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Economics of Libraries

Lewis G. Liu and Bryce Allen

Issue Editors

University of Illinois
Graduate School of Library and Information Science
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The style and tone of the journal is formal rather than journalistic or popular. Library Trends reviews the literature, summarizes current practice and thinking, and evaluates new directions in library practice. Papers must represent original work. Extensive updates of previously published papers are acceptable, but revisions or adaptations of published work are not sought. Although Library Trends is not formally peer reviewed, articles are invited for submission and are critically reviewed by both the guest editor and the journal editor.

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Economics of Libraries

Lewis G. Liu and Bryce Allen

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Introduction

LEWIS G. LIU

This Library Trends issue contains contributions from library and information science researchers as well as economists. The contributors were identified based on their previous empirical research and publications in economics of libraries and library information services. The manuscripts were reviewed by the issue editors, the Library Trends editor-in-chief, as well as an anonymous reviewer when necessary. Final approved articles are included in this issue. Publications in this issue are characterized by empirical research. Almost all the contributions are empirical in terms of having theoretical or analytical frameworks, and original data collection, or real-world cases.

The theme of this issue is economics of libraries. However, when discussing economics of libraries, one would naturally think of economics of information since libraries are information-provision institutions and many library operations and management decisions are made based on costs of journal subscriptions, monographs, databases, and online information systems. The scope of economics of information is much broader than many think. The literature on economics of information and libraries may consist of the following areas: asymmetric information (e.g., George A. Akerlof, 1970; A. Michael Spence, 1974; and Joseph E. Stiglitz, 1977); microeconomic studies on libraries as decision-making institutions, such as studies on economies of scale and management of libraries using production functions (e.g., Stanley W. Black, 1969; Robert M. Hayes, 1979) and cost functions (e.g., Michael D. Cooper, 1979, 1983; Paul Kantor, 1981; Larry DeBoer, 1992; Lewis G. Liu, 2002), cost-benefit studies of library operations, services, and databases (e.g., Bruce Kingma, 1998; Gary W. White & Gregory Alan Crawford, 1998), cost and planning models of libraries (e.g., William J. Baumol & Matiyahu Mar-
curs 1973; Charles McClure et al., 1995), and data envelopment analysis of library operations (e.g., Tser-yieth Chen, 1997; Donald F. Vitaliano, 1998; Andrew Worthington, 1999; Kehm R Sharma et al., 1999); economics of scholarly publishing and communication (e.g., H. C. Peterson, 1992; G.A. Chressanthis & J. D. Chressanthis, 1994; Richard E. Quandt, 1996; Roger G. Noll, 1996; Carol Tenopir & Donald W. King, 1997; Andrew M. Odlyzko, 1999; Mark J. McCabe, 2000); financial management of libraries and information services (e.g., Stephen A. Roberts, 1985, 1998); outputs, performance measures, and evaluations of libraries and information services (e.g., D. W. King & F. W. Lancaster, 1969; F. W. Lancaster, 1977, 1993; Paul Kantor, 1984; Nancy A. Van House et al., 1987, 1990; J. C. Bertot, C. R. McClure, & J. Ryan, 2001); economics of networks (e.g., M. L. Katz & C. Shapiro, 1985; N. Economides, 1996) and economics of the Internet (e.g., J. K. MacKie-Mason & H. R. Varian, 1995); information as a public good versus information as a commodity and free information versus fee-based information (e.g., Ellen Gay Detlefsen, 1984; Roger McCain, 1988; Charles W. Robinson, 1989; Maribelle M. Davis, 1991; Anne Goulding, 2001); and economics of intellectual property and copyright protection (e.g., S. M. Besen & S. N. Kirby, 1989).

This list is by no means exhaustive. It intends to highlight some important research areas in economics of information and libraries. Some of these areas have been studied by both economists and library and information science scholars. Other areas have been only the concerns of economists. While this issue does not cover all the above areas due to the time limit to complete this issue and limited pages allowed, the contributions cover a wide range of issues related to economics of libraries and information services and can be classified into four broad categories: economics of academic libraries, public libraries, library cooperation, and financial management of libraries. They not only reflect the new research trends but also reflect the continuation of this body of research literature from the past.

**ASYMMETRY OF INFORMATION**

Many economists study economics of information in terms of asymmetric information, adverse selection, and moral hazard. They examine how possession of information or dispossess of information affects the market system. This body of research literature has been developed solely by economists. Some important theories are represented by the works of three economists, George A. Akerlof, A. Michael Spence, and Joseph E. Stiglitz, who have recently received Nobel prizes for their work in this area.

The notion of asymmetric information was illustrated by George A. Akerlof (1970) with a seemingly simple observation: in a market transaction, sellers know something that buyers do not know and buyers know something that sellers do not know. When asymmetric information exists between buyers and sellers, market failure occurs. An example given by
Akerlof was the used car market where the buyer does not know which used cars are good ones and which used cars are bad ones. The seller is motivated to mislead the buyer. And the buyer expects that and discounts the price of the used car he or she tries to buy. Since the sellers of good-quality cars are less willing to sell their cars at discounted prices, bad cars eventually drive good cars out of the market. Such a downward discounting effect is called *adverse selection*. A. Michael Spence (1974) explored asymmetric information in the labor market. He observed that job applicants tend to "signal" their ability to potential employers through costly education. Since potential employers cannot directly observe job candidates' ability, they screen job candidates by examining their educational credentials and records. Joseph Stiglitz and Michael Rothschild (1976, 1977) investigated the effects and economic policy implications of asymmetric information in the insurance market. Stiglitz explained how insurance companies use the screening process to identify high-risk insurers and use various price structures, such as deductibles and premiums to classify insurers by their risk levels.

A fairly large body of research literature on asymmetric information and its effects on a wide range of markets has been generated since the initial research. A keyword search in *EconLit*, a primary index to the economic literature, retrieved over 1,700 records, indicating the magnitude of this body of research and the influence of this research orientation on economists. More importantly, this body of knowledge in economics has posed serious challenges to the wisdom of traditional economics that believes that the market is perfect (although sometimes it is believed to be less than perfect) and the "invisible hand" will be at work and eventually solve all the supply and demand problems. Through this body of research, it is now known that many markets are imperfect and that asymmetric information exists between buyers and sellers and therefore affects behaviors of individuals and organizations. Stiglitz's recent article (2000) provides a comprehensive review on research on asymmetric information and its contribution and role in the field of economics.

Research on asymmetric information provides useful policy guidelines. To correct market imperfection, government intervention can be necessary. The recent series of events related to corporate corruptive behaviors, such as falsifying accounting records to hide financial losses, have further exemplified the notion of asymmetric information and prompted the Bush administration to impose new laws and regulations to curb corporate mischief and to restore the investors' confidence in the stock market. This line of research can be applied to the library and information service industry to examine how asymmetric information affects this particular market. Information can be misrepresented by information providers such as publishers to information consumers such as libraries. So far, little systematic research has been conducted on this market.
Microeconomic Studies of Libraries

Microeconomic studies on libraries can be classified into a number of categories: economic theory of libraries, economies of scale using production functions and cost functions, data envelopment analysis, cost-benefit analyses, cost modeling, and performance measures.

Economic Theories of Libraries

Theoretical works on economics of libraries are also lacking. While the nonprofit nature of libraries is well recognized, little effort has been made to specifically differentiate libraries from other nonprofit organizations. As a result, no economic theoretical work on libraries has been developed. Theoretical works are important since they are tested and universally accepted principles that govern the behaviors of organizations and individuals and can be used to predict future behaviors of organizations and individuals. Economic theories of libraries help to explain why libraries seek certain goals and behave in certain ways and provide guidance for policymakers.

In this issue, Lewis G. Liu’s first article looks at the economic behavior of academic research libraries and how they maximize their utilities given budget constraints. He argues that academic research libraries, like some other nonprofit organizations, seek prestige as opposed to seeking profits. Unlike other nonprofits, academic research libraries seek to maximize their utilities by expanding the size of their collections. He examines the relationship between the size of collections and prestige of universities. The findings show that library collections account for a significant portion of the variance in university prestige.

Bryce Allen examines the economic theory of public choices in the context of public libraries. High quality of public library services and high levels of demand for such services are believed to correlate with high level of public funding. The findings show a marginal relationship between the use and funding of libraries and no association between public opinion and levels of funding. Allen concludes that noneconomic factors may play a role in funding for public libraries.

Robert M. Hayes applies the economic game theory to library cooperative environments in terms of resource sharing, cooperative acquisitions and automation, cataloging and storage sharing, preservation and access, and digital library development. Library consortia or other kinds of library networks may find this article useful for guiding their collaborations.

Economies of Scale, Production Function, and Cost Functions of Libraries

Lewis G. Liu’s second article deals with economies of scale of academic research libraries. He points out that libraries in general and academic research libraries in particular are multiproduct and multiservice information provision institutions. (Previous studies on economies of scale of librar-
ies using the Cobb-Douglas production function ignored that very nature of libraries and used a single output variable for estimating economies of scale of libraries.) He formulated a cost function incorporating a wide range of output variables into the cost function. The output variables used in the cost function reflect a variety of library products and services. The findings indicate that academic research libraries have slight economies of scale.

In fact, economies of scale studies on libraries can be traced back to as early as the 1960s when economist William J. Baumol and his colleagues published a report commissioned by the National Advisory Commission on Libraries in 1969 (Libraries at Large, p. 168) and entitled The Costs of Library and Information Services. Since then, many economic studies have been conducted to examine libraries as organizations or economic entities in terms of the production process of libraries. This body of research literature treats libraries as decision-making units (either as a group or as a single unit) in terms of how libraries can maximize their services and minimize costs given limited resources.

In the same year, Stanley W. Black (1969) developed an economic model for public libraries using the Cobb-Douglas production function. He used circulation as the dependent variable and library staff and book stock as the independent variables. This production function permitted him to estimate scale economies of public libraries. Given the high multicollinearity between the labor and capital variables, he assumed that constant returns to scale existed. With that assumption, he was able to figure out the coefficients for labor and book stock variables. Black’s study on public libraries, particularly the econometric methodology he used, has a far-reaching influence on the later studies.

Since Black’s empirical study, several studies on scale economies and management of libraries have been conducted by economists as well as library science researchers. Some used production functions (Haynes C. Goddard, 1973, Robert M. Hayes, 1979). Others used general cost functions (Michael D. Cooper, 1979, 1983; Paul Kantor, 1981; Lewis G. Liu, 2002). Still others used translog cost functions (Larry DeBoer, 1992; Christopher J. Hammond, 1999). This body of research literature is small in number but covers a variety of libraries and utilizes quite diverse econometric models. It covers public libraries, scientific and technological libraries, private and public college and university libraries. Some were interested in scale economies of libraries only. Others examined scale economies of libraries as well as input substitution elasticities. These studies tend to specify inputs, outputs, labor, capital, and costs associated with these variables, and attempt to find whether economies of scale exist in various libraries, particularly public libraries. The economic reasoning is that consolidating smaller-sized libraries can lead to cost savings.
Data Envelopment Analysis (DEA)

Wonsik Shim provides a detailed discussion on the DEA model and the calculation of the relative technical efficiency of ninety-five academic research libraries. According to his findings, a number of academic research libraries have lower scores, indicating that they do not operate as efficiently as many of their counterparts. As Chen (1997) pointed out, there are no quality measures built in to DEA. To know more about library operations, it is important to use both DEA and site visits.

Data envelopment analysis is a mathematical programming method that incorporates multiple inputs and multiple outputs to evaluate the relative efficiency of an organization, a project, or a program. Although it is mathematically complicated, it is essentially an output-to-input ratio. If this ratio is 1, then it can be concluded that the organization operates efficiently since its inputs produce the same amounts of outputs. The extent to which the organization is considered efficient depends on how close its efficiency scores are to 1. This body of literature in the past was exclusively generated by economists. DEA was originated by Charnes et al. in 1978, mostly for nonprofit organizations (William F. Bowlin, 1998, p. 1) whose goals are not for making profit, and whose performance is not evaluated based on profit criteria. This method enables researchers and managers to evaluate efficiencies of organizations. Since for-profit organizations also need to improve efficiencies of their operations, this method has been quickly applied to a wide range of business, industry, and service sectors.

Only in recent years, have economists started examining efficiencies of libraries using DEA. In 1997, Tser-yieth Chen investigated the efficiencies of twenty-three university libraries in Taiwan. He found that about half of the libraries under investigation are relatively efficient. A few libraries are highly efficient. But a few libraries managed their resources poorly. In 1998, Donald F. Vitaliano studied 184 public libraries in New York using DEA. He found that 67 percent of the libraries evaluated were efficient and attributed inefficiencies to long opening hours. Two studies using DEA in 1999 were conducted by Andrew Worthington and Kehm R Sharma et al. Andrew Worthington (1999) looked at 168 New South Wales local government libraries in Australia. The findings show that about 67.2 percent of the libraries met various efficiency criteria. Sharma et al. (1999) looked at the efficiencies of forty-seven public libraries in Hawaii. They found that only about 30 percent (fourteen of the forty-seven) libraries are technically efficient.

There are advantages and disadvantages of using DEA. Traditionally, economists use regressions such as the production function and various forms of cost functions (translog cost function and general cost functions) to evaluate efficiencies of organizations. They normally take the advantage of log transformation to calculate the function coefficient. The function coefficient (which can be either the production function coefficient or the cost
function coefficient) is used to determine whether or not an organization operates efficiently. The regression techniques can also help economists to formulate models for predicting future demand for labor and materials.

But regression techniques have limitations. The first limitation is that in order to use regression techniques, there must be enough data points to achieve statistical significance. In many cases, it is impossible to run a meaningful regression with limited data points. For example, Chen’s study on the efficiency of academic libraries in Taiwan would not have been possible using the regression technique simply because there were only twenty-three libraries. That number is not sufficient enough to run a successful regression. The use of DEA is perfectly suitable for this small sample of data. The second limitation is that the regression using the production function only permits one output variable. DEA allows a number of output variables. Libraries are multiproduct and multiservice information provision institutions. Using only one output variable ignores that very nature of libraries. The third limitation is that regression techniques are not able to identify sources (inputs and outputs) and specify the amounts of inefficiencies related to these sources. DEA is able to identify sources and specify the inefficiency amounts (William F. Bowlin, 1998).

The disadvantages of DEA are mostly the advantages of using regressions. They include the following: no statistical significance is tested for DEA; lack of predicting power; and difficult to calculate, although some software programs have been developed for DEA. Chen also pointed out that DEA lacks quality measures and suggested that researchers visit libraries to gain a better understanding of the quality side of services provided by libraries. He recognized that the complexity of the method makes it difficult to communicate with library administrators (p. 79).

**Cost and Benefit Analyses, Cost Modeling, and Performance Measures**

Traditional economic cost and benefit analysis calculates present value of a stream of cost items and present value of a stream of benefit items in monetary terms. If the total present value of costs outweighs the total present value of benefits, the project is not worth pursuing. Bruce Kingma (e.g., 1998) applied cost-benefit analyses to access, ownership, and interlibrary loan service. Cost and planning models are developed and used to predict future costs based on a given level of labor, capital, services, and outputs. William J. Baumol and Matityahu Marcus (1973) developed cost and planning models for academic libraries. Charles R. McClure et al. (1995) developed Internet cost models for public libraries. F. W. Lancaster (1977, 1993), Nancy Van House et al. (1987, 1990), and J. C. Bertot, C. R. McClure, and J. Ryan (2001) developed performance measures for various libraries and information services.

In this issue, Donald W. King, Peter B. Boyce, Carol Hansen Montgomery, and Carol Tenopir provide a cost-benefit analysis of library electronic
collections and services. As libraries, particularly academic libraries, are increasingly moving toward digital libraries, it is critical for libraries to have a better understanding of the nature of electronic collections and services, how they affect library policies toward print collections, and what optimal choices are available during the transition period from print to digital libraries. King, Boyce, Montgomery, and Tenopir present an analytical framework for comparing electronic journal collections and services with their print counterparts using a number of measures including inputs, outputs, performance, usage, cost effectiveness, and outcomes. They demonstrate the use of these measures by applying them to a number of library settings. The framework they have developed is multidimensional and certainly contributes to our better understanding of measuring the performance of library services.

Glen E. Holt and Donald Elliott provide a cost-benefit analysis framework for public libraries. Although their empirical research is still in process, the methodology to be used in their investigation can be useful for those who intend to do similar projects.

As more and more information is available on the Web and more and more people use the Web, many academic libraries, public libraries, as well as special libraries have started providing digital reference services including email reference service and e-chat service. Since digital reference service requires staff time and technical support it is important to know how efficiently and effectively this service is provided. R. David Lankes, Melissa Gross, and Charles R. McClure discuss two types of standards (utilization standards and technical standards) for calculating costs, gathering statistics, and developing measures for digital reference services. Utilization standards consist of two broad measures: quality measures and performance measures. Both quality and performance measures contain a number of subcategories to reflect user satisfaction level, service scope and service quality, staff time, and costs. Technical standards consist of question interchange, profile, and knowledge base. Both types of standards provide useful guidelines for helping library administrators make decisions as to how to plan, implement, and evaluate digital reference services.

**Economic Studies on the Scholarly Publishing Industry**

This area of research tends to focus on the demand and supply of information in the scholarly publishing industry. Researchers explore questions like: What factors affect costs and prices of journals, books, databases, library computer hardware and software and storage, Internet information services, and other information services, what role publishers play, and how libraries respond to these price changes. Since scholarly journals play a crucial role in scholarly research and communication and prices of scholarly journals have been escalating year after year, this issue has
drawn a great deal of research attention from library and information science researchers and economists.

There has been a long struggle between libraries and publishers about prices of scholarly journals. Libraries have limited budgets but are faced with increasing prices of journals to the extent that many libraries have to cancel some of their journal subscriptions and cut book purchases to keep up with such increases and to protect their core journal collections. Some reasons given for escalating journal prices are increases in journal production costs, fluctuations in currency exchange rates, decreases in journal circulations, and so on. But libraries are not convinced that these are the only sources of increasing journal prices. Instead, they believe that commercial publishers "reap monopoly profits." To investigate the causes for rising prices of journals, the Association of Research Libraries (ARL) contracted Economic Consulting Services to conduct a study on serials prices offered by four major commercial publishers in 1988 (Economic Consulting Services, 1989). The findings show that the increases in journal prices charged by four major commercial publishers cannot be totally explained by the increasing production costs of these journals. A 1997 study on U.S. scientific journals by Carol Tenopir and Donald W. King also pointed out that the increases in journal prices were higher than increases in cost factors, such as inflation, the increased size of journals, capital, labor, and other costs. They believed that pricing policies of publishers accounted for "the majority of the remaining increases" and the sharp decline of individual subscriptions led publishers to increase prices of institutional subscriptions. Publishers were able to impose discriminatory prices on institutions because of relative price inelasticity of demand for journals by institutions (Tenopir & King, 1997, p. 52).

While libraries tend to blame publishers for reaping monopoly profits, some have not been convinced that publishers are the only ones to blame (Henderson, 1998; Mobley, 1998). Others questioned the accuracy of the calculations of profit margins of publishers (Noll & Steinmueller, 1992). Albert Henderson argued that at least part of the serials crisis was attributable to libraries' parent institutions: universities. He pointed out that libraries have been increasingly receiving less and less share of university spending for decades (p. 2). Canceling journal subscriptions by libraries drove up the average costs of journals and therefore the journal prices. This is because the budget problem was created by universities that invested their revenue surpluses in real estate, equity, and fixed-income markets instead of investing in library collections (p. 4). He also pointed out that the important role of science libraries in supporting research and information dissemination is also neglected by various government agencies and called for reforming the current federal "indirect cost" policies on information resources and for strengthening financial support for research libraries (p. 6).

Emily R. Mobley (1998) also argued that publishers are not the only
ones that caused the problem. Many factors contributed to the current serials crisis. Federal funding for research programs has been shrinking as a result of domestic policy shifts, and corporate downsizing has also impacted libraries in the commercial sector. She maintained that it is not unusual for commercial publishers such as Reed-Elsevier to seek dominant control of the publishing industry since it behaves no differently from corporations in other industries. She believed that it is too easy for faculty to give up their copyrights and too easy for faculty sitting on editorial boards to approve price increases or policies that later lead to price increases, such as increases in page numbers to provide more opportunities for their colleagues who are faced with the "publish or perish" situation. She argued that scholarly societies also play a role in this crisis. Although increases in journal prices of scholarly societies are lower than those of commercial publishers, they are still higher than general inflation (p. 5) and they charge libraries higher prices than they do individual members. She further argued that university administrators are not helping the crisis. Instead, they push libraries to solve the problem through cooperations with other libraries and consortia agreements.

In this issue, Richard E. Quandt discusses the issue of the economics of traditional publication media and digital media for scholarly publications, provides a comprehensive review and in-depth analysis of the research literature related to the phenomenon of journal price increases, and identifies the causes of these increases. He discusses this important issue in the macroeconomic context as well as the context of the scholarly publishing industry and explains why computer applications in the 1960s through 1980s did not contribute to economic growth in general and to solving the problems of scholarly communication in particular during that time period. He then focuses on the economics of scholarly publishing in terms of costs of producing, distributing, archiving, and using print and electronic scholarly materials. Finally, he discusses issues related to pricing of scholarly journals and bundling scholarly materials and explains why price discrimination exists for scholarly journals. He concludes that commercial publishers will still control electronic scholarly publishing media at least in the near future. His article certainly sheds new light on the current debate over scholarly publishing and will help library administrators and librarians gain more insights into this important research topic.

Financial Management of Libraries

Financial management of libraries is the process of managing financial resources of libraries, including financing, planning, accounting, budgeting, controlling, and so forth. While financial management is an important part of library administration, the research literature on financial management of libraries is small.

In this issue, Jennifer Ellis-Newman’s article deals with cost accounting
in academic libraries. She specifically explains the advantages of using activity-based costing (ABC). ABC is a management tool of identifying and assigning indirect costs to library products and services based on the factors that are most relevant to them. She has analyzed and classified cost drivers commonly used in libraries. These cost driver classifications can help library managers look at relevant cost data and make accurate cost estimates and good decisions to improve efficiencies of libraries. Cost accounting of libraries is part of the financial management of libraries and provides a cost basis for economic analyses, such as the relationship between average cost and marginal cost. Using irrelevant cost data can cause miscalculation of average cost and therefore affects accurate evaluation of efficiencies of libraries. ABC is certainly a useful management tool for library managers.

Stephen A. Roberts discusses the issue of financial management of library and information services from a macroperspective. He examines the impact of the macroeconomic environment on the library information service industry and observes that business management models have been increasingly applied to library management. He presents a number of criteria for library and information service management based on Maurice Line’s work and develops objectives for financial management of library and information services. It is a useful article for library administrators to understand the issues related to financial management of libraries.

**SUMMARY AND CONCLUSION**

In this *Library Trends* issue some articles have addressed issues that have not been explored before. Others have followed the existing line of research but have broken new ground. Still others have integrated a vast body of research literature, and provided in-depth analyses and valuable insights into the issues under investigation. Measuring and evaluating performance of library operations and services are still major research concerns. Some microeconomic and managerial accounting tools, such as the cost functions, DEA, ABC, and CBA have been used to measure operating efficiencies of libraries. The focus is on academic libraries. Another main research concern is managing electronic resources and services as a result of their increasing applications in libraries in recent years. New paradigms, standards, and analytical frameworks have been developed to guide and measure electronic or digital collections and services. Scholarly publishing is also a key issue. We have to wonder why, as costs of digital communications, computation, and networking are increasingly falling, and as producing, organizing, bundling, and distributing digital information are becoming increasingly inexpensive and digital information can be even reproduced at zero marginal cost, prices of scholarly journals are still high—high enough for many academic libraries to cancel them in order to protect their core journal collections. Some answers to this puzzle can be found from articles in this issue. Given the current technological, political, and economic envi-
enronments, cooperation among libraries and library consortia in terms of sharing resources and services are not uncommon. Descriptive articles on library cooperations are many, but few offer theoretical insights into cooperative activities. This issue provides theoretical guidance for cooperative decision-making and reflects the continuing research interest in library cooperation. More efforts in theoretical works need to be made. The unique nature of libraries as one kind of nonprofit organization needs to be further explored.

