 1, p.143).

Demand analysis of information retrieval systems has been conducted at Project INTREX. Molnar et al. (76) have developed a demand function and have simulated several charging policies using the function. Reintjes & Therrien (98) continue and extend the analysis in Molnar et al. (76) by suggesting economically feasible regions of operation within which the price of the service should be established.

In the course of a cost-effectiveness analysis of an information system for medical doctors, Dei Rossi et al. (35) develop a model to predict the demand for the service. The dissemination system is designed so that doctors can call a toll-free telephone number and hear recorded messages on topics of current interest. The model predicts usage of the system (in calls per month) as an exponential function of the total physician population, number of recorded messages available, and length of time (in months) since the last advertising promotion publicizing the system.

Prediction of the demand for scientific journals has been performed by Berg (4, 5). In his models, two subscription-demand curves are distinguished: one generated by institutions such as libraries, and the other generated by individual subscribers. Berg mathematically formulates demand as a function of the price of the journal, number of pages published, number of researchers in the field, and number of institutions employing the researchers. Empirical estimates of the parameters are made, the elasticity of the curve is examined, and pricing and page policies are evaluated in light of the functions.

Marketing research. Demand analysis that is done empirically relies on information about consumer needs to make predictions about preferences and behavior. As an aid to gathering data for this type of analysis, marketing research techniques are often employed. The applicability of these techniques to the marketing of information products and services is
discussed by Kuehl (63). Bucklin et al. (21) report on a conference intended to explore the applicability of marketing concepts to education. One begins by attempting to determine the educational needs of students, parents, educators, politicians, etc. Note that one is not interested in creating needs, or artificially stimulating them, as in a classical marketing approach. As Bucklin et al. see it, the idea is to segment the potential market, assess the needs, model the adoption process, and develop an educational dissemination and diffusion program. The concepts that the paper develops for use in the National Institute of Education seem applicable in marketing of information products and services.

A very comprehensive quantitative marketing analysis of information products was performed by Wanger (134) and Wanger & Henderson (135). In a study designed to determine the effectiveness of National Center for Educational Communication (NCEC) publications, close to 5,000 educators were asked to examine subsets of 146 NCEC products. Wanger analyzed the products in terms of their type (i.e., state-of-the-art review, bibliography, etc.), level of effort required to develop the product, level of visibility of the product (as measured by the number of copies distributed), and subject area of the product. She also analyzed user reaction in terms of quality, utility, and impact of the documents. Further analysis concentrated on user and non-user evaluation as well as evaluation by type of user (e.g., researcher, teacher). The report provides a very good base from which product evaluation can be undertaken.

**Pricing policy.** Estimation of demand for information products and services involves use of market intelligence and cost-of-product data to arrive at a price-quantity relationship. There are many problems that have to be dealt with in establishing pricing policy, including whether the service should be provided without fee, what the fee should be if there is one, and how the fee should be collected.

Most library service has traditionally been provided without charge to the patron. One of the reasons for this is that library service is presumed to be a "collective good." A "collective good" is a product or service that is made freely available to all without charge because to charge would be cumbersome (e.g., a ship passing a lighthouse), use is not voluntary or clearly definable (e.g., national defense), or there is no market price with which to appraise its value (e.g., library service). The nature of collective goods is such that private enterprise would be reluctant to provide them because there is no flow of income to the provider (Dorfman, 36).

Pfister & Milliman (87, pp.48-55) argue that there is little economic justification in providing free public library service because use is voluntary, libraries can distinguish whom their users are, and libraries could charge individual users as do private libraries. Thus, libraries are not providing a
collective good. They also argue that because of the way public libraries are funded (mainly through the regressive property tax), poorer people are paying proportionately more for the service, while using it less than people with a higher income. In this situation, charging those who use the library would be more equitable than the present arrangement.

If a decision is made to charge a price for information service, there are a number of methods available for determining the fee. Lutz (67) suggests four possible strategies: (a) a fixed charge per request with the option of either a single price for any type of request, or a discriminatory price schedule; (b) a schedule of fees based on a subscription such as a flat rate; (c) a flat rate with either price breaks or a discriminatory fee schedule; or (d) variable pricing as a function of the value added per request.