It is our hope that contributions in this issue provide useful, practical guides, research tools, and the latest research findings for library administrators and researchers to better understand issues and problems related to the economics of libraries.

Note
1. While much of the performance and measurement literature tends to focus more on statistical measures of various library services and operations than on economic analyses, it provides quantitative tools for economic analyses, and in some cases, it does consider cost factors.

References


The Economic Behavior of Academic Research Libraries: Toward a Theory

LEWIS G. LIU

ABSTRACT
This article examines the economic behavior of academic research libraries. It argues that academic research libraries seek to maximize universities' utility by expanding library collections. The log-linear model that reflects the relationship between library collections and prestige of universities was formulated, tested, and proved to be the best fit of the data. The regression results show that about 40 percent of the variance of the dependent variable can be accounted for by library volume collections and 26 percent can be explained by library serials collections. The findings are consistent with those from a previous study using a different ranking system and sample data and reconfirm that indeed library collections contribute significantly to prestige of universities.

INTRODUCTION
The history of academic libraries in the United States is almost as long as that of academic institutions of higher learning.1 Academic research libraries play a significant role in supporting teaching and research at universities by acquiring and maintaining library collections and by providing a wide range of library and information services. This study examined the economic behavior of academic research libraries. It argues that academic research library administrators tend to maximize their library utility by expanding the size of library collections. The rationale for seeking to expand library collections can be exemplified by the statement made by a group of academic research library administrators who are associate deans for planning and administrative services, collections, and information access services. Ronald F. Dow, Salvatore Meringolo, and Gloriana St. Clair
(1995, p. 103) stated that "Library collections have been viewed as the soul of the academic disciplines, the repository of all the research and scholarly effort that has gone before. For that reason the size of the library’s collections in each of the disciplines in some way is seen as a reflection of the institution’s commitment to learning within an academic discipline. For as a college or university invests in collections, it vests the academic discipline on campus with local value and prestige too. As the library collections support research and study in an area of knowledge, the institution will be able to attract the best scholars and students of that discipline, enhancing faculty reputation, the value of the degree earned by students, and institutional image." This investigation explains why academic research libraries behave the way they do by empirically examining the relationship between the size of collections and prestige of universities. Prestige of universities is, according to the economic theory of universities, believed to be crucial for survival and competitiveness of research universities since it attracts fine scholars, top students, and funding from various sources.

It is important to differentiate academic research libraries from general academic libraries and nonacademic research libraries. Academic research libraries in this article refer to those that support missions and goals of research-oriented universities. There are about 110 of these libraries belonging to the Association of Research Libraries (ARL). ARL has specific requirements and standards for its members in terms of the level of collections, total number of staff, size of budget, and level of technologies used in the libraries. These academic research libraries have a strong emphasis on research collections. There are many more general academic libraries with collections that are mostly used to support teaching and do not have comprehensive research collections and services. There are also nonacademic research libraries, such as the New York Public Library, which have comprehensive research collections but do not share the missions and goals of academic research libraries. These three kinds of libraries have different missions and goals and therefore their economic behaviors may differ. The discussions of this article specifically focus on academic research libraries.

Why Economic Theory of Academic Research Libraries?

Scholars in all disciplines, such as the physical sciences and social sciences, have made great efforts in developing theories of their disciplines. The field of economics deals with how individuals and organizations utilize their limited resources to meet their needs and make better choices to maximize their economic welfare. Economic studies on academic research libraries are important because academic research libraries, like all other organizations, need to make choices and effectively and efficiently use their limited resources to achieve their organizational goals. Economic theory, like many other theories in the physical and behavioral sciences, is "a set of propositions" that have been tested and proved to be universally accepted prin-
ciples that allow us to explain and predict future economic behaviors of individuals and organizations. Economic theory of academic research libraries can help university administrators, library administrators, librarians, and others to better understand the economic behavior of these libraries. It provides a conceptual framework for understanding why libraries behave in certain ways and addresses questions like: What kinds of organizational goals do academic research libraries seek? How do academic research libraries differ from universities and other nonprofit organizations? What are the unique economic characteristics of academic research libraries? How do they maximize their utility and improve their operating efficiencies as compared with other nonprofit organizations?

While there have been studies on some economic aspects of academic research libraries, such as their costs, economic behavior has rarely been examined and no theory governing the economic behavior of academic research libraries has been put forward. This article intends to develop a theoretical framework governing the economic behavior of academic research libraries and to test some of the assumptions using empirical data.

THE RESEARCH LITERATURE

Before the discussion of the theory of economic behavior of academic research libraries, it is important to review the literature on economics of nonprofit organizations and economics of universities—for a number of reasons. First, an academic research library is a unit of a university and shares overall missions and goals of the university. Second, universities are commonly categorized as nonprofit organizations and share some common characteristics of nonprofit organizations. Third, some theoretical works on nonprofit organizations in general and on universities in particular have already been developed and can be used to serve as a basis for further development of the theory of economic behavior of academic research libraries.

Economics of Nonprofit Organization in General: Three Sectors of the Economy

In the United States, there are mainly three sectors in the economy: the for-profit sector, the government sector, and the nonprofit sector. The goal of for-profit enterprises is to make a profit. Profit can be made through producing low-quality goods or providing low-quality services and charging lower-prices or through producing high-quality goods or providing high-quality services and charging higher prices. The private sector is the largest sector in the U.S. economy comprising over 85 percent of GDP (U.S. Census Bureau, 2000, p. 452). Privately owned businesses and corporations that sell stocks to raise capital for their operations belong to this sector.

The public sector has emerged in many countries. One of the reasons for the existence of the public sector, according to the economic theory, is market failure. Market failure exists when private markets are not able to provide certain goods or not able to provide them at the optimal level. The
public sector provides a variety of public goods to meet economic, social, and educational needs of people, which the private sector is not willing or not able to provide. The nonprofit sector has become an important part of economic systems of many countries. It exists because of the failure of both the private sector and the public sector to provide certain goods and services demanded by certain segments of society. A nonprofit organization is a voluntary institution that does not seek to make a profit. U.S. nonprofit institutions are given tax-exempt status by the Internal Revenue Service. Unlike a corporation whose profit can be redistributed to its stockholders in the form of dividends, the surplus (excess of income over expenditures) of a nonprofit must not be redistributed to any members of the organization, but can be used for future operations. Henry Hansmann (1980) classified nonprofit organizations into donative nonprofit organizations and commercial nonprofits. Donative nonprofits receive donations from various individuals and institutions as the source of their income. Commercial nonprofits derive their income from sales and services. According to Hansmann, both forms of nonprofits can be either mutual or entrepreneurial. Donors control mutual nonprofits, whereas customers control entrepreneurial nonprofits. There are various kinds of nonprofit organizations, including hospitals, nursing homes, day-care centers, educational institutions, religious organizations, and various forms of voluntary organizations. Richard E. Quandt has recently pointed out that there exists another kind of nonprofit: charitable foundations which are neither donative nor commercial. He provided examples of the Andrew Mellon Foundation, the Ford Foundation, the MacArthur Foundation, and the Hewlett-Packard Foundation, and argued that these foundations may have at one point received donations but they are not controlled by the original donors. Their income is generated from portfolios.

The for-profit sector has long been researched by economists and there exists an enormous and well-established body of economic literature on the private sector. Economic studies on the public sector are also abundant. But economists did not pay much attention to the nonprofit sector until the 1970s when more and more nonprofits emerged and became an important sector of the national economy. The lack of understanding of the roles and behaviors of nonprofits and the need for policy guidance prompted many economists as well as scholars in other academic fields to study why they exist and how they perform. In 1977, the Program on Non-Profit Organizations at Yale University was established. Economic researchers were assembled to study theories and practices of nonprofit organizations and to provide policy guidance for government agencies as well as for nonprofits. As a result, hundreds of journal articles, books, and working papers have been published (Brewster, 1986).

Some economic studies on nonprofits were conducted as early as the
1960s, such as Kenneth Arrow's study (1963) on medical care and William J. Baumol and William G. Bowen's study (1966) on performing arts. Serious theoretical inquiries into the roles and the behaviors of nonprofits by economists probably did not start until 1970 when Newhouse published his article entitled "Toward a theory of nonprofit institutions: An economic model of a hospital" (Newhouse, 1970). There is no single universal economic theory explaining the role and behavior of nonprofits. But rather, there are a number of theories and models developed to explain the existence and goals of nonprofits, such as the public goods theory, contract failure theory, subsidy theory, consumer control theory, entrepreneur theory, and competition theory (Rose-Ackerman, 1986; Hansmann, 1987). This is due to the fact that there exists a wide variety of nonprofit organizations in terms of control, such as mutual versus entrepreneur and donative versus commercial (as Hansmann classified) and in terms of the different nature of these nonprofits, such as performing arts, day-care centers, hospitals, educational institutions, religious organizations, and so on. While these theories and models are not completely consistent with one another, they are mostly interrelated.

The mainstream theory of nonprofits was proposed by Burton Weisbrod (1986). He believed that the existence of voluntary nonprofits is the result of government failure in providing certain public goods for a certain segment of the population. Public goods provided by the public sector through the political process are not adequate to satisfy the demand of all voting citizens. Citizens demanding higher levels of public goods and services would have to make altruistic donations to voluntary organizations that are willing to provide such goods and services. As Susan Rose-Ackerman (1986) pointed out, Weisbrod’s theoretical assumption suggests that a Pareto superior situation exists in which both the public and the nonprofit sectors provide higher levels of public goods and services than the public sector alone does—everyone is at least as well off as in a situation without the nonprofit sector. Weisbrod’s theory was criticized by Jeffery Weiss and Henry Hansmann. Weiss (1986) argued that “…if the levels of voluntary and governmental provision are determined simultaneously, then a high demander may be worse off with voluntary provision than without it.” Hansmann (1987) also pointed out that “The services provided by many nonprofits do not seem to be public goods but rather appear to be private ones. This is true especially of commercial nonprofits.” Despite the criticisms, Weisbrod’s theory remains the major contribution to explaining the existence of voluntary nonprofit organizations.

Another main theory that attempts to explain the existence of nonprofit organizations is the contract failure theory that originated from the study of day-care centers by Nelson and Krashinsky (1973). According to this theory, parents may have difficulties in judging the quality of services pro-
vided by for-profit firms and worry that they may provide low-quality services to maximize profit. Parents tend to trust nonprofit firms that have no incentive to maximize profit given their nondistributive nature. People buy products and services of nonprofits because they believe that nonprofit organizations are trustworthy. Later, this theory was broadly applied to other kinds of nonprofit organizations (Hansmann, 1987, p. 30).

While economists try to explain why nonprofits exist in our economy by developing theories, they also attempt to describe economic behaviors of nonprofits. Joseph Newhouse, one of the early pioneers studying economic behavior of nonprofit organizations, particularly hospitals, believed that the goal of nonprofits is to reach the highest possible utility by maximizing quality and quantity of their services and that the seeking profit criterion as used by for-profit organizations cannot be applied to nonprofit organizations. Newhouse (1970) argued that “... the prestige of the institution is prominent among other variables,” and “... a pursuit of status ..., a desire to serve society, ... a desire to show professional excellence or technical virtuosity by stressing quality” are some of the nonmonetary goals nonprofit organizations seek. Although Newhouse stressed the prestige or quality side of services, he recognized that nonprofits have budget constraints and it is impossible to maximize both quality and quantity of their services with these constraints. He observed that nonprofit organizations may prefer a higher level of quality to a higher level of quantity if they have to choose between quality and quantity of services. This behavior obviously differs from that of many profit-maximizing firms, which would tend to make profit by producing a larger number of lower-quality goods and services. Once a nonprofit organization achieves a given level of quality, it will maximize quantity of its goods and services to reach the highest utility.

*Economics of Education*

Institutions of higher education are considered as nonprofit organizations. Economists did not pay much attention to economics of education until 1961 when Theodore Schultz (1961) published the seminal article *Investment in Human Capital*. He eventually won the Nobel prize in economics for his contribution to economics of education and agriculture. Since then, much of the research on economics of education has been dominated by the human capital theory. Studies on investment in education and training and rate of returns on investment in higher education, secondary education, and primary education have become prevalent. Such studies have been conducted not only by economists but also by scholars in education in the attempt to improve productivity of workers as well as to achieve economic growth and development in less developed countries. Economic analyses of educational institutions, such as higher education, were also scarce before the 1970s. James Maynard (1971), Donald Verry, and Bleddyn Davies (1976) were among the earliest to study economics of institu-
tions of higher education. Maynard studied economies of scale of higher education in the United States and Verry and Davies examined costs and outputs of universities in the UK.

Two important theoretical works on economic behavior of colleges and universities were produced by Estelle James (1978) and David A. Garvin (1980). James formulated a model for postsecondary educational institutions in the United States and argued that it could also be applied to some types of nonprofit organizations in general, such as health and the arts. She maintained that universities produce multiproducts: undergraduates, graduates, and research, and engage in “cross-subsidization” activities, and argued that undergraduate education is a “profitable activity” and graduate education and research is a “consumption activity” since revenues generated from undergraduate tuitions are larger than those from graduate education because undergraduate classes are bigger than graduate classes. The revenues gained from undergraduate education could be used to support graduate education and research since the latter is considered as a more preferred activity.

Garvin specifically studied the economic behavior of universities. He argued that universities are utility-maximizing nonprofit organizations and that prestige is the most important part of a universities’ utility function. According to his assumption, administrators of universities prefer to enhance prestige of their institutions by recruiting top students and well-known scholars. Garvin also observed that faculty members also want to increase their personal prestige and prestige of their academic programs to attract research grants and enhance their own market value. Quality and quantity of students are also considered as important factors of the utility function of universities. Garvin believed that to improve prestige, universities need to offer advanced academic degrees, such as doctoral degrees. Both quantity and quality of research activities are crucial to enhance prestige of departments.

**Economic Studies of Academic Libraries**

Academic research libraries play an important role in accomplishing the missions and goals of universities. They select, acquire, organize, and maintain collections (books, journals, databases, and other library materials) and provide various library and information services to support teaching and research at universities. Empirical economic studies of libraries were conducted notably by a few economists and library science scholars with in-depth training in quantitative research methodologies. Most of these studies focused on scale economies of public libraries and academic libraries.

William J. Baumol et al. (1969) studied costs of various types of libraries. They looked at scale economies of libraries and found that economies of scale existed for large-sized public libraries but pointed out that savings were small. Baumol and Marcus published a book on economics of academ-
ic libraries in 1973. This book looked at growth rates of college and university libraries, costs of acquisitions, costs of library operations, and cost trends, and explained the role of economic analysis in library budget preparation. They separated public and private college libraries, grouped them by various enrollment levels, and specifically regressed a number of dependent variables such as total library staff, volumes added, cost of volumes added, and total library operating costs on a number of explanatory variables such as volumes held, expenditures per student, and college enrollment level. The results of these linear regression analyses were statistically significant. The authors argued that such regression models can be used for long-term planning and budget preparation. For example, a library’s operating budget can be determined by volumes needed to be added and professional librarians needed to be hired in the future. This study was one of the earliest economic analyses applied to academic libraries.

Stanley W. Black (1969), Haynes Goddard (1973), Kathleen Foley Feldstein (1976), Michael D. Cooper (1979), Larry DeBoer (1992), and Christopher J. Hammond (1999) studied scale economies of public libraries. Black; DeBoer; and Hammond also looked at input substitution elasticities. Robert M. Hayes (1979) examined the optimal use of labor and capital in providing services. A very few researchers studied academic libraries. Kantor (1981) specifically formulated a total cost function for scientific and technical libraries with total cost as the dependent variable and in-house material use, circulation, and reference queries as the independent variables. Cooper (1983) studied two-year and four-year private and public academic libraries. Some researchers used the Cobb-Douglas production function. Others used cost functions. Findings were mixed. Some found increasing returns to scale and others found decreasing or constant returns to scale. Robert M. Hayes and Harold Borko (1983) examined the relationship between the size of academic research libraries’ collections and faculty research productivity as measured by faculty publications. They found a significant contribution of library collections to faculty research productivity.

Cost-benefit analyses and cost modeling have also been used in various library settings. For example, Bruce Kingma (e.g., 1998) applied cost-benefit analyses to issues on access, ownership, and interlibrary loan service. Charles McClure et al. (1995) developed Internet cost models for public libraries.

In recent years, economists began to apply data envelopment analysis (DEA) to academic (Chen, 1997) and public libraries (Vitaliano, 1998; Sharma, et al., 1999). DEA is a methodology for measuring the efficiency of programs and organizations. It is widely used in business and industry. There are a number of advantages to using this methodology: it can be used to deal with multiple inputs and outputs and can be used as a standard criterion to compare peer institutions. Because of the highly quantitative
nature of DEA, it has not been utilized as a management tool by either librarians or library science researchers.

**This Study**

Economic studies on libraries are intended to improve efficiency of libraries and for long-term planning related to library materials, staff, and services. Empirical studies on economic behavior of libraries, particularly academic research libraries, in terms of what kinds of goals and objectives they pursue, how they maximize their utility, and why they behave the way they do, seem to be ignored. This article argues that academic research libraries, like universities, are also utility-maximizing institutions and that academic research libraries seek prestige by expanding and maintaining their volume and serial collections to support teaching, research, and learning at their universities. This article further explains why academic research libraries seek to expand their collections by specifically examining the relationship between the size of print collections of academic research libraries and prestige of universities. As part of a university, an academic research library is under the control of the university in a number of ways. First, the missions and goals of the academic research library must be consistent with the overall missions and goals of the university. Second, the academic research library receives funds from the university for its operations. The library's budget is part of the overall budget of the university. Third, the library is administratively controlled by the university. Its administrators, such as its director, are recruited and appointed by the university. In other words, the academic research library is not a complete, independent unit in terms of finance, administration, and the overall mission. However, the utility function of the academic research libraries is different from that of academic departments because of the role of academic research libraries in supporting the teaching and research at universities and the nature of services they provide. Academic departments maximize their utility by increasing the prestige of their programs. To do so, they recruit well-known scholars and enroll top students. A famous faculty member is likely to bring in more research grants and attract more top students. But the utility function of academic research libraries differs from that of academic departments. Academic research libraries seek prestige by maintaining and expanding the size of their collections. With comprehensive collections, an academic research library can adequately support the research and teaching of faculties. Given limited budgets, academic research libraries have to make a choice that can best contribute to the library's utility and overall university's utility. It is argued that their priority is collections. A larger size of an academic research library collection leads to a higher level of prestige for its university.

Quality and quantity of research contributes significantly to the prestige of universities. Academic research libraries play a significant role in
supporting research and facilitating scholarly communication. The current research is often built on previous research and previous research findings are normally documented in formal publications such as books, journal articles, working papers, and conference proceedings. Libraries select, purchase, and organize these materials in such a way that they can be readily accessed and retrieved. Scholars rely on books and articles for their research. They learn new ideas, discover new findings related to their research, and communicate with their peers formally through reading books and articles. To a certain extent, the effectiveness of research often depends on the size of the collections of the library. An instant access to an article needed by a scholar certainly will help to expedite the research process. Difficulties in getting information that a scholar needs can slow down or even stop the research. A widely used phrase in the library research literature to describe this situation is “Access delayed is access denied.” An adequate collection is crucial for effective research. Although Internet technology, such as the use of Ariel and a Web site to send and receive articles, has emerged and is used to speed up the process of borrowing items located outside the library, locally owned items or items that can be accessed locally are still more readily accessible than items that can be obtained from other libraries via interlibrary loan or membership of a library consortium.

Academic libraries have been collecting print materials for hundreds of years. While print collections have been an important indicator of capacity to support teaching and research at universities, in recent years Internet technology has been applied to many areas of scholarly information production, organization, and delivery, and it has had a great impact on library services (Liu, 2001a). Many academic libraries have started developing digital collections and include electronic journals and full-text databases in their collections. Many journals are published in electronic format. Many print journals have been scanned into electronic format and can be retrieved from Web sites. Electronic journals provided by commercial vendors have become widely available for libraries to use. Examples are Science Direct, EBSCO, and JSTOR. Despite the emergence of electronic collections, print materials are still major sources of information for a number of reasons. First, most full-text journals are limited to recent years of publication. Some vendors, such as JSTOR, provide back issues of full-text journals which go back to the turn of the twentieth century. But the journal coverage is limited. Second, books are still in print format. Although some attempts have been made to digitize books, they are limited to those books whose copyrights have expired. Digitizing books in libraries is a huge task. A large research library can hold many millions of volumes and to scan them into computer format can take years. Also copyright is an important issue. To digitize books requires copyright permissions from publishers and probably hundreds of publishers must be dealt with before such a process can begin. The main assets of academic research libraries are still their print collections.
Collections can be in print and electronic form. Print volumes held, and number of serial subscriptions, are used in this study as measures of library collections simply because libraries are still in the process of moving from print libraries to digital libraries. The fact is that books in libraries are still in print form, journals in libraries that cover over a ten- to fifty-year time span are still in print form. In the future when all library collections are stored in digital format, the measures will be the ones that reflect library digital collections.

**Measurements**

It was hypothesized that the size of library collections contributes to prestige of universities. The dependent variable was prestige of universities. The measurement for prestige was the U.S. News and World Report (USNWR) rankings of universities (*U.S. News 2000 College Ranking Online*). "Academic reputation" was used for prestige ranking in this article. The ranking data of the top 100 universities were gathered from the list provided by the USNWR based on their "academic reputation scores." According to the USNWR, academic reputation scores were calculated based on a survey of the presidents, provosts, and deans of admissions at institutions. Eighty-two of these one hundred universities and their libraries were eventually used in the regression because the other eighteen universities were not ARL members and did not have the library volume and serial data consistent with those of the ARL. A previous study (Liu, 2001b) looked at the relationship between prestige of academic programs and library collections using a linear model and the data compiled by the National Research Council. The ranking by the National Research Council was based on the amount of research, number of publications, and funding received by academic programs.

The independent variables were the total number of volumes held and total number of serials held by academic research libraries. Volumes held by libraries as defined by the ARL were used as a measure because they are the most expensive and important assets of libraries, which have been built over a long period of time and are crucial for research and teaching. The total number of serials was used as another measure because serials, like books, are indispensable for research, teaching, and learning. Researchers rely on journals for obtaining current research findings, exchanging ideas, communicating with their peers, and presenting their research results. The levels of volume and serials holdings reflect the commitment academic research libraries make to support their universities. The proposed models intended to include the most important assets of academic research libraries and capture their influences on prestige of universities. Data on the total number of volumes held and total number of serials held by academic research libraries was collected from the 1998–1999 data file compiled by the Association of Research Libraries (1998–1999).

The initial correlation analysis showed that volume and serials variables
are highly correlated. As a result, either one may be used as a measure of library collections although the volume variable with a higher $R$ square accounts for more of the variance in prestige. But additional efforts were made to identify the unique influence from each independent variable. The regression models with both volumes and serials as independent variables were tested. In testing the models, it was found that multicollinearity existed between the two independent variables. Multicollinearity refers to situations in which two independent variables in a regression model are so highly correlated that their effects on the dependent variable cannot be separated. The coefficient of volumes was statistically significant but the coefficient of serials was not. In the attempt to overcome this problem, a model using the volume-to-serial ratio as well as serials as independent variables was tested. The results showed that the model was statistically significant and was able to identify the unique influence from each independent variable, but overall results were inconclusive. Another solution to deal with the multicollinearity problem is to "drop" one of the independent variables and test it separately. Various forms of models, such as the quadratic functions were also tested. The linear models in general and log linear models in particular turned out to be the best fit of the data. The following are the final regression models:

The Models

1. $\ln P_i = \ln \beta_o + \beta_1 \ln V_i + \epsilon_i$
2. $\ln P_i = \ln \beta_o + \beta_1 \ln S_i + \epsilon_i$

Where

- $i$ indexes individual institutions ($i = 1, ..., N$),
- $N$ is the total number of observations,
- $P$ is the prestige indicator or rankings for universities,
- $V$ is the total number of volumes held,
- $S$ is the total number of serials held,
- $\beta_o$ is the intercept,
- $\beta_1$ is the coefficient,
- $\epsilon$ is the statistical noise or the error term.