Two groups of information suppliers who have been faced with difficult pricing decisions are the producers of magnetic computer tapes containing bibliographic citations, and the operators of selective-dissimination-of-information centers. In a meeting of center operators, a series of pricing recommendations were made (Association of Scientific Information Dissemination Centers, 2). The operators urged consistency in the fees charged for the same data base. They also recommended that pricing be in terms of a fixed base-cost for tapes (covering production, distribution, postage, handling, etc.) and a sliding usage fee, which would be a supplemental charge per unit of use of the data base. The unit-price supplementary charge would decrease as the volume of use increased.

Cost-Effectiveness Analysis

Cost-effectiveness analysis is a tool of systems analysis in which the cost of a project is compared to the project’s effectiveness. The purpose of such a comparison is to aid resource allocation by evaluation of the project in terms of cost versus performance, not just cost information alone.

One of the developers of cost-effectiveness techniques, Quade (95), argues that cost-effectiveness analysis represents the merger of three disciplines: economic theory, operations research and systems analysis, and engineering. In clarifying the distinction between cost-benefit analysis and cost-effectiveness analysis, Quade notes that the cost-effectiveness analysis that grew out of systems analysis “did not become cost-benefit analysis; attention was focused on the question [of] which of a restricted class of alternatives was best, rather than on the more complex question of whether the task being considered was worth performing at all, since the resources required would have to be drawn from other uses.” (Quade, 95, p.11).

Quade continues his analysis of the history of cost-effectiveness by discussing two possible analysis methods: a fixed-budget approach and a
fixed-effectiveness approach. A fixed-budget approach to cost-effectiveness analysis assumes that the amount of funds available for a project is fixed. A system must then be selected that maximizes the effectiveness given the fixed budget. The fixed-effectiveness approach assumes that the level of effectiveness of the system is fixed and selects the minimum cost alternative for the fixed level of effectiveness. Both of these concepts are dealt with extensively in an excellent monograph by Fisher (43), which covers the concepts of cost and cost-effectiveness analysis. Fisher's book includes a chapter by Bickner (7), which touches on the economist's view of cost analysis and also discusses some of the concepts of cost-benefit analysis.

Part of cost-effectiveness analysis involves measuring the effectiveness of the system. A useful bibliography on measurement of library and information services has been prepared by Reynolds (100). Evans et al. (41) have surveyed a number of measures of library effectiveness and have classified them into a number of categories including accessibility of the library and materials, user satisfaction, response time, and use.

Several measures of library effectiveness have been presented, including those by Orr & Schless (84) and Rzasà & Baker (103). Orr & Schless (84) propose the use of a document delivery test as a measure of effectiveness. The test begins with the development of a standard list of materials that are to be retrieved from a library or a set of libraries. A capability index is formulated that measures the effectiveness of the library in terms of the delivery speed that a user might expect, the holdings of the library, the short- and long-term usage of materials in the library, and the extent to which the library has access to other libraries to help it retrieve documents.

Rzasà & Baker (103) develop two mathematical measures of effectiveness for university libraries. Their primary measure of performance takes into account the number of users of the library, the number of material items used, the total number of non-material items sought and supplied, and the number of users who are studying their own material or who are at the library for social purposes. The secondary measure of performance attempts to classify library use by determining the extent to which various user groups avail themselves of library service. A sensitivity analysis is conducted on each measure to see the effect on the performance of changing the values of each of the parameters.

The paper by Dei Rossi et al. (35) provides a good example of cost-effectiveness analysis of information systems. It describes a system whereby medical doctors can phone a centrally located facility using an in-WATS telephone service and hear recorded technical messages. The first step in the analysis is the development of a demand model for the service. Then a cost analysis of two possible configurations—a single center and
multiple centers—is performed. Assuming a Poisson arrival pattern of messages, the number of in-WATS telephone lines necessary to provide a specified level of service is calculated for a library having a given number of recorded messages available for playback. With the use of the demand model to project usage of the system, calculations of the cost-effectiveness of the system are made for various center configurations, various operating costs, and various probabilities that telephone lines will be busy when a call is placed.

Cost Analysis

Approaches in cost analysis. The necessity for cost analysis as a resource allocation tool, as a control device, and as an aid to managerial decision-making has permeated the field of information science. This section continues a review of the literature on cost analysis of information science activities from J. Wilson (141) and Leimkuhler & Billingsley (66) in the previous volume of this annual review series.

In addition to last year's Annual Review chapters, two other bibliographies covering cost analysis have appeared. They include one by Billingsley (8) that is concerned mainly with library automation but includes a section on cost analysis. Added to this is the latest update of Olsen's bibliography (83) with a section on cost analysis.

This section reviews the cost analysis literature as it relates to libraries, library automation, computer systems, and mechanized information storage retrieval and dissemination systems.

There are two approaches that can be taken in cost analysis. In the first, one assumes that cost analysis is a continuing process in which a data collection system is integrated with processing routines to generate periodic status reports on the financial condition of an organization or process. An ongoing accounting system implies the existence of a set of accounts that serve as a basis for allocating expenditures to processes or projects. This continuing financial reporting methodology is advocated by Price (92, 94) in a summary of his important previous work (93) on an accounting system for information products. Unfortunately, the work by Price is the only available description of continuing mechanized cost collection systems. The second type of cost analysis, that of a one-time study of a particular library or function, is much more prevalent in the literature.

Library cost analysis. One interesting departure from the standard library cost analysis studies is reported by Wilkin et al. (140) and Robertson et al. (101). They record the time taken by an individual to perform a task such as abstracting a document. They also record the language of the document, the number of pages of the document, the
presence of an author abstract, etc. Analysis-of-variance techniques are used to determine which of the variables explain most of the variation in time taken to perform the abstracting. A regression equation is then formulated to predict the time required to abstract an article given certain characteristics of the article.

Valid cost data useful for comparisons among institutions are particularly difficult to obtain, but a report of a nationwide study by Pamlour et al. (85) presents costs of interlibrary loans for a stratified random sample of 12 university libraries. Assuming indirect costs of 50% of direct salaries and wages, and including only direct costs of processing a request, it was found that the average interlibrary lending cost was $4.12 per unfilled request and $<.67 per filled request. The analysis also tested the sensitivity of these values by varying the overhead rate to see the effect on unit costs.

Palmour & Gray (86) have also reported on a parallel study of interlibrary lending and borrowing within the state of Illinois, but in the Illinois study they extend their analysis to cover the cost of providing reference service. Reference questions were subjectively categorized into four groups: bibliographic citation, simple fact, multiple fact, and complex fact. They found that the cost per answered question ranged from $0.32 to $2.77, depending on its complexity.

Library automation cost analysis. An analysis of the cost of a library automation program from a managerial-planning perspective is given by Dammers (32). He begins his analysis by stating that the objectives of an automated system should be to provide flexibility, improve utilization, and provide better user-system interaction than a manual system. Dammers then considers the current allocation of resources within British universities and university libraries to see if his objectives could be met by an automation program. The analysis of staff utilization, acquisition patterns, and material usage patterns over time finally led to a prototype ten-year expenditure plan and staffing plan for an "average" university library engaged in automation activities.

A comparative study of the cost of a manual and an automated university library circulation system is reported by Ross & Brooks (102). They determine the percentage of staff time spent on specific circulation functions and calculate the cost per loan using the manual system. Estimates of amortized computer equipment costs and processing costs enabled calculations to be made of the cost per loan using an automated system. During the first year of operation of the system, the projected cost per transaction using the automated system exceeded the manual system cost by approximately 19%. By the sixth year, the authors project that the
manual system would cost 11% more per transaction than the automated system.

Another comparative analysis was conducted by Kilgour (60) in measuring the cost difference between computer-produced and manually-produced catalog cards. Kilgour states that the cost of a computer-produced card for the Ohio College Library Center is $0.106, while the cost of manually producing a card is $0.236. The problem with this comparison is that one does not know if the same accounting procedures were used to derive both cost estimates. The manual cost is a composite figure derived from two separate projects (Kilgour, 60, p.146).

Costs of converting bibliographic records to machine-readable form were the subject of a study by Bregis (16). Bregis analyzed the cost of creating a file of 300,000 catalog records using an on-line terminal to enter the data. Costs for staff time and computer support are given, along with percentages of time spent in keyboarding, editing, and proofreading the records.

An ongoing cost accounting system for planning, control, and resource allocation within the University of Köln (Cologne) library is reported by Stegemann (118). Detailed breakdowns of labor, building, computer equipment, and indirect costs over three years are presented for a number of cost centers in the library.

**Mechanized information systems cost analysis.** Until recently, researchers conducted much of the evaluation of mechanized information storage, retrieval, and dissemination systems by measuring the retrieval effectiveness (e.g., recall and precision) of such systems. The point has been reached at which it is possible to build mechanized information systems without too much technical difficulty. Questions now arise as to the economics of such systems. This section reviews a number of papers that focus on the problem.