It is specified that:

- $\beta_1 < 0$ because the relationship between the direction of rankings and the sizes of holdings is inverse due to the fact that 1 is the highest rank in the ranking system, yet numerically it is the smallest, $\beta_o > 0$ because only a positive sign of the intercept makes sense.

The Results

Table 1 shows that both the coefficients of $V$ and $S$ are statistically significant at high confidence levels. The negative signs of both independent
variables conform with the theoretical assumption, that is, an increase in total number of library volumes and an increase in total number of library serials can boost prestige of universities. The $R^2$ squares show that about 40 percent of the variance of $P$ can be accounted for by $V$ in Model 1 and about 26 percent can be explained by $S$ in Model 2. These findings are similar to the ones in a previous study using data compiled by the National Research Council and seem to reconfirm the underlying theoretical assumption.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>t Value</th>
<th>Sig. Level</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
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<td>.0001</td>
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<tr>
<td>$V$</td>
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<td>0.18316</td>
<td>-7.30</td>
<td>.0001</td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>13.20329</td>
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<td>.0001</td>
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<td>$S$</td>
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<td>0.18398</td>
<td>-5.24</td>
<td>.0001</td>
<td></td>
</tr>
</tbody>
</table>

The findings of this empirical experiment have shown that volume and serials collections make a significant contribution to prestige of universities, particularly when considering their supporting role in universities' research and teaching. This article has argued that while academic research libraries are part of nonprofit organizations and universities since they share many characteristics of nonprofit organizations, are under the jurisdiction of universities, and share the missions and goals of universities, they seem to have their own utility function. They seek to expand and maintain their collections because the larger size of library collections leads to higher prestige of universities. Whereas, academic programs seek prestige by recruiting top scholars to increase research and publication activities. Given budget constraints, academic research libraries must make choices and prioritize their spending. This article argues that the priority is given to collections. This study seems to show that library administrators in these research-oriented universities under investigation understand how to maximize universities' utility by maximizing library collections. Academic research libraries have been able to maintain the level of volume and serials collections to such an extent that its significant relationship with prestige can be visibly and quantitatively identified.

The findings of this investigation may have policy implications for university and college library administrators. Academic research libraries may help to improve their institutional prestige by increasing the size of their library collections. However, it does not mean that a university can become a well-known institution of higher learning instantly after its library
purchases millions of volumes overnight. The library's contribution to institutional prestige is mostly through providing research support for their faculty members in academic departments. Researchers rely on books and journals to obtain research information, communicate with their peers, and report their research results. Instant access to research literature can expedite the research process and makes scholars more productive.

**SUMMARY AND CONCLUSION**

This investigation intended to observe economic behavior of academic research libraries and to find out how they contribute to overall university utility by maximizing their own utility. This article argues that academic research libraries seek to maximize their utility by expanding the size of their library collections. Furthermore it has provided the reason why they do so. The hypothesis that library collections contribute to overall prestige of universities was tested using a natural log linear model. The results show that there is a fairly strong association between library volume and serial collections and prestige of universities. Library volume and serials collections accounted for a significant amount of contribution to prestige of universities, particularly when considering their supporting role in research and teaching at universities. These findings are consistent with those of the previous study using a different ranking system and sample data. It seems that this investigation has reconfirmed the proposed theoretical assumption that library collections contribute to prestige of universities as well as their academic programs.

It must be pointed out that while, in this study, print collections were used as library collection measures, there should not be much difference between print volume and serial collections and electronic volume and serial collections in terms of the measurement of library collections. If, in the future, libraries will be able to digitize all their print collections, then electronic collections can be used as library collection measures. However, some researchers have expressed the concerns that when books and journals are all stored in computers, scholars would lose browsing opportunities. Lack of browsing opportunities may lead to decreases in research productivity.

Economic theories on a variety of nonprofits, including higher educational institutions, have been established since 1970. There have been economic studies on libraries in general and academic research libraries in particular by a few economists and library science scholars. But there has been lack of theoretical works. It is hoped that this study can contribute to a better understanding of the economic behavior of academic research libraries and encourage more research efforts in the future.

**ACKNOWLEDGEMENTS**

First, I would like to thank Richard E. Quandt, an emeritus professor of economics at Princeton University, and Yan Gao, a professor in the Fi-
nance Department of the City University of New York at Baruch College, for their valuable comments on the model and econometrics used in this study. Discussions with Robert M. Hayes, an emeritus professor of library and information science at UCLA, and Bryce Allen were very constructive. I am solely responsible for all possible errors.

NOTES
1. John Budd recorded in his book, *The Academic Library: Its Purposes and Its Operation* published by Libraries Unlimited Inc. in 1988, that the Harvard College Library, the first academic library, was founded in 1638 when the library received a few hundred books from John Harvard, two years after Harvard College was established.
2. Richard E. Quandt commented on the earlier draft of this article and pointed out the existence of charitable foundations.

REFERENCES
The Cost Function and Scale Economies in Academic Research Libraries

LEWIS G. LIU

ABSTRACT
THIS EMPIRICAL RESEARCH EXAMINED scale economies of academic research libraries that belong to the Association of Research Libraries and developed a total cost function for estimating economies of scale. The author argues that libraries in general, and academic research libraries in particular, are information provision organizations that provide multiproducts and multiservices and points out that some previous studies that used the production function have limitations due to the fact that the production function only permits a single output variable. This investigation incorporated a wide range of collections and service output variables into the total cost function. The regression results show that the adjusted $R^2$ square of the cost function model is 0.8 and that the coefficients of three very important output variables (volumes held, serials, and group presentations) are statistically significant at high confidence levels. The final findings of this research show that the function coefficient is 0.93, indicating that slight economies of scale exist in academic research libraries.

INTRODUCTION
Libraries are important economic entities in modern society. At present there are 9,046 public libraries, 3,685 academic libraries, 98,169 school libraries, 9,763 special libraries, 1,376 government libraries, and 335 armed forces libraries with a total of over 122,300 libraries in the United States. Improving efficiency and preventing misallocation of resources in libraries are as important as in other economic sectors of the national economy. One way to evaluate an organization’s efficiency is to examine whether scale economies exist in the organization. The concept of scale economies is
rooted in economic studies of manufacturing. Massive production makes it possible for a firm to increase output and in the meantime reduce average cost to the extent where the firm needs to hire more people, purchase more equipment, and rent more facilities. Economies of scale exist because of many factors. New technologies and specialization of knowledge enable staff to work more efficiently. Purchasing a large quantity of supplies at a discount price can also result in substantial savings. Diseconomies of scale exist when output increases and average cost increases as well. Unskilled labor, outdated technologies, and poor management decisions can contribute to diseconomies of scale. Constant returns to scale occur when neither economies of scale nor diseconomies of scale exist. In many cases, researchers look at the relationship between marginal cost and average cost to determine whether or not excess capacity exists. If marginal cost (cost for producing an additional unit of output) is less than average cost, the firm is still better off by producing additional output.

Economic researchers have long been concerned with improving efficiencies of firms. Econometric models, such as production function, total cost function, and average cost function have been developed to measure economies of scale and to improve efficiencies of firms as well as government agencies and nonprofit organizations. Although many of the early research efforts focused on manufacturing and industries, such as railroads, metals and machinery, aircraft, gas, coal, telephone industries, and so on (Mansfield, 1997), later research began to study government agencies (Bauer, 2000), and educational institutions (Cohn, Rhine, & Santos, 1989; Koshal & Koshal, 2000; Chakraborty, Biswas, & Lewis, 2000). In the past, a few studies were conducted to examine economies of scale of libraries. Much of the previous research focused on public libraries. A handful of studies dealt with scale economies in academic libraries. Researchers wanted to know whether library sizes make a difference in terms of cost savings. They tested the assumption that larger-sized libraries tend to operate more efficiently than smaller ones.

Studies on scale economies have strong implications for public policy-making. The evidence that shows cost savings as a result of economies of scale can convince policymakers to make decisions for consolidating smaller-sized libraries (Baumol et al., 1969; DeBoer, 1992), although in many cases convenient service to local communities can be a more important factor than economic consideration. This investigation focused on academic research libraries that belong to the Association of Research Libraries. The purpose of this investigation was to examine whether economies of scale exist in academic research libraries. If economies of scale do exist, academic research libraries can, in the long run, provide better quality information services as well as increase the range of information services for faculty and students of their institutions at relatively less costs.
The missions and goals of academic research libraries are different from those of general academic libraries and public libraries (Liu, 2000). For example, academic research libraries have a stronger research orientation than general academic libraries that focus on teaching. To support their universities' mission for research, academic research libraries develop comprehensive collections that include a large number of research journals. Research journals consume a large portion of a research library's budget. Compared with academic research libraries, general academic libraries have only a limited number of research journals, and general public libraries have virtually no research journals at all. This and other differences between academic research libraries and general academic libraries and public libraries affect output factors in a cost function and warrant a new investigation.

**Literature Review**

The previous empirical research produced mixed results. Some researchers found evidence of increasing returns to scale. Others found evidence of decreasing returns to scale. Still others found evidence of constant returns to scale. The research on scale economies of libraries may be classified into three categories: studies that examined scale economies using the Cobb-Douglas production function; studies that looked at scale economies as well as elasticities of input substitution using the translog cost function; and studies that explored scale economies using general cost functions.

**Early Studies**

The cost study on libraries commissioned by the National Advisory Commission and conducted by William J. Baumol et al. in 1969 and another study by Stanley W. Black in the same year are probably the earliest studies on costs and economies of scale of libraries. Baumol et al. studied various types of libraries and examined total expenditures on staff and library materials, volumes owned and circulated, and growth rates. The report provided a library cost trend analysis and showed that library cost per capita and circulation unit cost decreased as sizes of public libraries increased, indicating economies of scale, but it also pointed out that savings were not expected to be substantial (p. 224). Baumol and Matityahu Marcus later studied costs of academic libraries, which led to the publication of a book in 1973. No production function or cost functions were dealt with in their book.

**Studies Using the Cobb-Douglas Production Function**

Stanley W. Black used the Cobb-Douglas production function for public libraries and treated circulation as the sole output, and labor and book stock as inputs. The coefficients of the two observed variables were not statistically significant due to a high degree of multicollinearity between them. As a result, he assumed that returns to scale were constant and was able to esti-
mate labor and bookstock elasticities, which were 0.833 and 0.167, respectively. Black's study seemed to have a far-reaching influence on the later studies since the methodologies used by the later studies tended to resemble his.

Haynes C. Goddard studied more than one hundred public libraries in Indiana using the Cobb-Douglas production function (1973). In his study, circulation was treated as output and bookstock, labor, materials, and capital were treated as inputs. Labor was measured based on circulation staff hours, and materials were measured in terms of their values by annual expenditures on them. Capital was measured by furniture associated with library services such as tables, chairs, card catalog, and so forth. He found that the function coefficient was 1.076, indicating slight increasing returns to scale. In addition, from a subsample, he estimated that the marginal costs of circulation were lower than average costs (p. 200), an indication of excess capacity in the libraries.

Robert M. Hayes used the Cobb-Douglas production function to study both public and academic libraries (Hayes 1979; 1981; Hayes & Borko, 1983). In the 1979 paper he studied optimal use of labor and capital by applying the Cobb-Douglas production function to large public libraries in California as well as in Illinois, Ohio, Wisconsin, and Missouri. He regressed circulation, a measure of output, on capital measured by the size of collection, and staff needed to maintain the facilities and the collection; and on labor measured by service staff. About 60 percent of the total variance in the dependent variable was accounted for by the Cobb-Douglas production function. Although Hayes used a single output measure, he recognized that other output factors, such as reference service, could also be considered. However, he pointed out that reference statistics available at that time might not be consistent and reliable. In his 1981 study on the use of library collections as measured by circulation and in-house use, he concluded that circulation did not adequately measure the usage of library collections. In 1983, he and Harold Borko published an article examining the relationship between library collections and faculty productivity using the Cobb-Douglas production function. The findings showed that library collections contribute significantly to faculty productivity as measured by faculty publications.

Studies Using the Translog Cost Function

Like Black (1969), Larry DeBoer and Christopher J. Hammond examined not only scale economies but also substitution elasticities of inputs (DeBoer, 1992; Hammond, 1999). However, they used a translog cost function instead of a production function. The translog cost function can be used to deal with issues of the demand for inputs of libraries as well as scale economies. This method is flexible in approximating production technologies in terms of input substitution elasticities. DeBoer used the translog cost function to examine economies of scale and input substitution elasticities of 194 Indiana public libraries. Book circulation was used as the output measure. Total cost was treated as the dependent variable. The translog cost function
required three input price variables for three inputs (labor, books, and supplies/services). The labor price was calculated by total labor expenditures divided by total number of FTE employees. He constructed a price index for supplies/services based on wages and prices in each district county. The relative book prices were used in the estimated equation. His findings showed that economies of scale existed for small libraries and constant returns to scale existed for large libraries. He also found that all production inputs were substitutes. Higher labor costs caused increases in purchases of supplies and services as well as books. Higher book prices led to an increase in purchases of supplies and services. But supplies and services were more responsive to higher labor prices than to book prices. Higher prices of supplies and services resulted in increases in purchases of both labor and books.

In a recent analysis of the cost function for UK public libraries, Christopher J. Hammond also used the translog cost function to examine scale economies and input substitution elasticities. He found that there existed increasing returns to scale and diseconomies of scope. Hammond also concluded that all production inputs were inelastic substitutes. What differentiated this study from some of the previous studies was that Hammond recognized the multiproduct nature of libraries, and used annual bookstock, audio-visual materials, and number of inquiries as outputs in the cost function.

**Studies Using General Cost Functions**

Not all researchers were interested in studying substitution elasticities of inputs. If the issue of the demand for inputs is not the research concern, a general cost function is sufficient for studying scale economies. The research conducted by Kathleen Foley Feldstein, Michael D. Cooper, and Paul Kantor used the general cost function approach (Feldstein, 1976; Cooper, 1979, 1983; Kantor, 1981a, 1981b). A general cost function can be logarithmic or nonlogarithmic. Economic researchers often transform a cost function into a common log form or a natural log form for the convenience of calculating the function coefficient or for the convenience of developing a model that is a better fit of a data sample.

Feldstein examined scale economies of public libraries using the national data and developed various cost functions. Since she used circulation as a single output measure, she was able to measure marginal costs from the total cost function, and average cost function using total costs divided by circulation. She found that although library systems had small diseconomies of scale, some individual libraries had economies of scale (p. 87).

Cooper examined whether or not there existed economies of scale in public libraries as well as academic libraries. Cooper’s 1979 study collected data from public libraries in California. He recognized the fact that libraries provide multiproducts and services and regressed total expenditure on a number of output variables including volumes added, volumes borrowed, volumes lent, reference transactions, and circulations. He tested a number of alternative models, linear and nonlinear, logarithmic and non-
logarithmic and concluded that the log-linear model was the best fit of the data. He found that the function coefficient was slightly larger than 1 and argued that it should be interpreted as constant returns to scale. Cooper's 1983 study on academic libraries was similar to his 1979 study except that he added one more output variable: library hours opened. He found evidence of diseconomies of scale for two-year and four-year public, and four-year private college and university libraries, and economies of scale for two-year private college libraries. But the $R^2$ square of the model for two-year private college libraries was low (0.50). He warned that careful interpretation of this finding was necessary.

Another noted author in the cost studies on academic libraries is Paul Kantor. Kantor (1981a, 1981b) developed cost functions for library operations in scientific and technical libraries. Kantor was also aware of the multiproduct nature of libraries. He thoughtfully included in-house material use, circulation, and reference queries as output variables. He concluded that the best-fit model clearly demonstrated economies of scale.

The previous studies utilized various econometric models. Some used the Cobb-Douglas production function. Some used the translog cost function. Others used general cost functions. As Cooper argued that "Both models (production function and cost function) are useful in determining whether scale economies exist" (1979, p. 66), Hayes, Cooper, Kantor, and Hammond recognized the multioutput nature of libraries and were able to incorporate various output variables into their studies while other researchers tended to use circulation as the sole indicator of output. DeBoer and Hammond used the translog cost function to estimate input substitution elasticities in addition to scale economies. Goddard and Feldstein also examined the relationship between the marginal cost and average cost.

The previous studies tended to focus on public libraries. There probably are a few reasons why the earlier research focused on public libraries. First the data on public libraries were readily available at the local, state, and national level. Second, the policy incentive for studying public libraries was stronger because consolidating smaller-sized libraries could lead to cost savings. Third, it was believed that production activities of public libraries could be measured by a single output indicator. It was convenient to use a production function model with a single output measure.

**This Study**

This study argues that libraries in general, academic research libraries in particular, are information provision organizations providing multiproducts and multiservices. Their outputs are not homogenous and cannot be measured simply by a single output indicator. Traditional econometric methods, such as the production function, that can only be used to measure a single output are certainly not a sufficient measure of the production of academic research libraries. The multiproduct and multiservice
nature of libraries was not fully recognized by some researchers and multi-output variables were not incorporated in some previous studies. Hayes, Cooper, Kantor, and Hammond are among the very few researchers who were able to incorporate some multioutput variables into their studies.

To be able to provide more accurate estimates for library costs and economies of scale, this study took into account the multiproduct and multiservice nature of academic research libraries. This study is different from the previous studies in a number of ways. First, this study dealt with the cost function and scale economies of academic research libraries that belong to the Association of Research Libraries. As stated in the introduction of this article, academic research libraries have different missions and goals from general academic libraries and public libraries. One of the important goals of academic research libraries is to support research in universities. This research orientation demands that academic research libraries have extensive scholarly journal subscriptions, which consume a substantial part of library expenditures. This study treated serials as an independent output variable. Second, this study treated general library collections as outputs. A wide range of collection output variables were incorporated in the cost function. Third, this study added a new library service output variable, group presentations by librarians, to the cost function. Such data were not available to the previous research. Fourth, in this study, circulation was treated as only one of the service outputs.

Data, Measurements, and Model

All the data used in this study were collected from the ARL 1999–2000 survey of 112 academic research libraries (Association of Research Libraries, 2001). The model in this study incorporated eleven independent variables and one dependent variable. Because not all libraries had the data related to all of these variables, eighty-nine academic research libraries were included in the regression analysis.

A Multioutput Measure versus a Single Output Measure. In the previous studies on public libraries, most of the researchers used circulation as the sole output measure. Circulation was used as a single measure of output for public libraries because it was believed that circulation could capture most of the usage activities of public libraries and that the Cobb-Douglas production function was convenient to measure library output. Other reasons were that data on some of the output variables at that time were unavailable. The data collected unsystematically were considered as unreliable and inconsistent. In this study, the ARL data were used. The ARL has been systematically gathering data from its members for many years and its dataset has been widely used by researchers, library administrators, and practicing librarians. The ARL data are believed to be reliable and comprehensive although more detailed and more consistent data on academic research libraries need to be collected in the future.
This study treated the library collections and various library services as outputs. It included various types of library collection materials and library services. Library collections include volumes, serials, maps, graphs, videos, and audios. Library services are also an important part of library outputs. They include reference service, library seminars and workshops, interlibrary loans (borrowed and lent), and circulation or information delivery service. Library collections were used as output measures for a number of reasons. Library collections in this study were considered as final products of libraries. Although libraries do not directly create contents of library collections, such as contents of books and journal articles, and do not physically print these library materials, libraries do process them. The value added to materials acquired and purchased by libraries lies in the fact that these materials can be readily accessed, retrieved, and used by library patrons.

Volumes Held versus Volumes Added as an Output Measure. In this study, volumes held was used as an output measure instead of volumes added (which was used in two previous studies (Cooper, 1979, 1983)) because volumes added only measure the costs of volumes added to collections for one time period, typically one year. The volumes-added approach may be appropriate in other studies, but for this study, it was assumed that library users do not use just newly added volumes, they also use volumes purchased in the past. Maintaining existing volumes or entire bookstock is an ongoing process and involves a greater amount of staff time and effort and incurs more costs than newly added volumes and circulated items. The library collection management process generally includes assessing collections in terms of the needs of their patrons or communities, identifying, selecting, acquiring, classifying, cataloging, shelving, or storing all kinds of materials acquired and purchased by libraries. Many libraries assess their library collections in terms of their age and subject strengths and weaknesses so that librarians can make adjustment to support teaching and research or to compare with other libraries for collaboration purposes. Such an assessment requires searching and sorting entire collections and may take years to complete, but it is a necessary procedure to maintain relevant and useful collections. To put collections into a library, library staff must go through this collection management process. When library materials are in place for use, library staff also need to frequently evaluate collections, weed out those that have low values to make room for new purchased items, bind monthly and quarterly serial issues into annual volumes, repair damaged materials, replace missing items, and reshelve returned items. Other visible operating costs include electricity for lights and air conditioning. These costs are for entire collections not just for volumes added in a year. The use of the volumes-added approach in this study might tend to have biased estimates on the costs necessary to maintain entire collections.

In their recent study, Stephen R. Lawrence, Lynn Silipigni Connaway,
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and Keith H. Brigham provided a convincing case that maintaining library collections is far more costly than one-time purchase costs using the ARL data (2001). For example, they demonstrated that unit cost for monographs is $47.78, yet their life-cycle costs are $343.03; unit cost for serials is $590.97, yet their life-cycle costs are $801.78; unit cost for videos is $15.70, but their life-cycle costs are $107.50; and unit cost for many government documents is 0 (free), but their life-cycle costs are $55.40 (p. 553). Life-cycle costs take into account ongoing expenses which include operating expenses, wages and salaries of staff, building and facilities, and facility maintenance. All of these costs are for one purpose: to make library collections readily available for use. Because the volumes-added approach might produce biased estimates on costs of maintaining existing volumes, the volumes-held approach was used in this study.

**Volumes Held versus Circulation as an Output Measure.** The use of circulation as a single output measure only considers costs of those items that are checked out from libraries. But whether or not library items are circulated is not very relevant from the fixed-cost perspective since most of the costs of making them available have already been incurred even before items are checked out. The function of circulation service is simply putting readily available items or finished products in the hands of users. The cost of circulation of a library item is only a small part of the total cost of processing this item and involves no more than staff time and equipment in the check-out process. Circulation was considered in this study as one of the service output measures.

Another reason for using volumes held as one of the output measures is that the use of circulation as an output measure for academic research libraries tends to ignore the fact that some parts of collections are not circulated and that users may use library materials in-house. Some materials, such as reference materials, must be used in the library. Many libraries do not have financial, human resources, and a mechanism to consistently track the in-house use of reference materials. Many academic research libraries also provide graduate students and faculty members with carrels where they can put the books for their learning, teaching, and research, and there is no need to check them out. Many users also use general library collections inside the library. They simply do not check them out. Circulation records do not reflect the usage of these library resources. The use of volumes held as an output variable covers all in-house use of library volume materials.

**Serials as Output.** Academic research libraries have extensive scholarly journal collections that are important library assets for learning, teaching, and research. Journals make up a large portion of serials. In general, journals in virtually every academic research library, like reference materials, are not circulated items and are not recorded for use. Some libraries may record current journal usage, but they are unlikely to record usage of back
issues on a regular and continuous basis since it would incur too much cost related to staff time and efforts. Some academic libraries may track the use of current journals by requiring patrons not to put them back on the shelves so that library staff can record which journals have been used and how often. To track the use of back issues of tens of thousands of serials is extremely difficult, if not impossible. Back issues of journals are used a great deal by both faculty and students because they contain accumulated research findings in the past and are indispensable for research and teaching. To study scale economies of academic research libraries without including serials would miss a critical part of academic research library output. Serials collections consume a large portion of academic research libraries’ budgets and were treated as an important output variable in this study.