Cooper (29) reports on a mathematical model for comparative cost analysis of information retrieval systems. He shows that the costs of operating a system can be divided into user and system costs and that the dialog with an on-line retrieval system takes place during three phases, each of which places different burdens on the user and the system. Given the cost per unit of user and system time, it is demonstrated that there is an optimal allocation of time between the user activities and system activities, for a required performance level of the system.

Negus & Hall (79) also look at the overall economics of information retrieval systems in terms of several factors: the cost of obtaining references, the cost of conversion of the references to machine-readable form, storage costs, computer search time, and the frequency of use of the system. Empirical estimates of these costs are given for one specific system,
and the cost per search as a function of the number of searches processed per month is plotted.

Search costs are an important factor in any analysis of a retrieval system. A number of papers have explored this problem (21, 38, 39, 58, 124, 139). In Wilde's paper (139), equations are given for the cost of searching tape files using a mini-computer. Tschudi & Meredith (124) also discuss search costs for tape files. They describe an accounting system that determines the cost of searching single or multiple fields of records, the cost of weighted versus unweighted searches, and the cost of testing numeric fields such as dates or accession numbers. El-Hadidy (38, 39) documents the costs of searching Chemical Abstracts Condensates tapes in terms of fixed and variable costs of the search process. Two other papers that discuss search costs are by Kabi (58) and Corbett (31). Both papers present costs for selective dissemination of information systems; in Kabi's paper, the costs are for searching Chemical Abstracts tapes, and in Corbett's analysis, data are from Chemical Titles, INSPEC, and Nuclear Science Abstracts tapes.

An analysis of the MEDLARS system by Lancaster (65) also contains information on a measure of search cost. In the case of Lancaster's evaluation, search cost for a user at an on-line terminal is determined by dividing the total time a user spends at the terminal by the number of unique relevant citations found by the user during the search. For 39 searches, the average cost per relevant citation (expressed in time) was 4.5 minutes and the median cost was 3.4 minutes. Also studied was the relation between the search cost and the experience of the users. As user experience increased, the unit cost decreased.

Storage costs of an information retrieval system are discussed by Smith & Herr (115). As part of a selective dissemination of information (SDI) and retrospective search system, the Lawrence Berkeley Laboratory stores data from Nuclear Science Abstracts tapes on an IBM 1360 Photodigital Storage System, a device with a one-trillion-bit capacity. Information given on the computer costs for SDI searching using the device indicates a reduction in costs by 20%.

Computer systems cost analysis. Evaluation of the economics of computer systems is a necessary step in the systematic analysis of library automation and mechanized information retrieval systems. Such an analysis must include cost and performance evaluation of both the hardware and software of the system.

An excellent economic analysis of computer systems is given by Sharpe (107), who first discusses the tools of micro- and macro-economics, using examples of computer systems to illustrate the concepts. He devotes the second part of the book to an application of this methodology to
computer problems. The size and growth of the computer industry is explored, problems of sale versus lease of computer equipment are analyzed, methodologies for measuring system performance are presented, component costs are discussed, and pricing of computer services is investigated.

The increased sophistication of computer systems has often led to increased productivity but has also caused numerous problems in the determination of equitable prices for computing service. Most of the problems stem from the introduction of multiprogramming, multiprocessors, and time-sharing where tasks are competing for computer resources and where there is no "standard" or fixed time within which a process or program will terminate. One approach to solving the accounting aspect of this problem has been suggested by Rettus & Smith (99). They report on an accounting system for a computer center that accumulates operations, managerial support, systems support, and programming support costs into an extensive series of accounts. Then, employing past usage statistics of the computer facility, they develop standard costs. These costs serve as the basis for charging an individual user for computer center services (including computer time). Variances from the standard costs are accumulated and adjustments in the standard rates are made periodically.

Operations Research Models

A number of operations research models have been used in aiding resource allocation for information service activities. They include location, queuing, search, and simulation models. In addition, two reviews of the application of operations research in libraries have appeared. The first is by Mackenzie & Buckland (69). They describe operations research studies that have dealt with collection size, loan and duplication policies, shelving and stack organization, and evaluation of libraries. Seymour (105, 106) reviews the research on methods for weeding a library collection to eliminate obsolete monographs and serials.

Location theory provides a methodology for optimizing the physical placement of a facility relative to a specified criterion. Raffel & Shishko (96, 109) have applied this technique to selecting a site for a new branch library within a university. Arguing that libraries are market-oriented (i.e., user-oriented), they suggest that the physical location of library facilities should be closer to the user than to a central library's technical processing facility. To locate new facilities, they calculate a matrix of the distances and the costs of travel between the physical location of user groups and library facilities. In addition, they calculate the number of trips between
points on the grid. Given a cost and frequency matrix, potential locations can be examined in terms of their cost of access.