Other Library Collections as Output. In addition to volumes held and serials, other library collections, such as audios, videos, and maps were also treated as library outputs since they are different kinds of materials from volumes and serials. The prices of these materials differ from those of volumes and serials and do incur costs related to staff time and library equipment in order to make them readily available for use. In general, some library materials such as large-sized maps and some audio and video items may well be in-house use materials. Circulation records do not record such use of library collections. Although it is true that only a small portion of library collections is used at a certain time period, it does not necessarily mean that only that portion incurs costs.

Library Services as Output. Libraries provide various types of services including reference service, instruction in the form of library workshops and seminars, borrowing items through interlibrary loan for local users and lending items through interlibrary loan to external users, and circulation service. These services incur costs in terms of staff time, facilities, and equipment necessary to carry out these activities. Reference service can be measured by reference transactions, and library workshops and seminars are measured by library group presentations. Interlibrary loan and circulation data are also readily available from the ARL dataset.

Library Costs. Total library expenditures were used as a measure of total library costs on library materials, staff, binding, and other operating activities. Library materials expenditures consist of costs for monographs, serials, other materials such as maps, audio and visual items, and the items other than materials such as bibliographic utilities. Total salary expenditures include those for professional staff, non-professional staff, and student assistants.

The Model. The general form of total cost function is the following:

$$TC = f (V, S, U, D, M, G, P, R, B, I, C);$$

$TC$, the total cost, is a function of a wide range of library outputs. The
letters $V, S, U, D, M, G, P, R, B, L,$ and $C$ represent library collections and service outputs and can be written as:

1. $TC = A V^{p_1} S^{p_2} U^{p_3} D^{p_4} M^{p_5} G^{p_6} P^{p_7} R^{p_8} B^{p_9} L^{p_{10}} C^{p_{11}}$

Taking the natural log of both sides to derive the following cost equation:

2. $\ln TC_i = \ln A + p_1 \ln V_i + p_2 \ln S_i + p_3 \ln U_i + p_4 \ln D_i + p_5 \ln M_i + p_6 \ln G_i + p_7 \ln P_i + p_8 \ln R_i + p_9 \ln B_i + p_{10} \ln L_i + p_{11} \ln C_i + \epsilon_i$

Where
- $i$ indexes individual institutions ($i = 1, \ldots, N$),
- $N$ is the total number of observations,
- $TC$ is the total cost,
- $A$ is the constant,
- $p_1, p_2, p_3, \ldots, p_{11}$ are the coefficients,
- $\epsilon$ is the statistical noise or the error term,
- It is specified that: $A > 0, p_1 > 0, p_2 > 0, \ldots, p_{11} > 0$.

Library collections outputs:
- $V$ is the total number of volumes held,
- $S$ is the total number of serials,
- $U$ is the total number of audio items,
- $D$ is the total number of video items,
- $M$ is the total number of maps,
- $G$ is the total number of graphs.

Library service outputs:
- $P$ is the total number of group presentations,
- $R$ is the total number of reference transactions,
- $B$ is the total number of interlibrary loans borrowed,
- $L$ is the total number of interlibrary loans lent,
- $C$ is the total number of circulated items.

Findings and Analysis

Table 1 shows that the adjusted $R$ square of the model is 0.8, indicating that about 80 percent of the variance of the dependent variable can be explained by the model. The adjusted $R$ square is high enough not to reject the model. The $t$ statistics show that the coefficients of volumes held and serials, very important parts of library collections, are statistically significant at a very high level (.0001 and .0003 respectively). The coefficient of group presentations, part of library services, is also statistically significant. The coefficients of other variables are not statistically significant except for the coefficient of maps with a negative sign, which does not make any sense, and needs to be disregarded. As Hammond pointed out, "it is not practical to include all the identifiable dimensions of output. In addition, some
dimensions may not be easily quantified (1999, p. 274).” With three variables that measure important parts of libraries’ collections and service outputs, the regression results should be considered satisfactory.

To measure scale economies, the total coefficients of the independent variables are summed. If the function coefficient is larger than 1, then diseconomies of scale exist. If the function coefficient is smaller than 1, then economies of scale exist. If the function coefficient equals 1, then constant returns to scale exist. The function coefficient \((\beta_1 + \beta_2 + \beta_p + \ldots + \beta_{11})\) is found to be 0.928597 or 0.93, indicating that small economies of scale exist in academic research libraries.

### Comparing With Previous Research

The studies on scale economies of libraries have reached different conclusions: diseconomies of scale, economies of scale, and constant returns to scale. The mixed findings should not be surprising for a number of reasons. First, studies were conducted on a wide range and diverse groups of libraries, including public libraries, scientific and technical libraries, two-year and four-year academic libraries, private and public college libraries, and academic research libraries. Second, the data were gathered at different levels. Some studies focused on libraries within one state. Some studies gathered data from a region or a number of states. Others used the national data. Third, econometric models used in the studies vary from study to study. Some used the production function. Some used the translog cost function. Others used general cost functions. Fourth, the variables used in the models vary from study to study. Some used a single output variable. A few used multiple output variables. The production coefficient which measures scale
economies is very sensitive to the number of variables used and which variables are used. Table 2 shows such a diversity of studies on scale economies of libraries in terms of model, output and input variables, and findings.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Variable</th>
<th>Coefficients</th>
<th>Model</th>
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<tr>
<td>Black</td>
<td>Inputs</td>
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<tr>
<td>1969 p. 595</td>
<td>1. Bookstock</td>
<td>0.167</td>
<td>Log Production</td>
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<td></td>
<td>2. Labor</td>
<td>0.833</td>
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<td></td>
<td>Conclusion</td>
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<tr>
<td>Goddard</td>
<td>Inputs</td>
<td></td>
<td></td>
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<tr>
<td>1973 p. 198</td>
<td>1. Bookstock</td>
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<td>Log Production</td>
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<td>2. Labor</td>
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<td>3. Materials</td>
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<td>4. Capital</td>
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<td></td>
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<td>Sum of the Coefficients</td>
<td>1.076³</td>
<td>Slight Increasing Returns to Scale</td>
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<td>Conclusion</td>
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<tr>
<td>Feldstein</td>
<td>Outputs</td>
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<tr>
<td>1976</td>
<td>1. Circulation only</td>
<td></td>
<td>Total Cost Function</td>
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<tr>
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<td>Observed Marginal Cost</td>
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<td>Average Cost Function</td>
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<td></td>
<td>and Average Cost</td>
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<td></td>
<td>Conclusion</td>
<td></td>
<td>The Library System had Diseconomies of Scale; but Some Individual Libraries had Economies of Scale.</td>
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<tr>
<td>Cooper</td>
<td>Public Library Outputs</td>
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<td>Log Cost Function</td>
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<td>1979 p. 74</td>
<td>1. I.L.L. Borrowed</td>
<td>0.551</td>
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<tr>
<td></td>
<td>2. I.L.L. Lent</td>
<td>-0.00058</td>
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<tr>
<td></td>
<td>3. Reference Transactions</td>
<td>-0.0062</td>
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<tr>
<td></td>
<td>4. Circulation</td>
<td>0.017</td>
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<td>5. Volume Added</td>
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<td>Constant Return to Scale</td>
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<td>Two-Year Public College Libraries Outputs</td>
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<td>In Cost Function</td>
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<td>1983 p. 216</td>
<td>1. Volumes Added</td>
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<td>2. Reference Transactions</td>
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<tr>
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<td>3. Circulation</td>
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<td>4. Hours Opened</td>
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<td>5. Interlibrary Loan Lending</td>
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Table 2. Con’t.

<table>
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<tr>
<th>Investigator</th>
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<th>Model</th>
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<td>2. Reference</td>
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<td>3. Circulation</td>
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Kantor Outputs In Cost
1981 1. In-House Materials Use 0.11

Function
Table 2. Con't.

<table>
<thead>
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<th>Investigator</th>
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<td>2. Circulation</td>
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<td>3. Reference Queries</td>
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<td>DeBoer 1992 p. 266</td>
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<td>1. Bookstock</td>
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<td>2. Supplies/Service</td>
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<td>3. Books</td>
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<td>Circulation Level</td>
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<td>55,409</td>
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<td>842,610</td>
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<td>Economies of Scale for Smaller-Sized Public Libraries but Constant Returns to Scale for Larger-Sized Public Libraries.</td>
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<td>Hammond 1999 p. 287</td>
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<td>Increasing Returns to Scale. Diseconomies of Scope for the Average British Public Library.</td>
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<td>Liu 2002</td>
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<td>Library Collections Outputs</td>
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<td>1. Volumes Held</td>
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<td>2. Serials</td>
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<td>3. Audio</td>
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<td>4. Video</td>
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<td>5. Maps</td>
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<td>6. Graphs</td>
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<td>Library Service Outputs</td>
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<tr>
<td>1. Group Presentations</td>
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<tr>
<td>2. Reference Transactions</td>
<td>0.024787</td>
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</table>
Investigator Variable Coefficients Model

3. Interlibrary Loans
   Borrowed 0.030396

4. Interlibrary Loans Lent -0.042342

5. Circulations 0.005471

Sum 0.928597

Conclusion Slight Economies of Scale for Academic Research Libraries.

The findings of this study show that volumes held and total number of serials are significant output variables. The coefficients of these two variables are statistically significant at a very high level. A correlation analysis (not presented here) indicated that each of them is highly correlated with the dependent variable. The correlation between volumes held and the total cost was found to be 0.89 and the correlation between serials and the total cost is 0.82, confirming that they are good indicators of outputs of academic research libraries. Group presentations that reflect the total number of library workshops and seminars offered is also a significant output. The data related to group presentations were collected only in recent years by the ARL.

This study was not concerned with input substitution elasticities under the assumption that volumes held, serials, and group presentations, three major output variables, are not likely to be substitutes. Academic research libraries do not buy more books using serials expenditures simply because books are cheaper. Journals provide up-to-date research findings. They are critical for research and teaching and cannot be replaced by books. It is also unlikely that libraries would reduce the number of library instructors teaching library workshops and use the savings to purchase journals due to higher labor costs. Library instruction is indispensable training and education for students. It provides students with the information competency they need to effectively access, retrieve, evaluate, and use information.

The regression results of this study also show that circulation is not a good measure of library output since it is not statistically significant. The correlation analysis also revealed that the correlation between circulation and the total cost is only 0.50, lower than volumes held (0.89), serials (0.82), group presentations (0.54), and audios (0.57). Given the nature of academic research libraries, a great deal of library materials, such as serials, reference collections, and materials in carrels, is used in-house. Circulation records do not reflect such usage.

The results in a separate regression that used volumes added as an output variable in place of volumes held with other variables unchanged showed that the adjusted Rsquare decreased to 0.76 from 0.8 and the sum of the coefficients decreased to 0.86 from 0.93. As expected, using volumes
added for the purpose of this study could have overestimated economies of scale because volumes added do not take into account staff and operating costs involved in maintaining existing collections.

**Summary and Conclusion**

This study examined scale economies of academic research libraries and reviewed the research literature on economies of scale in various libraries. It argued that academic research libraries are information provision organizations providing multiproducts and multiservices. The total cost function was developed and the natural log linear model was proved to be the best fit of the data. A wide range of collections and service outputs were incorporated into the cost function to reflect this information provision function. Library outputs were measured by library collections, including volumes held, serials, audio and video materials, maps, graphs; and library services, including library workshops and seminars in the form of group presentations, reference transactions, circulation service, and interlibrary loan services. Three major output variables—volumes held, serials, and group presentations—stand out in terms of statistical significance. It was found that slight economies of scale exist in academic research libraries.

Previous research has made an important contribution to our understanding of scale economies of libraries and developed various methodologies that can be used in the later studies. But previous research also has some limitations. One of the obvious limitations is applying the Cobb-Douglas production function, which is normally used to measure a single output, to libraries that provide a wide range of outputs and services. This problem could be overcome by applying the production function to cross-section data at the departmental or division level. But this did not happen probably because of the lack of understanding of library operations by some researchers and the lack of consistent and reliable data related to library outputs, which frustrated researchers. The ARL has been collecting data for academic research libraries for many years. The statistics gathered have increasingly reflected the multiproduction nature of academic research libraries. For example, data on group presentations measured an important service activity of academic research libraries. More work needs to be done in the future to collect data on capital, labor, and costs at the department or division level so that cross-section department or division production functions can be used to measure the multiproduct activities of academic research libraries.

It is hoped that this investigation on scale economies in academic research libraries will provide some new insights into the existing literature in terms of understanding of scale economies for libraries and output variables used in the total cost function. Because scale economies are very sensitive to the number and the nature of output variables used in the regression model, it is very important for researchers to carefully select output
variables. Good output indicators should reflect the true costs of libraries' outputs.

**Acknowledgments**

I would like to thank Dr. Richard E. Quandt, an emeritus professor of economics at Princeton University, and Dr. Robert M. Hayes, an emeritus professor of library and information science at UCLA, for their comments and suggestions on an earlier draft of this article. I am alone responsible for all possible errors. This article was first published in the September 2002 issue of *College & Research Libraries*.

**Notes**

2. See works by Black; Goddard; Feldstein; Hayes; Cooper; DeBoer; and Hammond.
3. The function coefficients do not add up to the sum although it is close.

**References**


Applying DEA Technique to Library Evaluation in Academic Research Libraries

Wonsik Shim

ABSTRACT
Increasingly, libraries are asked to justify their use of resources in terms of producing meaningful services and impacts to the users and the parent organizations. This study applied an analytical technique called Data Envelopment Analysis (DEA) to calculate the relative technical efficiency of ninety-five academic research libraries that are members of the Association of Research Libraries. Instead of providing the average performance among libraries, DEA, with the proper model of library inputs and outputs, can reveal the best practices in the peer groups, as well as the technical efficiency score for each library. The technique was applied to the libraries using the 1996 and 1997 ARL annual statistics. The study also reviews the applications of DEA technique in the library environment.

INTRODUCTION
Researchers recognize two broad aspects of evaluating library performance: "effectiveness" and "efficiency." Effectiveness here means the extent to which library services meet the expectations or goals set by the organization. In the library field, there has been a growing desire to measure effectiveness in terms of impact of library services on their users.

The second aspect of library performance measurement, "efficiency," measures the library's ability to transform its inputs (resources) into production of outputs (services), or to produce a given level of outputs with the minimum amount of inputs. The efficiency aspect of library performance has received less attention in the library literature, but it is an immediate concern for decision-makers at the parent institution.

The success of the library, like that of other organizations, depends on
its ability to behave both effectively and efficiently. We can put these two dimensions of library performance in a 2 by 2 matrix as shown in Figure 1.

Performance improvement requires constant and careful monitoring and assessment of library activities and operating environments. This, in turn, requires the development of proper measurement tools or devices. This study assesses the technical efficiency of academic research libraries that are members of the Association of Research Libraries using a complex tool called DEA. While the development of effectiveness is equally important, this study is focused solely on measuring library efficiency.

Figure 1. Library Performance Matrix Using the Levels of Effectiveness and Efficiency as Two Dimensions.

<table>
<thead>
<tr>
<th>High Effectiveness</th>
<th>Low Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective but Excessively Costly</td>
<td>Best All-around Performers</td>
</tr>
<tr>
<td>Problematic, Underperforming</td>
<td>Efficiently Managed for Insignificant Results</td>
</tr>
</tbody>
</table>

DATA ENVELOPMENT ANALYSIS

Overview

Data Envelopment Analysis (DEA) measures the relative efficiencies of organizations with multiple inputs and multiple outputs (Charnes et al., 1978). The individual organizations, teams, or units analyzed are called the decision-making units, or DMUs. The basic point of DEA is to identify the so-called efficient frontier in some comparison set of DMUs. All units on this frontier are said to be operating at 100 percent efficiency. DEA provides an efficiency score for each of the inefficient units, as well as a benchmark set of efficient units that lead to that conclusion. The results of the DEA analysis can be used in performance measurement of libraries, especially for benchmarking purposes.

Since the DEA technique was first developed by Charnes, Cooper, and Rhodes in 1978, it has been widely applied to industries as diverse as healthcare, finance, education, and transportation, as well as many other industries and organizations. The technique is well documented in both the operations research (Banker, Charnes, & Cooper, 1984; Dyson & Thanassoulis, 1988; Golany & Roll, 1989; Cooper, Thompson, & Thrall, 1996) and economics literature (Sengupta, 1987; Banker & Maindiratta, 1988; Seiford & Thrall, 1990; Leibenstein & Maital, 1992). The DEA bibliography compiled by Seiford (1994) includes more than 400 articles, books, and disser-
tations between 1978 and 1992. A recent bibliography (Emrouznejad, 2001) reports more than 1,000 applications of the DEA technique.

DEA allows the weights of individual inputs and outputs of each DMU to vary until it gives the best possible combination for the focus library. In DEA calculations, through mathematical optimization, each DMU is assigned the weights that maximize its efficiency score. In doing so, DEA gives all the other DMUs “the benefit of the doubt” by allowing them to apply the same weights to see if any of them looks better than the library being evaluated, which is called the “focus” DMU. If the focus DMU looks at least as good as any other DMU, it receives an efficiency score of 1. However, if some other DMU looks better than the focus DMU, even when the weights are calculated in a way that is most favorable to the focus, it will receive an efficiency score less than 1. In DEA, a separate calculation is done for each DMU.

**Graphical Illustration**

Suppose, for the sake of illustration, we have seven libraries or DMUs that each have only one input and output. We assign these libraries to the coordinate values associated with the points L1 through L7 in Figure 2 where the input is represented on the horizontal axis (X) and the output is represented along the vertical axis (Y).

*Figure 2. Envelopment Surface. Adapted from Charnes et al. (1994), p. 33.*
For example, library 1 (L1) uses two units of input and produces two units of output. Library 2 (L2) uses 3 units of input to produce 5 units of output. The best a library can do is the top left section of the graph where input is low but output is high. Using the given data, the DEA identifies a set of units in the comparison set (our seven libraries) whose efficiency score equals 1. In the figure, these are the libraries 1 through 4 (L1–L4) because there is nothing to their left. These libraries are called the efficient frontier and define the limits of what a library can achieve in the given situation. In DEA, determination of whether a unit is part of the efficient frontier is based on the units included in the analysis. The heavy line connecting the efficient libraries is called the "envelopment surface" because it envelops all the cases, thus giving the name "Data Envelopment Analysis." Notice also the regression line (the thin line shown in Figure 2) that represents the average relationship between the input (the independent variable) and the output (the dependent variable).

DMUs L5 through L7 are not on the envelopment surface and thus are evaluated as inefficient in the DEA analysis. There are two ways to explain their weakness. One is to say that, for example, library 5 (L5) could be imagined to produce as much output as it does, but with less input. This could be accomplished by moving horizontally until it hits the line between L1 and L2. It should stop there because, with these data, there is no evidence that any unit can do better than that.

One of the assumptions here is that if L1 and L2 can be attained in the real world, then any point between L1 and L2 is also possible. This is called "convexity," which is almost always assumed in economic theory (Farrell, 1957). Mathematically, any point between L1 and L2 represents the weighted average of the two.

Libraries 1 and 2 (L1 and L2) are called the benchmark set for L5 and are interpreted as peers for L5 in DEA. The term "peers" has a special meaning. It is the set of efficient frontiers with which an inefficient unit is compared. We can also say that the units are compared against a virtual DMU on the envelopment surface which produces the same output as the unit being evaluated (which we call the "focus DMU") but with less input. If DEA finds such a DMU, either a real unit or a weighted average of several units, then the focus DMU is regarded as inefficient. If there is no evidence for a given focus DMU that a better virtual DMU exists, the unit is evaluated "technically" efficient because there is no waste of input.

Another way of looking at efficiency is to say that library 5 could produce more output, consuming the same amount of input. This could be accomplished by moving up vertically until it hits the envelopment surface between L2 and L3. Again, for the same reason, it should stop there. This time libraries 2 and 3 become peer libraries for library 5.

We see that there are two possible definitions of efficiency depending on the purpose of the evaluation. One might be interested in possible re-
duction of inputs (in DEA this is called the input orientation) or augmenta-
tion of outputs (the output orientation) in achieving technical efficien-
cy. No matter how efficiency is defined here, library 5 is not efficient. De-
pending on the purpose of the evaluation, the analysis provides different
sets of peer groups to learn from. In the input-oriented evaluation, the
efficiency score is the (proportional) reduction of input required to move
a unit onto the envelopment surface. In the output-oriented evaluation,
DEA software reports the (proportional) augmentation of output that
achieves the same purpose.

However, there are times when reduction of inputs or augmentation
of outputs is not sufficient. In our example, even when library 6 reduces
its input from 4 units to 2, there is still a gap between it and its peer library
1 in the amount of one unit of output. In DEA, this is called the “slack,”
which means excess input or missing output still exists even after the pro-
portional change in the input or the outputs.

One could argue that instead of taking either input or output orienta-
tion, a DMU could be compared to its peer in the nearest point on the
envelopment surface. Frei and Harker (1996) investigated this type of op-
timal projection of inefficient units onto the envelopment hyperplane. The
definition of “nearest” requires establishing a relative importance of inputs
and outputs. This approach will not be explored further here.

**DEA Formulation**

The previous section presented several key concepts in DEA. As an
evaluation technique, DEA is fairly easy to understand on the abstract lev-
el. However, some of its main subtleties are only appreciated if one exam-
ines its computational aspects. At present, various software packages are
available to facilitate the complex computation required in DEA applica-
tions. While these tools alleviate the need for setting up complicated DEA
programming runs, some familiarity with the basic DEA model (Charnes
et al., 1978) will be useful for further discussion of DEA application in the
libraries.

**The CCR Ratio Model**

Essentially the Charnes-Cooper-Rhodes ratio model (Charnes et al.,
1978) can be thought as an extension of the simple efficiency ratio (output/
input) to situations with multiple inputs and outputs. The efficiency score
for a DMU was previously defined as the ratio of the weighted sum of out-
puts (virtual output) to the weighted sum of inputs. Suppose DMU (j) con-
sumes a vector \( \mathbf{X}_j = \{x_{ij}\} \) of inputs \( (i = 1, \ldots, m) \) and produces a vector \( \mathbf{Y}_j = \{y_{rj}\} \) of outputs \( (r = 1, \ldots, s) \), the score for the particular DMU labeled by \( j \)
can be expressed as follows:

\[
\text{Score} = \frac{\sum_{r=1}^{s} \mu_r y_{rj}}{\sum_{i=1}^{m} \nu_i x_{ij}}
\]

In the formula, \( \mu_r \) represents a set of weights for the outputs and \( \nu_i \) a
set of weights for the inputs.
As was noted, there are two constraints on the model:

1. \( h_o \leq 1 \) for \( j = 1, \ldots, n \) (\( n \) = number of DMUs)
2. \( \mu_i, v_i \geq 0 \).

The model is expressed in a fractional form which has an infinite number of solutions. For any optimal solution \((\mu^*, v^*)\), any multiple of it still satisfies the constraints. Charnes and Cooper (1962) developed a transformation technique that converts linear fractional optimization into a linear programming (LP) problem.

In linear programming, there is an objective function that serves as the goal to achieve, most often expressed in terms of either maximizing benefits or minimizing costs.

\[
\begin{align*}
\text{max } h_o &= \sum_r \mu_r y_{rjo} \\
\text{subject to} & \sum_i v_i x_{ij} = 1 \\
& \sum_r \mu_r y_{rj} - \sum_i v_i x_{ij} \leq 0; j = 1, \ldots, n \\
& \mu_r, v_i \geq 0
\end{align*}
\]

Here, the objective function (the first formula) seeks the maximum score of the weighted output. The constraints that accompany the objective function are intended to limit the possible range of the decision variables \((\mu_r, v_i)\), so that the solution is not out of bounds.

DEA calculation requires the solution of \( n \) (the number of DMUs) such linear programming problems in the form of a set of \( m \) input and \( s \) output weights. For each solution, there are \( n + m + s + 1 \) constraints to be satisfied. For an analysis of a small number of DMUs, spreadsheet programs such as Microsoft Excel can be used to do the calculations.

For each such linear programming problem (which is called the primal), there is a complementary solution that is calculated from the so-called dual of the problem (Hillier & Lieberman, 1990, pp. 151–191). So the above primal can be converted to:
While both linear programming formulations have equivalent solutions, there are several reasons why solving the dual problem is useful. First, there are only \( m + s \) (the number of variables) constraints in the dual problem compared to \( n + m + s + 1 \) (the number of variables plus number of DMUs plus one) in the primal problem. So when the analysis involves a large number of DMUs (\( n \)), solving the dual is computationally efficient. Second, the variables in the dual have nice interpretations. When a DMU \((j_o)\) is efficient, both \( \theta \) and \( \lambda_{j_o} \) are equal to 1 leaving all the other variables equal to zero. Therefore, \( \theta \) is the efficiency score for the DMU and tells us that the DMU \( j_o \) is efficient. If a DMU is inefficient, then the value for \( \theta \) will be a positive value less than 1 and the unit will have positive \( h \) values for a set of the other DMUs. In fact, those other DMUs with positive \( h \) are the peers that form the benchmark set for the focus DMU.

DEA contributes to the measurement of efficiency in the following ways. First, in the multiple input-output situations, DEA produces a single technical efficiency score for each unit relative to all other units in the comparison population. If a DMU is operating at 100 percent efficiency, then there is no evidence, at least in the given data, to demonstrate that any other DMU can do better. Second, for each DMU evaluated as less than 100 percent efficient, DEA provides a set of DMUs, which we call the benchmark set, that define the corresponding best practices in the sample. The units included in the benchmark set are efficient, by the DEA definition, and can be used as potential peers from which lessons can be learned. In addition, DEA provides specific recommendations as to how much reduction of inputs or augmentation of outputs, in the form of efficiency gain, would be required to make a unit efficient. It should be noted that the inefficiencies calculated by DEA must be regarded as “potential.” Improvement in the efficiency may not be possible due to factors such as significant difference in the service quality or different external operating environments in the compared organizations. To sum up, unlike previous approaches to measuring efficiency, which tend to focus on average performance, DEA provides a viable alternative in which efficiency is defined by units that seem to perform best.
In general, for a given focus, DEA is likely to assign bigger weights to the least-used inputs and to the outputs that are produced most (Sexton, 1986). Units assigning zero weights to some of the inputs and outputs are not uncommon in DEA analysis. This situation is not quite desirable in academic libraries where the production of outputs (services) is not exactly market driven and substitution among outputs or among inputs is not feasible. Several weight restriction schemes have been proposed by Dyson and Thanassoulis (1988), Charnes, Cooper, and Li (1989), and Thompson, Langemeier, Lee, Lee, and Thrall (1990).

The first few chapters in Charnes, Cooper, Lewin, and Seiford (1994) provide an overview of the technical details of DEA.

**Comparison of DEA Applications in Libraries**

There have been a number of studies that applied DEA technique to the library environment. Table 1 shows a brief comparison of these studies. The table shows that nearly all types of library services have been scrutinized using the technique. It may be difficult to apply the technique to special libraries due to the lack of consistent and comparable data sets. The table also shows that DEA application is not limited to a particular geographic location—different people from different continents have applied DEA to the library environment.

Easun’s work appears to be the first one to apply DEA techniques to a library. However, it does not appear that her study influenced subsequent DEA work in libraries; only Shim (2000) cited Easun’s dissertation work. The size of the sample varies. For instance, Chen (1997) included all twenty-three university and college libraries in Taipei, Taiwan. Shim (2000) included all U.S. academic libraries that are members of the Association of Research Libraries (ARL). In Worthington’s study, 168 public libraries in New South Wales local government were studied. Only in Vitaliano (1998)

<table>
<thead>
<tr>
<th>DEA Application</th>
<th>Library Type</th>
<th>Country</th>
<th>Size of Sample</th>
<th>Data Period</th>
<th>Primary Author’s Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen (1997)</td>
<td>Academic</td>
<td>Taipei, Taiwan</td>
<td>23</td>
<td>1995</td>
<td>Economics</td>
</tr>
</tbody>
</table>
was some form of sampling conducted; only those public libraries that have a single service outlet were evaluated—libraries with branches are omitted due to the difficulty of comparison. Except for Easun (1992) and Shim (2000), the authors of all the other DEA works in libraries have academic affiliation in economics departments. In other words, the library was chosen as a case to apply DEA technique rather than the other way around. Also, most of these works were published outside the library and information science literature, making them difficult to access for library managers who are their intended audiences.

Table 2 allows us to compare the studies in terms of variables included in the DEA models. Except for Worthington (1999), all of the studies have multiple inputs and multiple outputs. Also, four out of seven studies included nondiscretionary input variables. All of these studies included the size of user population as part of the nondiscretionary variables.

For output variables, total circulation and reference transactions were most often used. Although there is a significant difference in terms of the number of variables included, the selection of output variables is fairly consistent—it is a matter of deciding how many, not which variable(s). For input variables, we see a wide variety of variables that include different aspects of library collection (e.g., book collection, net volumes added, serials, audiovisual materials) and library staff. Chen (1997) used library physical characteristics (e.g., physical space and seating). Library expenditure appears only in Worthington (1999)—it was the only input variable used. One interesting item is library service hours. It was used as an output in Chen (1997) but as an input in Sharma, Leung, and Zane (1999) and Vitaliano (1998).

Easun’s approach is unique in that she used a three-stage model where output variables in the earlier stages were used as input variables in later stages. For instance, the variables under the provision of information and resource-based instruction were used as output variables in the first stage of her analysis. But in the second stage, those variables were treated as input variables to produce output variables related to library use. The final outputs in her study were student performance in standardized tests. The study may be overly aggressive in the sense that the final outputs are school-related outcomes that are outside the context of DMUs (media centers) under consideration.

In summary, DEA technique has been applied to various types of libraries over the past ten years without being noticed and assessed by researchers and practitioners in the library science field.

**Selection of Data**

This study used the annual statistics (1996 and 1997) from the Association of Research Libraries (ARL) for the population of ninety-five academic research libraries in the U.S. For the purpose of valid peer comparison,
Table 2. Variables Chosen in Library DEA Studies.

<table>
<thead>
<tr>
<th>Output Variables</th>
<th>Discretionary Inputs</th>
<th>Nondiscretionary Inputs*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chen (1997)</strong></td>
<td>Library Visits; Book Circulation; Reference Transactions and Online Search; Patron Satisfaction; Annual Service Hours; Interlending Service</td>
<td>Library Staff; Book Collection; Book Acquisition Expenditure; Library Physical Space; Seating Capacity</td>
</tr>
<tr>
<td><strong>Easun (1992)</strong></td>
<td>Final Outputs: Student Achievement in Standardized Tests (Math, Reading, and Writing) Intermediate Outputs: Provision of Information (3 Variables); Resource-based Instruction (4); Library Use (3)</td>
<td>Initial Inputs: Human Resources (4 Variables); Material Resources (3 Variables)</td>
</tr>
<tr>
<td><strong>Hammond (Forthcoming)</strong></td>
<td>Total Circulation; Reference Transactions; Items Requested Processed</td>
<td>Opening Hours; Monographs, Audiovisual Materials; Serials; Newly Added Items</td>
</tr>
<tr>
<td><strong>Sharma, Leung, &amp; Zane (1999)</strong></td>
<td>Total Circulation; Library Visits; Reference Transactions</td>
<td>Book Collection; Library Staff; Days Open; Total Library Expenditure</td>
</tr>
<tr>
<td><strong>Shim (2000)</strong></td>
<td>Total Circulation; Reference Transactions; Interlibrary Lending; Interlibrary Borrowing; Library Instruction</td>
<td>Volumes Held; Net Volumes Added; Monographs Purchased; Total Serials; Professional Staff; Support Staff; Student Staff</td>
</tr>
<tr>
<td><strong>Vitaliano (1998)</strong></td>
<td>Total Circulation; Reference Transactions</td>
<td>Total Holdings; Weekly Hours; New Books Purchased; Serial Subscriptions</td>
</tr>
<tr>
<td><strong>Worthington (1999)</strong></td>
<td>Total Circulation</td>
<td>Total Library Expenditure</td>
</tr>
</tbody>
</table>

* Nondiscretionary inputs are the inputs that are beyond the control of library administrators. These inputs are included in the DEA formula but are not subject to proportional reduction during the efficiency score calculation.
the libraries are grouped by the main funding source of the parent institutions (publicly funded versus privately funded). A total of five output variables were selected, encompassing all the service measures reported in the statistics: interlibrary loans, interlibrary borrowings, reference transactions, total circulation, and library instruction. On the input side, the study includes two types of variables, discretionary and nondiscretionary. "Discretionary" variables include two main resources libraries use to provide services: materials (4 variables), and staff (3 variables). "Nondiscretionary" variables, which are beyond the control of the library administrator, include measures of the number of library users in several categories. They are treated as input variables because they help to determine how much service the library can provide. While the inclusion of the user populations as input variables seems to suggest that the market being served is used as an input, the rationale for their inclusion is that the level of use is a function of the size of the user population being served and that the DEA model accommodates these variables as a special kind of input variable and does not alter (or manipulate) the figures of user populations in its computations of best possible scenarios for each DMU. This study focused on inefficiencies in inputs; the DEA recommendations are represented as in the calculated input reduction for libraries deemed inefficient:

**Output Variables (5):**
- Total number of interlibrary lending transactions filled (ILLTOT).
- Total number of interlibrary borrowing transactions filled (ILBTOT).
- Number of people who participated in group presentations or instructions (PRESPTCP).
- Number of reference transactions excluding directional questions (REFTRANS).
- Total number of circulation including renewals (TOTCIRC).

**Input Variables (10):**

*Collection Characteristics (Discretionary)*
- Total volumes held (VOLS).
- Net volumes added during the period (VOLSADN).
- Monographs purchased, in volumes (MONO).
- Total number of current serial copies (CURRSER).

*Staff Characteristics (Discretionary)*
- Number of full-time, professional staff (PRFSTF).
- Number of full-time, support staff (NPRFSTF).
- Number of full-time equivalents of hourly student employees (STU-DAST).
University Characteristics (Nondiscretionary)
- Total full-time student enrollment (TOTSTU).
- Total full-time graduate student enrollment (GRADSTU).
- Total full-time instructional faculty (FAC).

Scaling of Data
The data values are in a wide range; volumes held are in the millions whereas the numbers of professional staff and staff assistants are in the hundreds or in the tens. The wide range of values—in one input and output, or in a particular variable across the units—can produce a so-called ill-conditioned matrix that causes computational difficulties (Ali, 1994). Therefore, the study applied scale changes for each variable, so that the scaled data fall below 100. Table 3 shows the ranges of each variable before and after scaling. The same scaling was applied to both 1996 and 1997 data.

Constraints on Weights
Because DEA allows the weights of both the inputs and the outputs of each DMU to vary until it gives the best possible combination for the focus library, the resulting weights will not always make much sense. To make the DEA analysis more reasonable, there should be some boundary (technically called a constraint) to limit the relative weight or importance of various inputs and of various outputs.

In the DEA literature, Charnes et al. (1989), Dyson & Thanassoulis (1988), and Thompson et al. (1990) applied various schemes for restricting the relative size of the possible weights. We follow the “Assurance Region” approach developed by Thompson et al. In this approach, instead of

Table 3. Scaling of Data.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Input</td>
<td>VOLS</td>
<td>13,143,350</td>
<td>1,606,642</td>
<td>200,000</td>
</tr>
<tr>
<td></td>
<td>VOLSADN</td>
<td>248,156</td>
<td>22,381</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>MONO</td>
<td>138,406</td>
<td>—</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td>CURRSER</td>
<td>96,353</td>
<td>10,284</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>PRFSTF</td>
<td>402</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>NPRFSTF</td>
<td>589</td>
<td>53</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>STUDAST</td>
<td>222</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>TOTSTU</td>
<td>52,637</td>
<td>3,988</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>GRADSTU</td>
<td>11,592</td>
<td>1,198</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>FAC</td>
<td>3,186</td>
<td>390</td>
<td>40</td>
</tr>
<tr>
<td>Output</td>
<td>ILLTOT</td>
<td>248,741</td>
<td>1,988</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>ILBTOT</td>
<td>74,598</td>
<td>1,702</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>PRESPTCP</td>
<td>42,222</td>
<td>—</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>REFTRANS</td>
<td>1,161,212</td>
<td>—</td>
<td>15,000</td>
</tr>
<tr>
<td></td>
<td>TOTCIRC</td>
<td>2,690,871</td>
<td>—</td>
<td>30,000</td>
</tr>
</tbody>
</table>
imposing a single set of weights, which is unrealistic, a range of weights in the form of the ratios between the weights is applied to the weight selection process. This approach will effectively limit the movement of the weights in a more realistic range and potentially improve the validity of the DEA analysis. The introduction of the constraints on the weights is expected to decrease the number of efficient DMUs.

Halme, Joro, Korhonen, Salo, and Wallenius (1999) argued against the use of constraints on the weights, proposing instead to use the explicit preferences of the decision-makers. This would make sense in a situation where the DMUs included in the comparison set are all under the control of the same centralized decision-makers. However, this is not applicable to this study population, as the data do not include the information regarding the preferences of library directors or decision-makers at the universities on the proposed inputs and outputs.

While DEA permits each library to "rearrange the world" so that it looks as efficient as possible, there are nonetheless some limitations on the distortions that are permitted. For example, if a staff person costs $40,000/year (the person's yearly salary) and a book costs $50 (purchasing), it would be unreasonable to let the DEA program set their weights or multipliers equal in determining the combined virtual input. A sensible approach might be to examine available data, and allow large, but not outrageous, variation around the median value reported in the literature. For example, the numbers given would lead to a nominal ratio of $40,000/$50 = 800. In applying this ratio, we will adopt two approaches. One is to permit a range from 200 (one quarter of the observed value) to 3,200 (four times the observed value). We call this the four-fold range. This seems extremely generous. Under a two-fold range this ratio would be allowed to vary from a low of 400 (half of the observed value) to a high of 1,600 (two times the observed value). The justification for varying degrees of range is based on the reports in the benchmarking literature that the observed performance difference among different organizations could be as large as a factor of several hundredfold (Boxwell, 1994; Zairi, 1996).

The literature reports a wide range of cost figures for the same service category. The studies listed in Table 4 were consulted for guidelines in deriving service costs. Please note that this study uses the cost of each service as the basis for its relative weight in comparison to other services. Similarly, the cost of inputs and their ratios were obtained directly from the ARL statistics. These are summarized in Table 5.

ANALYSIS OF RESULTS

The data was analyzed using the commercial program called IDEAS. Additional statistical analyses were conducted to delineate the characteristics of libraries evaluated to be efficient.
### Table 4. Cost of Services with Consulted Sources.

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Cost Adjusted</th>
<th>Year for 1997*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Reference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cable (1980)</td>
<td>Average Cost of Search (Excluding Hidden Costs)</td>
<td>$5.18</td>
<td>1980</td>
</tr>
<tr>
<td>Spencer (1980)</td>
<td>Reference Queries</td>
<td>$2.52</td>
<td>1980</td>
</tr>
<tr>
<td></td>
<td>Extended Reference Queries</td>
<td>$4.57</td>
<td>1980</td>
</tr>
<tr>
<td></td>
<td>Consultation, Training, Tours</td>
<td>$9.09</td>
<td>1980</td>
</tr>
<tr>
<td>Kantor (1986)</td>
<td>Query</td>
<td>$14.00</td>
<td>1982/3</td>
</tr>
<tr>
<td>Robinson &amp; Robinson (1994)</td>
<td>Average Total Cost per Reference Question Handled</td>
<td>$6.84</td>
<td>1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Interlibrary Loans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robinson (1994)</td>
<td>Borrowing</td>
<td>$18.43</td>
<td>1994</td>
</tr>
<tr>
<td>ARL/RLG average</td>
<td>Borrowing</td>
<td>(Average)</td>
<td></td>
</tr>
<tr>
<td>Robinson (1994)</td>
<td>Borrowing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average Total Cost per Reference Question Handled</td>
<td>$6.84</td>
<td>1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Circulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kantor (1986)</td>
<td>Per Circulation Cost (Includes Collection Cost)</td>
<td>3.72</td>
<td>1982/3</td>
</tr>
<tr>
<td>(4) Group Presentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From ARL Statistic (per participant)</td>
<td>Average Hourly Rate of Professional Staff (1996)</td>
<td>$34.96</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td>Assuming 2 Hours and 14 Attending per Session</td>
<td>$4.99</td>
<td>1996</td>
</tr>
</tbody>
</table>

*Note: * Applied 7 percent annual increase except for circulation (3.5 percent).

### Table 5. Cost Information for Inputs.

<table>
<thead>
<tr>
<th>Year</th>
<th>Category</th>
<th>Units*</th>
<th>Total Cost*</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>Professional Staff</td>
<td>8,242</td>
<td>$332,752,579</td>
<td>$40,373</td>
</tr>
<tr>
<td></td>
<td>Nonprofessional Staff</td>
<td>14,705</td>
<td>$313,687,653</td>
<td>$21,332</td>
</tr>
<tr>
<td></td>
<td>Student Assistants</td>
<td>7,469</td>
<td>$74,137,023</td>
<td>$9,926</td>
</tr>
<tr>
<td></td>
<td>Monographs Purchased</td>
<td>2,889,585</td>
<td>$173,567,824</td>
<td>$60</td>
</tr>
<tr>
<td></td>
<td>Serials (Current)</td>
<td>2,762,558</td>
<td>$319,589,674</td>
<td>$116</td>
</tr>
<tr>
<td>1997</td>
<td>Professional Staff</td>
<td>8,349</td>
<td>$350,265,615</td>
<td>$41,953</td>
</tr>
<tr>
<td></td>
<td>Nonprofessional Staff</td>
<td>14,702</td>
<td>$326,773,412</td>
<td>$22,226</td>
</tr>
<tr>
<td></td>
<td>Student Assistants</td>
<td>7,667</td>
<td>$76,831,246</td>
<td>$10,021</td>
</tr>
<tr>
<td></td>
<td>Monographs Purchased</td>
<td>2,815,990</td>
<td>$176,298,928</td>
<td>$63</td>
</tr>
<tr>
<td></td>
<td>Serials (Current)</td>
<td>2,783,810</td>
<td>$346,120,125</td>
<td>$124</td>
</tr>
</tbody>
</table>

*Note: * Total of 95 libraries.
Efficiency Scores

Table 6 summarizes the number of inefficient libraries revealed in different evaluation environments.

Reading the table from left to right, there is a marked change both in the number of libraries evaluated inefficient (efficiency score \( q < 1 \)) and the average efficiency scores. As the number of inefficient libraries goes up, the average efficiency score goes down. For instance, in 1996, without any constraints, about 28 percent (\( = 18/65*100 \)) of the libraries in the public group were evaluated inefficient, whereas with the strictest constraint environment (two-fold range, both input and output ratios), about two thirds (\( = 43/65 \)) of the libraries are evaluated inefficient. The average efficiency score fell from .96 to .83 accordingly. In the private group, again in 1996, the number of inefficient libraries increased from 3 to 11, and the average efficiency score decreased from .98 to .91.

Another noticeable change is that, as we expected, the narrower range (two-fold) will always find more inefficient libraries than the more generous range (four-fold). For instance, in 1997, imposing the four-fold range revealed thirty-three inefficient libraries in the public university group while the two-fold range revealed forty-one inefficient libraries.

The two-fold range seems to provide the reasonable discriminating capability that is required of an evaluation tool. Still, there are some differences in the two comparison groups. Under this particular constraint environment about two-thirds of the libraries in the public group seem to have some other libraries in the same peer group to learn from. On the other hand since two-thirds of the libraries are evaluated efficient in the private group, only about one-third of them will have peers to learn from. This difference should not be interpreted as an indication that academic libraries at the privately funded universities are better managed than their peers are at the publicly funded institutions.

Table 6. Number of Libraries Evaluated Inefficient and Average Efficiency Score under Different Constraints.

<table>
<thead>
<tr>
<th>Year</th>
<th>Group</th>
<th>No Constraint</th>
<th>Four-fold range (1/4-4)</th>
<th>Two-fold range (1/2-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>Public</td>
<td>18</td>
<td>34</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.96)</td>
<td>(0.90)</td>
<td>(0.83)</td>
</tr>
<tr>
<td></td>
<td>Private</td>
<td>3</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.98)</td>
<td>(0.94)</td>
<td>(0.91)</td>
</tr>
<tr>
<td>1997</td>
<td>Public</td>
<td>16</td>
<td>33</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.96)</td>
<td>(0.90)</td>
<td>(0.84)</td>
</tr>
<tr>
<td></td>
<td>Private</td>
<td>1</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.99)</td>
<td>(0.94)</td>
<td>(0.89)</td>
</tr>
</tbody>
</table>

Note: Public \((n = 65)\), Private \((n = 30)\). The numbers in the parentheses are the average efficiency scores.
The difference might have been simply due to the relative number of units included in the analysis and the density of the observed data values. If the number of units in the analysis is large, then the competition among the units is more severe than with a smaller number of units. Also, if the observed data values are not concentrated, meaning that there is a greater variation of the size of the libraries, more libraries are likely to become somehow unique, and thus become efficient for no other merit. It is expected that the libraries in the public group are more homogeneous in terms of their observed data values than the libraries in the private group.

Tables 7 and 8 show the rankings of the ARL libraries in terms of their efficiency scores. Random codes are used in place of the names of the institutions to keep their identities confidential. One of the considerations for not revealing the identities is that the DEA technique is only one way of measuring library efficiency. The DEA results need to be accompanied by other measures and data collection methods (e.g., site visits or interviewing library staff) to get a detailed picture of the libraries.

Through a series of sensitivity analyses, this study explored the relative impacts of the variables included in the study on the efficiency scores. Among output variables, removal of reference transactions and circulation variables made the biggest changes on the efficiency scores. All input variables seemed

<table>
<thead>
<tr>
<th>Rank</th>
<th>Library</th>
<th>Efficiency Score</th>
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To affect the efficiency scores to more or less the same degree. However, taking out a variable sometimes can have a huge effect on individual libraries either by decreasing the efficiency scores substantially or by changing their efficiency status, from efficient to inefficient. The selection of variables is not purely a technical issue. For practical, wide applications of DEA, it is recommended that the full set of variables be retained in the analysis.

In addition to sensitivity analysis, this study added random noise in the data and observed the resulting changes in the efficiency scores and the efficiency status. Four simulations of noise were conducted for each year. In each simulation, every observed data element was subject to a random distortion, causing it to vary according to a normal distribution in which the mean is the original value and the standard deviation is 5 percent of its true value. The results are remarkably consistent in terms of changes in the mean scores (.02-.03 for public, .01-.05 for private). The number of libraries that changed their efficiency status was from 4 to 7 in the public group, from 1 to 5 in the private group. Furthermore, the technique is fairly robust despite the presence of random dummy variables.

In conclusion, the DEA technique can be successfully implemented in research libraries in the U.S. This study provides a baseline approach, as well as results that can be further extended to studies using similar techniques to investigate the problem of assessing library efficiency.

**Fluctuation of Efficiency Scores Over Time**

Library statistics are extremely stable. The biggest median change of all fifteen variables over a two-year (1996–1997) period was 5 percent. All the input variables, on average, changed by less than 3 percent during the same period, most of them by less than 1 percent. Therefore, it would be logical to expect that the efficiency scores will stay more or less the same. If there was too much fluctuation, it would be a threat to the technique’s reliability and validity.
Table 9 shows the consistency of efficiency scores and the efficiency status over a two-year period.

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The mean efficiency score changed on average by 6 percent for the public group and by 7 percent for the private group. For the majority of libraries, there was either no change or less than a 5 percent change. However, the composition of the efficient frontier, measured by the number of libraries that change their efficiency status, shows a moderate change. Close examination of the results shows that significant changes accompanied changes in the observed data values of a similar magnitude. These results demonstrate that the DEA technique produces quite reliable results and can be used to track efficiency over an extended period of time.

**Characteristics of Efficient Libraries**

This study looked for the variables or library characteristics that are closely associated with libraries with high efficiency scores.