Another form of the location model has been proposed by Kraft & Hill (61) in optimizing the placement of information centers. The model is formulated as a linear programming problem. (An excellent discussion of the concepts of linear programming and other operations research tools may be found in Wagner [133].) The objective is to maximize a function composed of the cost of transporting a unit of service from one site to another, the amount of service available at a given site, and the cost of placing a library at the site. Any solution to the problem must take into account the amount of service available at a site, ensure that the demand for service at a proposed site will be above some minimum value, and limit the number of information centers at a selected site to one.

Queuing occurs when the rate of service at a facility is less than the rate at which people or objects arrive for service. Bookstein (11, 12) develops a queuing model to aid in analyzing whether a card catalog in a library should be split into a dictionary catalog and a subject catalog or kept as one catalog. He analyzes the congestion that would occur when each approach was used. Mathematical queuing models for three measures of congestion are formulated: the probability of a card catalog drawer being used, the mean time a user must wait for access to a drawer, and the average number of people attracted to the drawer at any time. The analysis is extended to consider the number of volumes into which a book catalog should be divided.

The problem of optimal ordering of items to facilitate searching is formulated by Morse (77). He develops a linear classification scale in which a mathematical formula is used to determine where along the scale a particular item will be located. Items whose history of usage indicates they are used at the same time will be placed close to each other on the scale.

Simulation techniques have been used by Hall (48), to model the magazine publishing industry, and by Cooper (30), to model a document retrieval system. Hall (48) builds an industrial dynamics model (Forrester, 44) of the Saturday Evening Post in order to examine the relationship between advertising rate, promotion expense, magazine sales, subscription rate, total number of readers, total expense, and total revenue. He also explores the relation between the growth of the number of readers, the growth of revenue, and the profit margin.

Cooper (30) tried to determine the feasibility of using simulation techniques to evaluate the performance of a document retrieval system. In this attempt, sets of pseudo-documents and pseudo-queries are created using simulation rules intended to model some of the linguistic properties of documents and queries. The pseudo-queries are matched against the
pseudo-document file to determine the effect of varying the values of certain parameters on the number of documents matching a given query. The motivation for construction of the simulation model is the belief that variability between "real" document and query collections prevent valid inter-system comparison and that the only way uniformity can be assured would be to control all properties of the document and queries during retrieval system evaluation.

Computerized management games provide a means whereby individuals can practice decision-making in a simulated environment. Shubik (111) provides an excellent history of games, and Buckland & Hindle (20) discuss the use of games in a library environment. Brophy et al. (17) report on a computerized library management game currently operating. The game requires that participants make management decisions about loan policies, duplication policies, and acquisition rates. Performance of the participants is measured in terms of how well they maximize user satisfaction as measured by the availability of the material.

CONCLUSION

This review suggests that the objectives of studying the economics of information should be to analyze, from an economic standpoint, the process of producing and distributing information as well as how information is used. The process involves determining who are the producers of information, what are the resources and constraints on information production, and what are the methods for allocating resources to the producers and users.

One important area of research in this field is concerned with the economic analysis of information processing by individuals. Gradually, models of information processing behavior are being developed, but unfortunately much of the research is based on strong assumptions about the rational behavior of individuals. While continued research will undoubtedly result in more general models, it may be wise to consider the work of psychologists, physiologists, and sociologists in formulating such models.

The variety of tools available for assisting with resource allocation decisions about information products and services is increasing. Nevertheless there are a number of difficult problems remaining to be solved. For example, while we are beginning to see the development of models to predict the demand for information products, considerable work remains to be accomplished. Up to this point, there has been no real incentive to conduct such analysis. Information has usually been considered as something that is freely available, not something that has a price. With
limited budgets and alternative uses of resources, careful demand analysis will be necessary to justify the development of information products and services.

There are other tools that need further refinement. With respect to cost-benefit analysis, it is safe to say there is little agreement as to what constitutes the benefits of an information service, how to measure benefits, or how to measure externalities. The problems connected with the application of cost-effectiveness analysis are similar to those of cost-benefit analysis but less formidable. While measures of effectiveness such as circulation, recall, or precision are available, one would have to say that they cannot be considered the final measures of system performance.

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