For the public group, libraries with large net volumes added and professional staff tend to have lower efficiency scores. On the other hand, libraries producing more reference transactions and circulation are more likely to be assigned higher efficiency scores. For the public group, the total circulation was the only statistically significant predictor of efficiency scores over a two-year period.

When all fifteen variables included in this study were used in the regression analyses to predict efficiency scores, a substantial portion of variation in the scores (in both groups) was accounted for by the model with $R^2$ values ranging between .72 and .80. However, when only a subset of the variables is used, such as input variables, output variables, staff variables, collection variables, or user variables, the $R^2$ measures deteriorate quite rapidly.

The amounts of library expenditures per student and per faculty were not significant predictors of efficiency scores. However, in the public group, the size of the library budget was a significant predictor. Libraries with a smaller budget were more likely to be assigned higher efficiency rating. This was not the case in the private group.

Interestingly, none of the per-user activities, measured by the number of various service outputs per student, was a significant predictor of the efficiency scores in either of the comparison groups.
Among the measures of library resource utilization, for the public group, the number of reference transaction handled per professional staff was a significant predictor. For the private group, libraries with a larger proportion of total volumes actively circulated tend to have higher efficiency scores.

Finally, as expected, university libraries that have both law and medical libraries tend to have lower mean efficiency scores (.79 for public, .87 for private) than libraries with neither (.87, 1.00 respectively) due to increased resource requirement. However, the differences were not statistically significant.

Conclusions and Next Steps

DEA seems to have the flexibility and expandability that other traditional measures lack. It provides a technical means to take a closer look at ways in which libraries can improve their performance. The approach is to look at other libraries, not the ones that are simply big or conventionally “good,” but the ones that function efficiently and from which better ways of doing things can be learned. However, this does not mean that the results are directly transformed into actionable recommendations in the real world. On the contrary, there are a host of issues that need to be considered. Two practical areas can be addressed to make progress on these issues.

First and foremost, although the DEA technique has some intuitive appeal, it is difficult to understand its formulations and some of the subtleties related to interpretation of key measures produced. This is the same problem that other applications of operations research techniques have suffered. McDonald & Micikas (1994) noted that the complexity of the models, the arbitrary, unverified assumptions, and the lack of adequate definitions involved in such research are the main stumbling blocks that hinder widespread use of the tools of operations research. One of the ways to address this issue is to form a small group of libraries that agree to adopt DEA as a model to assess the library as a whole or a specific service and collaborate with researchers who are familiar with the technique. As previously noted, most of the DEA applications in libraries were initiated by economists without much interaction with the libraries being evaluated. It is conceivable that the technical complexities can be overcome once the library field has the initiative and forms a nucleus of practitioners who are versed in the applications of the technique.

The second practical issue is that while DEA can provide a way to identify best practices for the purpose of benchmarking, the results need to be verified through followup examination—for example, case studies. The results from DEA analyses in most cases are suggestive rather than confirmatory. A followup is necessary to find out how the best practicing libraries (i.e., efficient libraries) achieve what they do and how other libraries can learn useful lessons by observing and adopting the processes that enabled the efficient libraries. For this reason, it is recommended that instead of
assessing the library as a whole—which was the case for all DEA applications in the libraries identified—it might be more meaningful to investigate a particular library operation or function (e.g., cataloging, reference service, digital content creation, and so on). This way, the libraries being evaluated can determine input and output variables more precisely and gain more useful results. After all, what goes in determines what comes out, and this is especially true in DEA applications.

ACKNOWLEDGMENTS
This research was supported in part by the Council on Library and Information Resources (CLIR) under Grant #6607. The author would like to thank Professor Paul B. Kantor for his encouragement and thoughtful discussions during the study.

NOTES
1. Here we use the input orientation model for the purpose of illustration. An analogous formulation is possible for the output orientation model.
2. Version 5.1, available from Software 1 Consulting Inc., P.O.Box 2453, Amherst, MA 01004–2453.

REFERENCES
envelopment analysis to selected school libraries in California." Ph.D. Diss., University of California, Berkeley.


Activity-Based Costing in User Services of an Academic Library

JENNIFER ELLIS-NEWMAN

ABSTRACT
ACTIVITY-BASED (ABC) IS A NEW COSTING METHOD that is rapidly gaining favor in service organizations. The rationale for using ABC in a library is the same as for other organizations; to allocate indirect costs to products and services based on the factors that most influence them. This paper discusses the benefits of ABC to library managers and explains the steps involved in implementing ABC in the user services area of an Australian academic library.

INTRODUCTION
The financial environment in which Australian universities operate is presently undergoing major changes. A reduction in funding by the Australian federal government and competition from other institutions for diminishing resources has created a political climate in which universities are being pressured to attract external funding to maintain infrastructure and courses previously funded by government. Students are being forced to contribute more of the funding towards their degrees. This is leading to greater expectations for quality services and a demand for more online resources to be provided by university support areas, such as the library, which further increases university costs. Escalating costs, diminishing resources, increased competition from other universities, and demands from legislators and the public for greater service and accountability are forcing university administrators to consider more effective management of resources and costs than has traditionally been the case. This phenomenon is not confined to Australia, but also concerns universities in the United States and Great Britain (Council of Aid to Education, 1997; Mitchell, 1997). The pressures currently

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facing universities are not unlike those encountered by manufacturing organizations, a decade ago. The manufacturing sector responded by developing new tools and techniques for measuring and allocating costs, while in the process gaining a better understanding of costs and cost behavior. Cost systems in the service sector are largely borrowed from the manufacturing sector and many service organizations followed their lead, adopting similar techniques to help with the management of costs. This has not been the case with educational institutions, which still maintain traditional fund-based accounting systems. However, things are changing, with recent studies being undertaken in Australia and overseas to examine the application of activity-based costing (ABC) in higher educational institutions (Ellis-Newman, Izan, & Robinson, 1996; DETYA, 2001). While full implementation of ABC in an Australian university has yet to occur, it is starting to take place in overseas universities (Tatikonda & Tatikonda, 2001).

Traditional accounting systems in universities focus on the budget, which is designed primarily as a means of demonstrating to external agencies how ‘efficiently’ the institution manages its resources. Decisions are often based on how new activities will affect faculty or staff workloads with little consideration given to the actual cost of providing services. If costs are considered, it is often only the incremental or short-term costs, with little consideration given to long-term indirect costs which may be considerable. Activity-based costing is a much more useful management tool for university managers as it provides information about the costs of providing services and what causes those costs to be incurred. Activity-based costing provides managers with information that enables them to make informed decisions concerning the optimal allocation of resources so that activities that are nonvalue-adding can be discontinued and resources shifted to activities that provide the most value to the university.

This paper discusses activity-based costing in the context of library operations at an Australian university; specifically at Edith Cowan University (ECU) in Perth, Western Australia. The paper discusses the benefits and limitations of ABC and illustrates the application of ABC to the user services area of the Churchlands campus library at ECU.

**Activity-Based Costing**

Activity-based costing is a new management accounting tool that has rapidly gained favor in practice. It was originally developed by Cooper & Kaplan (1988) and used in the manufacturing sector in response to dissatisfaction with traditional management accounting techniques that rely on volume-based methods for allocating overheads to product. Cooper & Kaplan (1988) argue that ABC provides a more accurate product cost than traditional cost methods because activities, not production volume, cause costs to be incurred. Activity-based cost systems collect costs to functional cost pools and then allocate these costs to products on the basis of activity-
cost drivers. The generators of costs are called cost drivers and cost behavior is caused by variations in activity volume. An activity is defined as an event or task undertaken for a specific purpose (Horngren, Foster, & Datar, 2000). Examples of activities to be found in a library include material accessions, cataloging, loans processing, and the shelving of library materials (see Figure 1, page 340, for a more comprehensive list of activities). Activity cost pools are the accumulation of all overhead costs involved in the processing of each activity cost driver. The cost pool may be a very general accumulation, such as aggregating all costs involved in user services into one cost pool, or it may be more detailed so that each separate activity carried out in user services has its own cost pool. Aggregating all user services costs into one cost pool will greatly reduce the accuracy of the measured service costs, as the majority of activities in user services are driven by different cost drivers. For example, the cost driver for interlibrary loan costs is borrower requests received from other libraries and campuses, whereas book loans are driven by loans to internal borrowers. The cost of processing a book loan is cheaper than an interlibrary loan since book loans require very little time and effort. Internal borrowers locate the books on the shelves themselves and take them to the loans desk person to scan through the computer. The borrower undertakes the tasks of locating and fetching items, thus saving the library much of the processing costs.

Interlibrary loans, on the other hand, employ higher-level staff and are much more time consuming to process than book loans. The interlibrary loan person has to locate the item on an ECU, Western Australian, Australian, or overseas database and then order and arrange delivery of the item to the borrower. An interlibrary loan request can take from five minutes to one hour to process depending on how difficult the items are to locate and their location. To allocate the same cost to interlibrary loans as is allocated to book loans would be inaccurate and would not adequately highlight the differences in the processing costs between the two activities. For the same reason, interlibrary loans have been further refined in this study to create four separate activities and cost pools because of differences in processing times, level of staff, and the cost drivers used in the various interlibrary loan functions (refer to Figure 1).

Cost drivers are the events that cause changes in the behavior of costs in the activity cost pool. Once key activities have been identified, they are analyzed to determine the event (cost driver) that causes the costs in the cost pool to be incurred. For example, the receipt of a purchase order for library materials triggers materials accessioning staff to place an order, while unshelved books trigger the accumulation of costs to shelving. The more books needing to be shelved, the more staff and time involved in shelving and the higher the costs accumulated to the cost pool. In an ABC system, attention is directed towards the relationships between the cost driver and the activity cost. The relationships recognize that, in the long term, many
costs are variable, leading to a strong cause-and-effect relationship between the cost driver and corresponding cost. It is the level of activity of the cost driver that determines the costs in the cost pool. As the level of cost driver activity increases, more staff are pulled from other areas to cope with demand, thus increasing the costs in the cost pool. As demand decreases in an area, staff are shifted away from that activity to other areas where demand is increasing. This effect can be illustrated by the activity reference desk. The cost driver for the reference desk is the number of inquiries received at the desk. During the fourteen-week semester periods, the number of student and staff inquiries at the reference desk is much higher than during periods when classes have ceased. In the busy times, in order to cope with the increased demand, more staff are employed and rostered on the desk than when it is slack. This increases the salary costs in the cost pool. If additional staff were not employed and there was no slack in the resource base, the quality of service during busy periods would decrease. At the reference desk, this is likely to result in long queues or users simply walking away unsatisfied. If staff were not shifted away from the reference desk during periods of low demand, the cost of processing inquiries would be unacceptably high and slack would occur.

Benefits and Limitations in Implementing Activity-Based Costing in the Library

Activity-based costing has many benefits for managerial decision-making, ranging from decisions concerning the overall direction of the library to matters of operational efficiency. One of the main benefits of ABC is that it provides for a more accurate costing of library activities. Activity-based costing provides managers with an understanding of what drives library costs, making them more visible for cost-benefit analyses. As managers gain awareness of the true costs of providing services, they can make choices that better utilize limited resources. Activities that are not value-adding can be eliminated so that resources are channeled to activities that are the most beneficial to the organization and increase efficiency, particularly where quality considerations need to be made. Activity-based costing can be applied to improving the quality of services provided by the library by ensuring appropriate allocation of resources to the most important areas.

Under the University's current accounting system, the library is provided with a line-by-line budget that allocates past expenditures to common cost centers according to expenditure type such as salaries, maintenance, travel, etc. Expenditures for user services and central library services are aggregated together with no identification of expenditure by campus, division, or section. There is no attempt to identify costs by activity or to determine what is driving the costs. For example, all expenditures on computer maintenance and software are allocated to common computer maintenance and software cost centers so the library manager has no idea whether the maintenance costs were incurred in cataloging or at the loans desk. Even main-
Activity-based costing can also be utilized to derive a fee for charging out services to internal and external users and to facilitate benchmarking (Ellis-Newman et al., 1996). Universities recognize that, under the current system, they are unable to accurately determine a true cost of providing teaching and support services and for the charging out of services. Activity-based costing provides management with a reliable method for determining an appropriate fee. Activity-based costing has many benefits to offer the library and other support areas of the university. However, one of the problems to be overcome if the library does decide to implement an ABC system, is that the current university accounting system does not support the collection of activity-based information. An ABC system uses many more cost pools than those provided by university accounts. For example, to implement ABC, the university's current single cost center for library salaries would need to be divided into multiple cost pools to represent the many activities carried out in the library. The setting up of the system will be initially costly. However, once the system is implemented, much of the necessary detail can be captured and analyzed using the university's existing computer system. In the process, the defining of activities and identifying of costs will provide library managers with a much better understanding of how the library uses its resources, which in itself is beneficial.

The Study

A study using activity-based costing was undertaken in the libraries at Edith Cowan University (ECU) and The University of Western Australia (UWA) in Perth, Western Australia in 1992 (Ellis-Newman et al., 1996; Ellis-Newman & Robinson, 1998). This paper discusses a subsequent study undertaken at the ECU Churchlands campus library in 2001. Since the 1992 study, ECU has undergone a major restructuring of its faculties and central administration. The faculty restructuring comprised a merger between the former five faculties to create three: the Faculty of Business and Public Management (Business); the Faculty of Communications, Health and Science (Health); and the Faculty of Community Services, Education and Social Sciences (Education). In addition, the former Library services support area merged with Student Central and many library tasks previously performed manually were computerized. These included the introduction of Easy Loan lending facilities and the online ordering of interlibrary and intercampus loans. Many journals previously ordered in, processed, and shelved by library staff are now accessible to faculty members from their offices via online databases and are no longer physically acquired. Staff who were formerly involved in processing these activities have since been reemployed elsewhere. Apart from the computerization of some activities, the
rest of the activities in user services are still being processed in a similar manner to the way in which they were handled in the previous study.

User Services

The research site used in this study is user services at Churchlands campus. The reason Churchlands was chosen was because it was featured in the 1992 study and was useful for comparative purposes. Churchlands is one of four ECU campuses and caters to full- and part-time students, university staff, and community borrowers external to the university. All three faculties are catered to by the Churchlands Library although Business has the largest number of students on campus. Churchlands Library user services is split into two main sections: circulation, which caters to loans of library materials including books, serials, film, and video; and reference which looks after users’ information requirements. Both sections are discussed in this study.

Applying ABC in the Library

There is a four-step approach to implementing an ABC system. The four steps involved are:

- identify the key activities and relevant cost drivers,
- allocate staff time to activities,
- attribute staff salaries and other costs to activity cost pools,
- determine a cost per cost driver.

The following section describes the steps involved in undertaking an ABC study in the library.

Step 1. Identify Key Activities and Relevant Cost Drivers.

Identifying Key Activities. The first step in implementing an activity-based costing system is to identify the key activities being performed. In the study, this step involved interviewing the library staff employed in user services. Staff were asked to identify the main tasks in which they were personally involved and to describe the steps they performed in carrying out each task. From the descriptions, key activities were identified and the steps flowchart ed. The purpose of the flowcharts was to determine whether there were any other expenditures, such as computing and database costs, which also needed to be captured in the activity cost pools.

Descriptions were found to be most accurate when described by staff as they physically performed the tasks and least accurate when provided by supervisors who were not personally involved in the actual performance of activities. This is because supervisors who are not directly involved in tasks may only have an overview of how an activity is performed causing them to miss important steps in the process.

Identifying Cost Drivers. Once the key activities were identified, the next step was to identify the cost drivers that caused the occurrence of each ac-
The cause-and-effect relationships had to be reexamined in 2001 because of changes in library record-keeping procedures and the computerization of some activities. In 1992, library statistics were recorded manually each time staff performed a transaction. For example, each time reference desk staff answered a student or staff inquiry they would press a button under the desk to record the inquiry statistic. Statistics were kept for the number of inquiries at the desk but not by individual subjects and faculties.

At the loans desk, book loans were recorded using a loan card system. At the end of each day, the cards were added and summarized into six categories of loans: Business; Health; and Education students; Staff; Community and Reciprocal Borrowers; and Higher Degree/Others. The availability of separate statistics for each of these groups made it possible to separately identify activities by user group (see Ellis-Newman et al., 1998).

In the mid-1990s, the library changed from a manual recording system to a computerized system and no longer records separate statistics for each type of borrower although the system is capable of recording separate statistics if programmed to do so. The inability to retrospectively capture similar data in this study prevented the allocation of costs by faculty and by borrower type. Instead, the study used the statistics currently being collected. These were the number of item checkins, item checkouts, item renewals, and item recalls. Advocates of a broad-brush\(^1\) approach would probably treat loans desk as one cost pool and divide the total amount in the loans desk cost pool by total activity volume. A more accurate approach is to analyze the key activities being performed at the loans desk and then divide the cost pool for each activity by the volume of activity transactions for that activity. This provides more useful information particularly where different activities are heavier users of resources and time than others. Figure 1 illustrates the key activities identified in 2001 and their relevant cost drivers.

**Step 2. Allocate Staff Time to Activities.**

Once key activities have been identified, the next step is to apportion library costs to the activity cost pools. The first step in this process is to determine the proportion of time library employees spend on each activity so that their salary costs can be allocated accordingly. There are various ways of doing this including the use of interviews, diaries, timecards, estimates, and retrospective allocation by individuals and library supervisors. The method used will affect the accuracy of the results. The use of timecards, where staff record the amount of time they spend on each activity, provides the most accurate results but is also likely to be the most time consuming and costly to collect. The use of a broad-brush approach will provide the least accurate results for the reasons discussed previously. Whichever method is used, it must give a fair and reasonable approximation of activity costs. In this study, library staff were interviewed and asked to estimate the amount of time they spend on the various activities. In user
services, most employees are rostered onto particular activities, such as shelving or loan desk inquiries, so this allocation was straightforward with each employee’s hours being allocated according to the roster. Estimates had to be used for the balance of other tasks that staff performed. These tended to be less accurate as some staff were new and did not feel capable of providing an accurate estimation. In these cases, supervisors’ estimates had to be used. Another problem was the fact that staff are often performing other smaller tasks at the same time as their main activities, with a crossover between tasks, so actual time spent on any one activity is not always easily estimated. Once all the employee hours were accounted for they were then recorded, by activity, as a percentage of the total hours worked by each staff member. Table 1 illustrates the proportional allocation of staff time to key activities.

Some of the above activities were capable of further refinement to smaller activities and these were reallocated after the initial accumulation of costs to the key activity areas. The three main areas where costs were capable of further refinement were the loans desk, reference desk area, and interlibrary loan areas. These are dealt with later on.

<table>
<thead>
<tr>
<th>Cost Pools</th>
<th>Cost Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Circulation Section</td>
<td></td>
</tr>
<tr>
<td>Item Loans</td>
<td>Number of Loans</td>
</tr>
<tr>
<td>Item Returns</td>
<td>Number of Book Returns</td>
</tr>
<tr>
<td>Item Renewals</td>
<td>Number of Renewals</td>
</tr>
<tr>
<td>Item Recalls</td>
<td>Number of Recalls</td>
</tr>
<tr>
<td>Easy Loans</td>
<td>Number of Easy Loans</td>
</tr>
<tr>
<td>Overdue Books</td>
<td>Number of Overdue Books</td>
</tr>
<tr>
<td>Closed Reserve—Set up</td>
<td>Number of Reserve Items</td>
</tr>
<tr>
<td>Serials Maintenance</td>
<td>Number of Serial Titles</td>
</tr>
<tr>
<td>Interlibrary Loans—ECU Requestor</td>
<td>Number of Items Requested</td>
</tr>
<tr>
<td>Interlibrary Loans—ECU Supplier</td>
<td>Number of Items Supplied</td>
</tr>
<tr>
<td>Intercampus Loans—Churchlands Requestor</td>
<td>Number of Items Requested</td>
</tr>
<tr>
<td>Intercampus Loans—Churchlands Supplier</td>
<td>Number of Items Supplied</td>
</tr>
<tr>
<td>Film and Video</td>
<td>Number of Film and Video Loans</td>
</tr>
<tr>
<td>Shelving</td>
<td>Items Shelved</td>
</tr>
<tr>
<td>Equipment Maintenance</td>
<td>Equipment Use</td>
</tr>
<tr>
<td>(2) Reference Section</td>
<td></td>
</tr>
<tr>
<td>Reference Desk</td>
<td>Number of Inquiries</td>
</tr>
<tr>
<td>Faculty Work—Business</td>
<td>Number of EFTSU—Business</td>
</tr>
<tr>
<td>Faculty Work—Health</td>
<td>Number of EFTSU—Health</td>
</tr>
<tr>
<td>Faculty Work—Education</td>
<td>Number of EFTSU—Education</td>
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<tr>
<td>Employee</td>
<td>Supervision</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
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<tr>
<td>C</td>
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<td>T</td>
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</tr>
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</table>
Step 3. Allocate Staff Salaries and Other Costs to Activity Cost Pools.

Step three involved a study of the library budget and accounting records in order to identify and assign library costs to the relevant cost pools. Staff salaries constituted the single largest cost for user services although there had been a significant increase in technology costs since the previous study.

Salary costs were allocated to activity cost pools by multiplying the individual salary costs of user services employees by the proportion of time they spent on each activity. Actual salary costs were used as there were not many employees and their individual salary costs were easily identifiable. Where there are many employees and it is considered too time consuming to separately identify individual salary costs, activity costs can be calculated using the median salary cost of all employees. However, this may result in distorted costs if some activities employ more expensive, higher-level staff than others. In addition to the actual salaries paid to staff, there are additional ‘on costs’ that need to be added to the cost pool. These ‘on costs’ consist of an additional loading to cover payroll tax, superannuation, long service leave, and workers’ compensation. The standard ‘on-cost’ loading at ECU is 27 percent so salary costs were increased by this amount before apportioning to activities. Where employees were directly involved in performing activities, their salary costs were easily allocated to activities. However, the cause-and-effect relationship was less visible between administration and supervision costs and activities. Most supervisory staff are involved in both supervising and performing some of the user services tasks. Their hours were allocated in the same manner as the other employees with an appropriate amount set aside for supervision activity and this was captured in a separate column. A supervisory cost was then calculated by multiplying the supervisor’s salary plus ‘on-costs’ by the percentage of supervision time attributed to them. The supervision cost was then allocated across the remaining activities according to the number of employee hours consumed by each activity. Employee hours was used as the allocation basis as it was agreed that there was a relationship between total employee hours and the proportion of supervision devoted to an activity. If employee hours had not been an adequate indicator, an alternative approach would have been for the supervisor to estimate the amount of time spent on supervising each activity. Other administration tasks undertaken by the supervisors, such as planning, report writing, attending meetings, etc., were not separately identified as key activities as it was considered that these related to their duties in user services and could therefore be attributed to the existing user service activities.

Table 2 provides the activity costs arrived at after multiplying the percentage of time spent on each activity (from Table 1) by the employee’s annual salary cost and adding supervision and other costs. The amounts in the activity columns were then added downwards to arrive at total cost per activity area.
<table>
<thead>
<tr>
<th>Employee</th>
<th>Loans Desk</th>
<th>Overdues Reserve</th>
<th>Reference</th>
<th>Serials</th>
<th>Film and Video</th>
<th>Shelving</th>
<th>Equipment</th>
<th>ILL</th>
<th>Total Costs</th>
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<td>$4,569</td>
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<td>$28,115</td>
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<td></td>
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<td></td>
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<td>$5,354</td>
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<td>$8,237</td>
<td>$11,120</td>
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<td>$39,866</td>
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<td></td>
<td></td>
<td></td>
<td>$36,691</td>
</tr>
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<td></td>
<td></td>
<td>$43,426</td>
</tr>
<tr>
<td>T</td>
<td>$5,563</td>
<td>$9,508</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$15,161</td>
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<tr>
<td>Supervision</td>
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<td>$629</td>
<td>$2,356</td>
<td>$29,292</td>
<td>$12,889</td>
<td>$892</td>
<td>$3,553</td>
<td>$9,458</td>
<td>$52,733</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$35,500</td>
</tr>
<tr>
<td>Total</td>
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<td>$5,549</td>
<td>$21,334</td>
<td>$212,082</td>
<td>$3,960</td>
<td>$9,129</td>
<td>$116,427</td>
<td>$35,152</td>
<td>$736,751</td>
</tr>
</tbody>
</table>
Accounting for Other Indirect and Direct Costs. At ECU, indirect overheads such as electricity and the depreciation of buildings and equipment are not charged to the library so these were ignored in this study. However, indirect costs, where possible, should be assigned to activities on the basis of their cause-and-effect relationship. For example, space costs would be allocated to cost pools based on the square-meter area used by the different activities while electricity would be allocated on a similar basis (for lighting) with perhaps a heavier weighting for activities that are heavier consumers of electricity, such as photocopying and computing.

Stationery costs are likely to be higher for the equipment cost pool which covers photocopiers than for the loans desk or reference desk areas so these should be apportioned according to activity consumption. The flowcharting of activities helped identify the heaviest users of these resources while staff estimates were used for apportioning database access charges and courier costs between interlibrary loans and cataloging. Although a sizable part of the library budget, it was not possible to separately identify the computing software and maintenance costs for Churchlands campus library, let alone user services, as all such expenditure is accumulated under one common cost center for all campuses. In a broader study of the entire university library system and, given more time, an appropriate basis for allocating these costs across activities could be determined. Using the cost driver to allocate costs to activity cost pools, loans desk, interlibrary loans, and reference were three areas identified in Step 2 as being capable of further refinement into smaller activities. The first of these, loans desk, was split into four activities; item loans, item returns, item renewals, and item recalls. If the four activities carried out under loans desk took the same amount of time to perform, then information would not be sacrificed by using just one loans desk cost pool and driver. However, if accuracy is truly desired, it is unreasonable to expect that an activity that takes five minutes to perform should bear the same cost as one that takes half an hour. For this reason, when determining the cost per cost driver, it is necessary to weight activity statistics based on the amount of resources they consume.

The processing of item renewals and item recalls at the loans desk takes approximately twice as long as the processing of item loans and returns, so the former were weighted by multiplying their activity volume by two to recognize that they consumed double the resources. The total amount in the loans desk cost pool in Table 2 was then divided by the total of the new weighted activity statistic to arrive at a cost-per-activity unit. Next, the total cost for each of the four cost pools was determined by multiplying the cost-per-activity unit by each activity's weighted cost driver volume. This enabled the total cost in the loans desk cost pool to be allocated across the four separate activities in the loans desk area according to their resource consumption. Finally, the total amount in each activity's cost pool was divided
by its original unweighted activity volume to arrive at a cost per cost driver. From Table 3 it can be seen that a straightforward item loan or return costs $0.95 to process while item recalls and renewals, at $1.90, cost twice as much.

A similar process was undertaken with the interlibrary loans cost pool. Interlibrary loans encompass intercampus loan (ICL) requests between the four ECU campuses and interlibrary loans (ILL) between ECU and other Australian and overseas libraries. In ILL, 75 percent of item requests take about ten minutes to process while the more difficult requests can take from fifteen minutes to one hour. To assign a cost to the ILL requests, 75 percent were weighted by one (ten minutes), and the more difficult 25 percent were weighted by three (based on an estimated average processing time of thirty minutes). This was considered sufficient for this study. It was determined that a straightforward ILL request costs approximately $8.80 (ten minutes to process) while the most difficult request costs $52.80 (one hour to process or six times the cost of processing straightforward requests). Most requests (75 percent) occur at the lower end of the range and so an average cost of $13.21 for ILL requests was calculated overall, after weighting for the percentage of straightforward and difficult items. Intercampus loans were cheaper to process because of lower salary costs (lower HEW-level staff employed) and the shorter time taken to process loans. The additional costs of $32,000 were made up of $5,000 for postage and $27,000 estimated for interlibrary loan access costs to the various Australian and overseas databases. The other $3,500 allocated to equipment is an estimate of stationery costs incurred by photocopying.

**Step 4. Determine Cost Per Cost Driver.**

Having determined a total cost for each activity, the next step is to calculate the cost per cost driver. This is calculated by dividing the total amount in each activity cost pool by the cost driver volume. The results are provided in Table 3.

Although reference desk inquiries, overdues, and shelving, were identified as key activities, it was not possible to determine a cost per cost driver simply because the library does not keep the relevant statistics. At first glance, one might presume that shelving is a function of the number of books borrowed, and, as such, activity costs can be determined through an analysis of loan statistics. While this may be true in some libraries, this is not the case for Churchlands Library because of its very high proportion of in-library use, which is not captured in the loan statistic. One method of arriving at a cost driver volume in the absence of recorded statistics would be to survey library users and to keep a record of books shelved by subject but the benefits in trying to achieve this level of accuracy are probably minimal. Observations by library staff involved in this type of activity can often be quite accurate so staff estimates could be utilized. Another alternative is to use the number of equivalent full-time student units (EFTSU) as a
Table 3. Activity Cost Driver Table for User Services—Churchlands Campus Library.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost Driver</th>
<th>Total Cost</th>
<th>Driver Volume</th>
<th>Cost Per Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item Loans</td>
<td>Number of Loans</td>
<td>$44,346</td>
<td>46,789</td>
<td>$0.95</td>
</tr>
<tr>
<td>Item Returns</td>
<td>Number of Returns</td>
<td>$112,882</td>
<td>119,100</td>
<td>$0.95</td>
</tr>
<tr>
<td>Item Renewals</td>
<td>Number of Renewals</td>
<td>$29,421</td>
<td>15,521</td>
<td>$1.90</td>
</tr>
<tr>
<td>Item Recalls</td>
<td>Number of Recalls</td>
<td>$2,506</td>
<td>1,322</td>
<td>$1.90</td>
</tr>
<tr>
<td>Easy Loans</td>
<td>Number of Easy Loans</td>
<td>$18,720</td>
<td>79,835</td>
<td>$0.23</td>
</tr>
<tr>
<td>Overdue Books</td>
<td>Number of Notices</td>
<td>$5,549</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Closed Reserve</td>
<td>Number of Reserve Items</td>
<td>$21,334</td>
<td>580</td>
<td>$36.80</td>
</tr>
<tr>
<td>Serials Maintenance</td>
<td>Number of Serial Titles</td>
<td>$3,960</td>
<td>10,797</td>
<td>$0.37</td>
</tr>
<tr>
<td>Film and Video</td>
<td>Number of Loans</td>
<td>$9,129</td>
<td>2,223</td>
<td>$4.11</td>
</tr>
<tr>
<td>Shelving</td>
<td>Items Shelved</td>
<td>$116,427</td>
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<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>Equipment Use</td>
<td>$35,152</td>
<td>1,308,634</td>
<td>$0.03</td>
</tr>
<tr>
<td>IL Loans—ECU Requestor</td>
<td>Number I/L Loans Requested</td>
<td>$60,613</td>
<td>4,589</td>
<td>$13.21</td>
</tr>
<tr>
<td>IL Loans—ECU Supplier</td>
<td>Number I/L Loans Supplied</td>
<td>$72,642</td>
<td>4,422</td>
<td>$16.43</td>
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<tr>
<td>IC Loans—ECU Requestor</td>
<td>Number I/C Loans Requested</td>
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</tr>
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<td>IC Loans—ECU Supplier</td>
<td>Number I/C Loans Supplied</td>
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<td>Invoicing</td>
<td>Number of Invoices</td>
<td>$2,277</td>
<td>2,800</td>
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</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td></td>
<td><strong>$755,471</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

proxy for library usage. This, of course, presumes that all disciplines and undergraduate and postgraduate students are equal users of library resources, which, in fact, is not the case. Reference desk faculty work encompasses all activities related to looking after and maintaining the library collection for each faculty, plus other faculty-related activities. EFTSU was used as the cost driver for reference desk faculty work as EFTSU was considered a reasonable driver of faculty referencing costs. Finally, a unit cost per EFTSU was determined for the overall user services section of Churchlands Library by dividing the total amount in the user services cost pool by the number of EFTSU at Churchlands. This gives the cost per EFTSU of providing library services at Churchlands campus and is useful for a comparison of costs across the other campuses and at other institutions. It also demonstrates the limited value of the information, had a broad-brush approach been adopted.
Conclusion

This paper discusses the benefits of ABC to library managers and provides an illustration of the type of information an ABC system can provide to assist with decision-making. The information provided in the above tables relates directly to the costs of activities of concern to library managers and is not readily available from the university's traditional accounting system. Although not trained as accountants, library managers rely on accounting information for strategic planning and operational decision-making. Increased demands for institutional accountability, with university performance and costs under increased scrutiny, place library managers under increased pressure to maintain quality services while faced with decreased funding and tighter budgets. A commitment to greater efficiency requires an understanding of cost behavior. The university budget reports provided to library managers are designed for legislative funding requirements rather than for management decision-making and generally mirror the requirements of the institution's funding bodies. University accounting reports fail to provide adequate information to enable managers to determine the cost of services and to make optimal decisions regarding the allocation of scarce resources. One of the best tools for understanding cost behavior and for refining a cost system is activity-based costing. The rationale behind using ABC in universities is the same as for manufacturing and industry—to allocate indirect costs to goods or services based on the factors that most influence them. The use of multiple cost pools and drivers under ABC leads to more detailed and accurate product costing than that provided by traditional cost systems. The individual activities become the central cost focus with the assigning of costs to activities based on the way in which the resources are consumed by the activities. Managers can then determine whether certain activities are necessary or whether they can be eliminated. Only services that are value adding are maintained while nonvalue-adding services can be eliminated, resulting in cost savings for the university.

Note
1. A broad-brush approach refers to the assigning of the cost of resources uniformly to cost objects (services) when the individual services actually use those resources in a nonuniform way. This is a cheaper method of assigning costs under ABC but it usually results in less-reliable data.

References


Scholarly Materials: Paper or Digital?

RICHARD E. QUANDT

ABSTRACT

The paper starts out by reviewing the so-called "library crisis" and the extensive literature on the determinants of journal prices. It discusses the impact of the recent merger activity among journal publishers and notes, among the possible remedies that have been suggested, the possibility that electronic publications may slow down the increase in journal prices. It next discusses the "productivity puzzle," i.e., the question of why the substantial improvements in computer technology may not have been translated into productivity increases at a faster rate. While the longer-term impact on productivity is not as unfavorable as initial approaches may have suggested, the paper argues that the cost savings in producing electronic rather than paper journals tend to be overestimated, particularly because the costs of archiving are not adequately dealt with in many approaches to this problem. While much attention has been devoted to how electronic approaches can affect the costs of producing journals, relatively few people have dealt with the even more important question of how these approaches affect productivity in teaching, learning, and research. The final substantive section of the paper deals with pricing and related issues, with particular attention to price discrimination and the bundling of journals.

INTRODUCTION

In 1994, The Andrew W. Mellon Foundation launched a project to study the impact on scholarly communication of electronic or digital approaches to the provision of scholarly library materials. The Foundation announced its willingness to fund projects that would
... assist the adoption of new technologies for acquiring, storing, and disseminating scholarly information. The greatest emphasis is placed on concrete, practical, and cost-saving projects, while leaving a little room for exploring more visionary projects with less well-defined payoffs in the short-run. In any event, it was intended from the beginning that projects would largely use existing hardware and software technologies, rather than concentrate on inventing new types of technologies (such as designing new types of chips). In all projects funded by the Foundation, grantees must pay considerable attention to the economics of the project, that is to say to the cost side as well as to the demand side. This requires that project personnel carefully track the evolution of costs and of old and new ways of providing and accessing scholarly information. (Quandt, 1996a)

The intention was to support "a variety of natural experiments in different fields of study using diverse formats including the electronic equivalents of books, journals, manuscripts, sound recordings, photographs and working papers (Bowen, 1999)." Preparation for the initiative began in 1993, and the basic objectives of the Foundation were stated in a paper that attempted to analyze the principal difficulties facing scholarly communication and the promises of new technologies (Ekman & Quandt, 1993, rev. 1995). Between October 1994 and March 1999, the Foundation awarded, under the auspices of this program, $18,977,000 to a total of fifty-four projects.

This initiative was by no means the first foray by the Foundation into an analysis of libraries, library technologies, and the economics of libraries. Two years earlier, in 1992, the Foundation sponsored the preparation and publication of a definitive analysis of the economic problems besetting research libraries (Cummings, Witte, Bowen, Lazarus, & Ekman, 1992). The principal problem appeared to be that the prices of library materials were increasing faster than library budgets, and that journal prices were increasing faster than monograph prices. Thus, for example, between 1982 and 1990, journal prices increased 131.9 percent in chemistry and physics, 125.6 percent in engineering, 91.9 percent in political science, and 58.0 percent in languages and literatures. While other authors reported slightly different figures, all agreed that the increase was most marked in science, medicine, and technology (Lynden, 1993; Ketcham & Born, 1994). Significant evidence was emerging that libraries were reducing their purchases of monographs and significantly reducing their purchases of serials, which appeared to threaten their ability to fulfill their traditional role of mediating scholarly communication. But these untoward economic developments coincided temporally with the enormously rapid development of various electronic technologies: the speed of processors, the capacity of storage devices, and the bandwidth (transmission capability) of networks. Thus, Moore's Law, enunciated in 1965, which predicted that computing power and storage capabilities would double every eighteen months, has been reasonably accurate during the next thirty years (Fuchs, 2001) communi-
cation costs per one million bits have declined between 1960 and 1992 from $1 to $0.00094 and the cost of routers (per million bits transmitted) from $10 to $0.00007 (MacKie-Mason & Varian, 1993). It seemed natural to wonder whether it might not be possible to deliver the materials that form the content of scholarly communication to users in a cost-effective manner.

It seems appropriate near the tenth anniversary of Cummings, et al., to revisit some of the fundamental issues of the library crisis and examine the relevance of some recent developments.

**VIEWS ON THE LIBRARY CRISIS**

While in a real sense there is only one "library crisis" (and not a separate book crisis and journal crisis), the major source of the problem is generally perceived to be the behavior of journal prices. To illustrate the level of journal prices, the annual subscription price of chemistry and physics journals in 1990 was reported by Cummings, et al. to be $412.66; engineering journals, $138.84; political science journals, $49.67; and language and literature journals, $30.63. To the extent that libraries are perceived to be in crisis, two kinds of questions can be raised: (1) Why are the subscription prices of some journals higher, and often very much higher, than those of other journals? (2) Why are the subscription rates of journals increasing faster than the rate of inflation and library budgets?

The first question has been attacked by various authors by means of straightforward econometric studies in which the prices of various journals are regressed in cross-sectional models on a variety of explanatory variables (Peterson, 1989, 1990, 1992; Chressanthis & Chressanthis, 1994a, 1994b). Typical explanatory variables are the number of issues per year, a dummy variable indicating the presence or absence of photographs or graphs in the journal, a dummy variable indicating the presence of advertising in the journal, the number of pages published per year, the number of years that the journal has existed, a dummy variable indicating whether the publisher is for-profit or not, and dummy variables indicating the geographic location of the journal. Other variables used include measures of the quality of the journal; these measures may be based on the number of citations to the journal, or the “half-life” of articles in the journal (measured by the most recent period accounting for half the total citations), or an immediacy factor (the ratio of citations to a journal divided by the number of articles in it), or finally, on an impact factor defined as the average number of times that articles appearing in the journal in a certain preceding period are cited in a given year. Some regressions also include the individual subscription price (since a measure of the library price minus the individual price divided by the library price may be a measure of monopoly power on the assumption that the individual price is close to marginal cost).

The results from these early regressions are not entirely consistent, but certain broad patterns do emerge. The subscription price of a journal is
increased the more issues it publishes per year and the more pages it publishes; an additional copy in circulation and an additional year of journal existence reduce the price; being published by a commercial publisher or in Europe substantially increases the price. Versions of these models that contain variables measuring the "quality" of the journal indicate that the higher the quality, the higher the subscription price. None of these findings is particularly surprising, and the higher price charged by commercial and European publishers tends to confirm the often articulated observation that commercial publishers are able to reap monopoly profits, particularly in the light of the well-known dominant position of publishers such as Elsevier, Kluwer, Springer Verlag, and others.

The latest study of this kind is by Richard Meyer, on behalf of the Associated Colleges of the South, which had received a Foundation grant for exploring the possibilities of database sharing among its member institutions (2000). The principal new contributions of the study are the use of a much larger database than was employed by earlier studies (859 periodical titles) and an explicit test of the hypothesis that monopoly power does not increase in the electronic journal domain. This hypothesis was motivated by the straightforward observation that entry costs are lower for electronic journals than hard copy journals. The dependent variable in the regression study was either the institutional price or a measure of monopoly power, as measured by the difference between the institutional price and the individual price.\(^4\)

Most of the regression coefficients (on a fairly standard set of variables for regressions of this type) have the expected signs and many are statistically significant. The major surprise was that the dummy variable measuring whether a journal is electronically available had a positive sign and was highly significant in both types of regressions, i.e., the regressions of institutional price or of (institutional price minus individual price) on the explanatory variables including the electronic availability dummy suggested that electronic availability increases monopoly power. This result is almost certainly due to a specification error and represents incomplete modeling of the interactions between electronic availability, the commercial or not-for-profit status of the publisher, and whether the journal in question was electronic-only or had a hard-copy variant. The study also finds a weak negative relationship between price and circulation, which it interprets to mean that price increases result in cancellations, hence lower circulation. While this is a correct interpretation of a dynamic process (Quandt, 1996b), in a cross-sectional analysis a more proper interpretation is that journals with large circulation are able to set lower prices because they can spread first-copy costs over a large number of units. The study also correctly recognizes that circulation may be jointly determined with price and that hence simultaneous equations estimation techniques would need to be employed, but does not actually implement this train of thought.
Finally, the study examines which journals charge prices that are, percentage-wise, significantly higher than the amount predicted by the regression equation and finds, not surprisingly, that among the top twenty such journals Elsevier and Academic Press account for twelve. But in order to estimate the magnitude of the “Elsevier-Academic Press effect,” it might have been better to include dummy variables for these publishers. All in all, the results of the cross-sectional studies are reasonable and provide a great deal of insight into the static factors that determine journal pricing.

The second question is why journal prices are rising faster than other price indicators, and hence deals with a dynamic process. There are hints in the static, cross-sectional studies that monopoly power has some role to play in this, because commercial publishers’ journals are typically much more expensive than those published by university presses, professional associations, and other not-for-profit organizations. Presumably, commercial publishers face an inelastic demand for their product and hence are continually attempting to raise prices in order to secure monopoly profits.

But this is not the only possible explanation for the tendency of subscription prices to rise. Journals have economic value because they provide information and because they play an important role in assessing the quality of a scholar (Noll, 1996). Noll and Steinmueller (1992) ask, in the light of the undoubted negative association between circulation and subscription prices, why some journals have low and others high circulation. They find the basic reasons in the behavior of scholars themselves. Since advancement in salary and academic rank heavily depends, at least at U.S. universities, on the scholar’s publication record, scholars attempt to publish articles, but are often unable to do so in the most prestigious general journals, because the demand for space far outstrips its availability. Since it is very difficult to create new, top-quality, general journals, publishers accommodate academics who wish to publish by creating more specialized journals. Creating a high-quality specialized journal is not as difficult as creating a more general-purpose journal, but more specialized journals are doomed to have much lower circulation; hence first-copy costs have to be spread over a smaller number of copies, resulting in a higher subscription price. But then the general pattern may repeat itself after some time, and the more specialized journal cannot accommodate the demand for article submissions, hence even more specialized journals with even smaller circulation and higher price are spawned.

There is much that is appealing about this explanation, but it is doubtful that it can ultimately explain the endless round of price increases that have been observed in the marketplace. Annual price increases, particularly for journals published by commercial publishers, have been striking at times, as is evident by examining the 1992–93 increases for Elsevier-Pergamon journals deemed to be of importance for the Scripps Institution of Oceanography Library. It is noted that price increases are justified by publishers
on the grounds that the number of pages have increased and that other changes have been introduced in the production of journals to justify the increases (as one would expect from the results of the regression studies cited earlier). The percentage increases in prices of titles which were expanded in scope and of those that were not expanded between 1992 and 1993 are shown in Table 1. While it is true that the journals that expanded in size or scope increased in price by a higher percentage than the others, the difference is not consequential, particularly in the light of the fact that journal publishing costs had not increased in an unusual fashion in recent times (McCabe, 1998). Moreover, attributing the price increase in individual cases to, say, an increase in the number of pages published can yield absurd answers; to wit, if the price increase in *Biochimica and Biophysica Acta* between 1992 and 1993 were attributed (entirely) to an increase in the number of pages published, then, using the regression coefficients of one of the Cressanthis and Cressanthis studies, the implied increase in the number of annual pages is 76,638.

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<th>Table 1. Elsevier-Pergamon Price Increases, 1992–93.</th>
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<td>1992 Prices</td>
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<td>Elsevier</td>
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<td>Expanded Journals (18)</td>
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<td>Expanded Journals (10)</td>
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It has also been the case that substantial merger activity has taken place among journal publishers. Elsevier merged with Pergamon, then with Reed, and most recently, Reed-Elsevier merged with Harcourt (although the Higher Education and certain Corporate and Professional business activities of Harcourt are to be spun off to The Thomson Corporation), thus acquiring another major journal publisher, Academic Press. Wolters merged with Kluwer, Lippincott merged with Kluwer, and while the Reed/Elsevier–Wolters/Kluwer merger was called off in March 1998 (McCabe, 1998), the trend toward increasingly higher concentration in the journal publishing industry seems indisputable, which tends to contradict Noll's view that market power has not increased among journal publishers (Noll, 1996, p. 13). The fundamental question is whether merger activity is likely to raise journal prices—an action that will be undertaken by a merged firm if doing so raises profits. McCabe's theoretical model (2000) is based on the assumptions that (1) all libraries have one of two budget levels (high or low), and (2) libraries purchase periodicals in declining order of \( \frac{U(i)}{C(i)} \), where \( U(i) \) is the "quality" or usefulness of journal \( i \) and \( C(i) \) is its cost, until its budget is exhausted. McCabe's model permits both outcomes, depending
on particular circumstances, but his empirical analysis of publisher and price data from some 3,000 journals in the 1988-98 period, which evaluates the effect of the Reed/Elsevier merger with Pergamon and the Wolters/Kluwer merger with Lippincott, indicates that in the first of these mergers there was a pure, merger-induced market-power effect, raising Elsevier journal prices by 5.2 percent and Pergamon prices by 27 percent. In the second of these mergers, Lippincott prices increased by some 30 percent (although some portion of this increase was due to an increase in the inelasticity of demand for those journals and thus did not represent pure market power), while Kluwer prices declined slightly. It seems reasonable to conclude that market power has a noticeable effect on journal prices over time.

There do not appear to be many strategies in the short run that could alleviate these problems. Interlibrary loans can certainly help libraries that cannot afford certain journals, but they are time consuming (they do not deliver the product ‘just in time’) as well as costly. While the annual growth of interlibrary lending services has been impressive (9–10 percent between 1988 and 1995 (Kyrillidou, 1995)), borrowing an item was reported to cost between $9.84 and $30.27 and lending between $6.29 and $17.49 (Quandt, 1996a); the median delivery time was found to be 12.5 days (Miller & Tegler, 1988). More recent figures put the average cost of borrowing an item at $18.35 and of lending at $9.48, with borrowing turnaround time averaging 16 days (although both costs and turnaround times are somewhat, but not massively, smaller for the ten research libraries with the best performance) (Jackson, 1997). Both the high cost and the turnaround time suggest that ILL is at best an imperfect remedy. Alternatively, a vigorous antitrust policy could perhaps slow the rate of merger-induced price increases, but since journals are often not perceived to be close substitutes, the journal market is not one in which far-reaching antitrust action is likely; in any event, this is unpromising as a short-run strategy.

It was therefore entirely sensible and natural that people should look to the new electronic technologies for possible solutions to the library crisis. Analogously with the effects of automation in industrial contexts, the possibility of electronic delivery of scholarly materials appeared to promise breakthroughs in costs, and suggested that both the speed of delivery and the reach of such library materials could be greatly enhanced. In other words, the new technologies appeared to promise major gains in productivity.

THE PRODUCTIVITY PUZZLE

Aggregate Productivity. Although fully transistor-based mainframe computers began to be available in the late 1950s, it is not unreasonable to claim that the modern computer revolution started in the 1970s. LSI and VLSI circuits started to come into existence in the early 1970s (although integrated circuits were available throughout most of the 1960s). Nineteen seventy-one was the year in which the revolutionary Intel 4004 chip made its
appearance (Computer History and Development). Unix was invented in 1969, although the first publication about Unix appeared only in 1974 (Ritchie, 1984). The first fairly widely available personal computer (Altair 8800) appeared on the market in 1975, Apple Computer was founded in 1976, Wordstar appeared on the market in 1979, and finally, in 1981, the IBM PC made its appearance. From 1981 to 1992, the number of PCs in use had grown from 2 million to 65 million.

But in looking over the decades of the 1970s and 1980s, it seems that neither the growth of GDP nor the growth of productivity reflected the massive advances in computing and their growing applications in the business world. In fact, the growth of total factor productivity dropped from an average of 1.45 percent per annum in the 1929 to 1966 period to 0.04 percent in the 1966 to 1989 period (David, 2000). The productivity paradox consists of the slowing of productivity growth in this period "in the face of phenomenal technological improvements, price declines, and real growth in computers and related IT equipment" (Moulton, 2000).

Why did measured output (GDP) not grow faster and why did productivity growth perform as badly as it did? Is the computer revolution a flash in the pan and are we unrealistic to pin our hopes on it for contributing to the solution of the problems of scholarly communication? There are several reasons for believing that the apparent lack of response of the economy to the computer and information revolution should not cause us to be surprised.

1. Investment in computers is still small as a fraction of total investment in the economy. In 1996, it accounted for less than 10 percent of gross investment and, according to Daniel Sichel, investment in computer hardware contributed only 0.2 percent of the total average annual growth rate of 2.3 percent of nonfarm business output from 1980 to 1992 (Blinder & Quandt, 1997; Sichel, 1997; David, 2000). According to Moulton, the contribution was in the 0.1–0.2 percent range between 1987 and 1994 and perhaps between 0.3 and 0.4 percent thereafter (Moulton, 2000, pp. 36–37). It is difficult to imagine that a sector that is so small relative to the total could induce revolutionary changes in a short period of time.

2. Aggregate output changes (and hence, productivity measures) are obtained by deflating nominal (i.e., current-dollar denominated) output by some appropriate price index. But there is plenty of reason to believe that price indices over the relevant period have not been measuring price changes correctly, and have, in fact, overstated price increases by an average of 1.1 percent. Making the relevant adjustment would, according to David, increase the total factory productivity rate for 1966–89 to the 0.64–1.14 percent range.

3. Productivity appears to have increased least in the areas in which one
can be quite certain that dramatic changes in production processes have taken place as a result of the computer revolution, namely banking, finance, insurance, and related areas. But these are the areas in which measuring quality change may be most difficult: how do we impute output to the convenience created by the existence of ATMs and by the ability of stock exchanges to process vastly greater numbers of trades?

4. New products appear at an alarming rate in computer and information technology. That brings with itself two problems, of which one is real and the other one is one of measurement. The real problem is that the avalanche of new products creates rapid obsolescence; as a result, the gross investment in computer equipment is far larger than net investment and much labor activity has to be expended on learning new computer and software systems (Blinder & Quandt, 1997, p. 29). The measurement problem is that the new products are not immediately "chained into" price indices, but only after they have achieved a minimal market share; however, the greatest price declines for new products tend to occur soon after their introduction, and hence they may not show up in price indices in a timely fashion (David, 2000, pp. 61–62).

5. Standardization and quality control, particularly in software, have been difficult to achieve since the provision of software has shifted from a few major manufacturers to hundreds of thousands of smaller providers—a development strongly associated with the rise of the personal computer. This clearly puts additional burdens on the users.

6. The implicit expectation that the introduction of computer technology would result in a nearly simultaneous increase in productivity and output growth is unrealistic and ahistorical. As David points out (2000, pp. 77–82), central electrical generating stations were introduced in 1881, but between 1899 and 1904, the electric portion of mechanical drives in manufacturing rose from 5 to only 11 percent, and the proportion of secondary electric motors in manufacturing reached the 50 percent mark only as late as the 1920s. Brynjolfsson and Hitt (2000) also find that "the effects of information technology are substantially larger when measured over longer periods," (and also that the effects are more easily visible in firm-level data rather than aggregate data, because the latter tend to obscure or mask the quality improvements resulting from information technology). The fact is that the diffusion of innovations takes time and it is plausible to argue that we are still in the beginning phases of the computer revolution.

The overall longer-term productivity promise of the computer revolution is therefore not nearly as unfavorable as initial views of the productivity puzzle might suggest. But we have a more stringent task before us: we need to come to grips with the productivity implications of innovations in the provision of scholarly materials. These materials are, first and foremost,
books and journals, but they also include visual and audio materials and multimedia materials that combine visual and audio features, such as films, etc. The urgency and possibly the difficulty of introducing innovations in these areas may well depend on the “stability” of the original materials, some of which may have a relatively high degree of stability and long-term existence, such as microfilm, microfiche, and paper, or may be relatively endangered as is material printed on acid paper, or may be rare and endangered such as materials many centuries old, or may be evanescent such as one-time performances.

The question of productivity enhancements resulting from the electronic provision of scholarly materials is ambiguous without substantial further clarification. Do we mean that the object (i.e., book, journal, journal article, live performance, or whatnot) can be created with less labor or less total-factor involvement? Or do we mean that the content of the scholarly material can be delivered to the end user in a more effective manner (faster, more convenient, less subject to wear-and-tear, etc.) and preserved for posterity in a more efficient manner? Or do we mean, and I think that this is both the most interesting and most difficult question to answer, that the activities that the end users of scholarly materials engage in, i.e., teaching, learning, and research, become more productive? There does not appear to be unanimous agreement concerning any of these questions.

Costs and Productivity in Producing Scholarly Information. Most of the attention of researchers on the economics of electronic libraries has been focused on the first two questions, and it is remarkable to what extent anecdotal evidence and visionary thinking has characterized the debate. One of the earliest debates was in response to a proposal by Stevan Harnad (1994), in which he proposed that authors of “esoterica” (i.e., the standard scholarly journal literature that could not conceivably earn royalties for the author) should simply post their papers on the World Wide Web by FTP, as has happened with Paul Ginsparg’s famous high-energy physics paper network, and “the long-heralded transition from paper publication to purely electronic publication . . . would follow suit almost immediately.” He estimated that the electronic “page costs” would amount to only about 25 percent of paper page costs, contrary to the usual estimate of 75 percent. In his model, the electronic material would be available for free for readers and costs would be recovered from authors at the rate of about $400/twenty-page article. Numerous persons participated in the debate that ensued, including Andrew Odlyzko, who identified as some of the principal costs of journal publication (a) typing or typesetting the manuscript, (b) peer review, and (c) copyediting, printing, distribution, etc. He then goes on to say that the only part of (b) that will continue to cost money is secretarial assistance, estimated to cost $100–$200 per paper, because editors typically work without compensation. This reflects the widespread fallacy that resources used without a corresponding payment (e.g., resources that are sto-
len) are in fact free and do not represent a social cost; as Jack P. Hailman said, "Things might be changing on the subject of paid editorships, at least my own views have changed. I served as editor of Animal Behaviour for three years (or was it five?) and never again would I devote that much of my life uncompensated." A similar "free" resource is cited by Odlyzko: "Scholars can run electronic journals themselves, with no financial subsidies or subscription fees, using only the spare capacity of the computers and networks that are provided to them as part of their job" (Odlyzko, 1995). (While assessing a zero cost for such use may be correct marginal cost pricing, for a computer, every machine cycle has, in effect, zero marginal cost until the last one, and marginal cost pricing will not pay for the computer.) Odlyzko provides the most extensive statement of a new vision for scholarly journals. In the paper, based mostly on information gleaned from paper-based mathematics journals, he attempts to estimate the cost of producing and distributing journals. Editorial costs per article are estimated at $4,000 and all other costs (typesetting, distribution, etc.) at another $4,000. He suggests that both of these can be cut dramatically by turning to electronic production; the cost of production and distribution for obvious reasons and the editorial costs by reengineering the entire process, and perhaps becoming satisfied with a less-perfect appearance for journals or individual articles. Dispensing with the noneditorial costs of papers, we still have the print environment's $4,000 per paper to cope with, and his calculations yield a per-paper cost of $75 for the Ginsparg high-energy physics server model. But there is some serious doubt whether the Ginsparg model can be easily transferred to other fields (Borgman, 2000, p. 89), and there is clearly a great deal of variation in these figures from journal to journal. The figures he provides for Physical Review B attribute 27 percent of the cost to editorial work and 66 percent to composition, printing, distribution, etc.; the corresponding figures for the American Economic Review are 36 percent and 38 percent respectively (Getz, 1999). Moreover, there are several journal models, and some of these do not lend themselves easily to a pared-down, electronic-only version, as in the case of journals published by professional societies with members who receive membership benefits for their annual dues that are beyond the journal itself. In contemplating a wholesale change away from print journals, it is particularly important to retain processes that ensure scientific quality control (Rowland, 1997). It is clear that ultimately the scholarly public will have to decide what services and qualities it desires from an electronic journal ("$250/paper gets you 90% of the quality that $1000/paper gets you.") (Odlyzko, 1999). Finally, there are even those who argue that the potential of the electronic medium for more elaborate publications is so high, that first-copy costs will actually rise if it were to supplant paper on a large enough scale (Noll, 1996).

Are there any firm conclusions we can reach concerning the costs of producing scholarly materials, and particularly journals, and what issues
remain in an unsettled state? First, there is general agreement that there is
a substantial fixed cost (“first-copy cost”) of producing a journal and a much
lower marginal cost, which is small but nonzero for paper-based journals
and is in effect zero or negligible for electronic products. Second, there is
no doubt that electronic approaches to producing journals have the poten-
tial for substantial savings, perhaps ranging from 25–75 percent of the cor-
responding costs of paper-based journals. However, it is by no means clear
that all the costs involved in a careful editorial process should be dispensed
with. As Halliday and Oppenheim point out, readers expect certain quali-
ties and the “quick-and-dirty” method may just shift the burden onto librar-
ians (2000). They, in fact, undertake an interesting simulation of the costs
of three models: (1) The traditional model in which editors and referees
are unpaid and production and delivery costs are recovered through sub-
scriptions, (2) The “Harnad model,” and (3) A free market model in which
authors pay charges but receive royalties and editors and referees work for
free or minimal honoraria. Under a variety of assumptions concerning
subscribers (where relevant), paper rejection rates, and overhead rates, they
compute the range of subscription rates and page charges (wherever these
are relevant). The traditional model with 500 subscribers produces annu-
al subscription rates ranging from $308 to $510. The Harnad model pro-
duces much higher per-page charges to authors than Harnad himself pro-
posed (except in the case of a 90 percent rejection rate); Halliday and
Oppenheim note that the New Journal of Physics, a new electronic journal
following this model, charges $500/paper, but has published only twenty-
seven papers in eighteen months. The market model produces subscrip-
tion rates not too dissimilar to those of the traditional model, but very high
per-page charges.

These are interesting insights, but it is a fact that no rigorous studies
seem to exist as yet of the cost structure of paper versus electronic journals
and most of the “data” adduced by partisans on one or the other side are
based on personal experience in a limited number of fields or with a limit-
ed number of publications. But just as the cost structure of libraries can and
has been studied by statistical analyses of library outputs (number of refer-
ce services provided, volume of circulation, number of interlibrary loans,
etc.) and library inputs (number of professional and support staff, acquisi-
tions, and stock of books and journals, etc.) (Charnes, Cooper, Lewin, &
Seiford, 1994; Hayes, 2000), so the costs of running journals could be stud-
ied by analyzing the relationship between types and quantity of costs and
services provided. It would be extremely instructive to carry out such a study.

Third, those that believe that the electronic medium will soon supplant
paper rarely pay detailed attention to the problem of archiving—the prob-
lem of obsolescence of hardware—and generally content themselves with
expressing the belief that powerful software will ultimately solve these prob-
lems. But there are several ways in which one could attempt to cope with
some of these problems such as archiving, and lack of attention to the details of this is bound to cause problems.\textsuperscript{15} Borgman notes that it is expensive to preserve materials in electronic formats and typically journal editors and publishers have not been willing to assume the responsibility for doing so (Borgman, 2000, p. 91).

Fourth, the enthusiasts for electronic-only journals have predicted the imminent demise of paper journals; to wit “Traditional scholarly journals will likely disappear within 10–20 years” (Odlyzko, 1995). This prediction was made some six years ago, and while electronic journals have multiplied, paper journals have not really started to disappear; hence it is doubtful whether the time scale envisaged is right. As Rowland (1997) put it, “It is true in theory that all the top researchers in a field could stop submitting their articles to commercial journals and refuse to referee for them, and transfer their energies to new electronic journals, thus raising their prestige. In practice it is unlikely that this will happen by voluntary action.” In fact, since paper journals tend to dominate in prestige, no individual scholar has much of an incentive to transfer his or her loyalty to electronic counterparts, which is the classic problem of public goods.

Fifth, one of the basic thrusts of the argument that journals should be published by the scholars themselves at low cost is to cut out the “middleman,” i.e., the for-profit publisher who skims off the fat of the land. But it is a fatal flaw in the argument that it rests on the belief that for-profit publishers will blithely stand by and see their livelihood eroded. In fact, seeing the technological potential of electronic publishing, one would have had to predict that for-profit publishers will also get in the act and provide their paper journals in electronic form, as well, and offer them for sale in a variety of bundled and unbundled forms.\textsuperscript{16} This, in fact, has happened and a number of publishers produce electronic versions of their journals; Elsevier alone provides over 1,200 current electronic journals, with an expanding backfile, accounting for a total of 1,463,900 articles.\textsuperscript{17} This has to be a serious obstacle to creating new, low-cost electronic journals which have to overcome not only the established prestige of an existing journal to become viable, but cannot even differentiate themselves by being electronic.

Of course, journals and books are not the only kind of scholarly material that are capable of electronic delivery. Standard databases are probably among the oldest forms of materials that could be delivered electronically, perhaps initially on diskettes or CD-ROMs and increasingly over the Internet. In the past decade, other types of materials, e.g., rare and historical works, maps, art images, and manuscripts, have been digitized and are broadly accessible. While the costs of digitizing and delivering such material can be highly variable, depending among other things on the resolution required, it is worth noting that the costs of creating such databases may be offset by costs that are avoided by the scholar who has access to such databases. Thus, if a coherent body of material that is physically dispersed
is brought, so to speak, under a single electronic roof, scholars needing to consult such data may be able to avoid substantial travel costs. To the extent that digitized journals permit libraries to remove paper copies from the stacks, building space is freed up and the need for new library construction is at least postponed (Bowen, 2000). Such savings do not accrue to the library, since scholars’ travel costs and construction costs have typically been treated as external to a library’s budget, but they accrue to the scholar’s home institution as a whole, and this fact may therefore require us to think in novel ways about allocating the costs or savings of electronic “publications.” Other cost factors that need to be considered in connection with electronic journals (and other scholarly materials) are the potential savings in physical space, as well as the additional costs of hardware and software in connection with both delivery of the product to end users and archiving. But whatever cost savings may occur in the digital environment, the visionaries appear not to heed Bowen’s admonition that we “need to be realistic in thinking about costs and avoid the ever-present danger of believing that great things can be accomplished ‘on the cheap’.”

At the opposite pole from the visionaries stand the troglodytes, the most notable recent example being Nicholson Baker (2001), who takes libraries and librarians to task for any number of wrongheaded views and activities. His point of departure is the lamentable destruction of old newspapers in many libraries for space-saving reasons and goes on to document erroneous beliefs in the impermanence of acid paper and in the virtues of microfilm, the checkered history of deacidification and the inadequacy of digitization. But quite apart from seeming to believe in massive conspiracies to destroy paper-based library materials, he is an absolutist and therefore must reject cost-benefit analyses. In fact, there is a trade-off between library space and digitizing, and while there may be a reasonable argument to the effect that not every copy of the old journals archived by JSTOR should be destroyed, there is no reason why every library should keep all its copies of these old journals. He cites (2001, p. 71) as an example of the “intolerably corrupt” optical character recognition (OCR) employed by JSTOR that a search on “modern life” returns an 1895 citation, because the “m” in modem was misread as “rn,” omitting the fact that on average, the search tool in JSTOR is exceptionally good and useful and saves scholars enormous amounts of time (not to mention the fact that the human eye is capable of even grosser errors). While his historical reflections are always interesting and often amusing, he is an enemy of digitizing scholarly materials, at least if doing so threatens the paper product.

Productivity Enhancements in Using Electronic Materials. It has been well known for some time that productivity increases are difficult or even impossible to achieve in certain heavily personal service-dependent activities. This is often expressed by noting that it will always take four people to perform a string quartet and that you cannot improve productivity by playing
it, say, at twice the normal speed (Baumol & Bowen, 1996). It is worth asking whether the activities that scholars and students engage in, namely teaching, learning, and research, might not be of a similar variety, i.e., not easily subject to productivity enhancements.

In dealing with this question, it is important to focus on what we might mean by “productivity enhancements,” and this is by no means obvious. The straightforward and easy answer is almost certainly wrong. When the catalog of a library is automated, it may be tempting to consider the number of new computer terminals in the library as a measure of enhanced productivity. When a library subscribes to various electronic databases, one may wish to use the number of databases that can be reached from it as a suitable productivity measure. To illustrate this further in a completely different context, when modern western business management programs are created in formerly socialist countries, one may use the number of graduates from such institutions as the measure of success. All of these data are relevant for something, but they do not tell us whether the teaching, learning, or research that takes place in a university has become better, more effective, or more extensive as a result of the introduction of information technology, and the number of business school graduates with MBA degrees does not tell us whether firms in the country are better managed and therefore make a greater contribution to GDP.

It is quite plausible that teaching and learning can both be improved by suitable applications of information technology. In fact, improvements in teaching and learning are routinely intended and frequently accomplished by the preparation of new textbooks containing ingenious new ways of guiding the student through the subject, and new “workbooks” with better and more intuitive examples. It is entirely plausible that information technology can effect improvements by making access to information faster, broader, and qualitatively better. But it does not automatically follow from this that the quantity of learning (however measured) will increase as a result. If information is obtainable faster, it is entirely possible that students will spend the time saved on activities that enhance utility directly rather than on additional learning; productivity will have increased (because a given amount of learning can now be acquired with less labor time), but as academics, we might hope that the gain will also be translated into more learning.

But the problem of measurement is even more difficult in the case of research. With faster and broader access to information, it may well be the case that a given piece of research can be accomplished in less time. The total quantity of research may increase (although any self-respecting academic promotion committee will shudder at the thought of measuring the quality of a candidate only by the quantity of his or her research!), or it may not, if professors decide to spend the time gained on utility-enhancing activities. But will the quality of research improve? This is a very difficult question and it is not obvious how to go about answering it. One might be
tempted to look at citation indices on the supposition that better research is cited more frequently. While there is merit in this hypothesis for evaluating the work of an individual scholar, there is a fundamental identification problem if the quality of research improves for all scholars: how would one know that citation frequencies have not increased just because information technology makes it easier to provide citations?

There do not appear to be many studies of educational productivity enhancements resulting from the application of information technology. One careful study deals with the costs of and the learning achieved in an art history course given at Yale biannually (Bennett, 1999). The course, normally attended by about 500 students, traditionally made available 200 photographs of art objects before the midterm examination and 400 photographs before the final examination in a 480 sq. ft. gallery space for a period of several weeks; during this time students had to practice visual memorization and had to prepare themselves to identify art objects and comment on them in the examinations.

Under the new system, 1,250 photographs were scanned and made available to students over the Yale intranet. Students were no longer crammed into a small space and could examine the art objects at their leisure from their rooms at any time. All costs were carefully tracked, including selection of images, further selection of slides by teaching fellows for their class sections, cost of digitization, network connection, etc. Of course, a basic factor that was not held constant was that the number of images under the digital scenario was more than three times greater than under the old system. The costs of the digital scenario were 36 percent greater when amortization was assumed to be carried out over a six-year period; breakeven between the two methods occurred over a sixteen-year amortization period. In the short run therefore, the digital scenario was substantially more expensive. But in a hypothetical scenario in which the digital approach also used only 400 images, it was 6 percent less expensive than the older approach. But in another hypothetical scenario in which the teaching fellows selected their own images for class sections (instead of accepting the head teaching fellow’s selections), the digital scenario obtained a 44 percent cost advantage. All this indicates that even in something relatively straightforward, such as measuring dollar costs, we need to be extremely precise in defining what scenarios are being compared.

The picture with respect to the amount of learning that took place was ambiguous. One teaching fellow reported that students liked the digital approach, but they could not be said to have learned more or to have submitted better written work; another teaching fellow thought the same, with the qualification that the students seemed to learn more easily. But the head teaching fellow reported that student test performance on visual recognition was much improved over past years, and another teaching fellow claimed that the students learned more and wrote better papers.
While the evidence from the Bennett study is somewhat ambiguous, this is precisely the kind of information that one would like to obtain from a whole range of teaching and research innovations. If a digital archive of first folios and quartos were accessible, would papers on textual variants of Shakespeare plays be better and more comprehensive and definitive, or would it merely take less time to write them (because the scholar would no longer have to make repeated trips to Oxford, Wroclaw, and other places)? Would research on library acquisition policies be more authoritative by virtue of the fact that library data are broadly available on the Web? These are the types of questions to which answers have generally not yet been forthcoming, and yet without which the question of the impact of information technology on productivity in academic endeavors cannot be decided.

**Pricing and Related Issues**

While some of the early enthusiasts of electronic journals believed that it would cost only perhaps 25 percent of the corresponding paper journal costs to produce an electronic journal and that many could actually be distributed free of charge (as, for example, Ginsparg’s preprint server in high-energy physics), the actual experience is different, and MacKie-Mason, Riveros, Bonn, and Lougee observe that “Pricing electronic access to scholarly information is far from being a well-understood practice” (1999). They report on the basis of a sample of journals and publishers that in cases where a paper version and an electronic version coexist and where the publishers charge a single combined price, the surcharge over the price of the paper version ranges from 8 percent to 65 percent. They also report that half the publishers in the sample offer the electronic version by itself at a price ranging from 65 percent to 150 percent of the paper version, with the most frequent price being 90–100 percent of the paper version.

There are two primary reasons that the pricing of information goods is complicated: (1) publishers can practice price discrimination, i.e., sell the same good to different consumers at different prices, and (2) publishers can bundle different units of information goods in a single “bundle.” The former is commonly practiced by publishers who charge different subscription prices to libraries and to individuals; such a system requires for its effectiveness that there be no easy way in which individuals can undercut publishers by reselling to libraries, which in fact is the case. Varian (1995) uses the following simple example to illustrate this phenomenon. Imagine that it costs $7 to produce the first copy of a journal and nothing to produce the second (zero marginal cost); further imagine that consumer A values the journal at $5 and consumer B at $3. There is no single price at which production costs can be covered: if the journal is priced at $5, only A will buy and revenues are $5, if it is priced at $3, both will buy, but revenues are only $6. To be able to produce the journal profitably, the publisher must be able to sell at different prices to A and B.
Varian’s example of bundling assumes that there are two journals, valued at, say, $5 and $3 respectively by one consumer, with another consumer valuing them at $3 and $5 respectively. If the publisher (of the two journals) sells them for $3 each, both consumers will buy both journals, and total revenue will be $12 (one copy each of the two journals sold to the two consumers). But if the publisher bundles them, i.e., ties them together as a package, and sells the package for $8, again both consumers will buy both journals by purchasing the bundled package, but revenue now is $16. Note that units of scholarly information are not peculiar in permitting bundling: Adams and Yellen note in one of the earliest papers on bundling that “Commodity bundling . . . occurs when firms sell the same physical commodity in different container sizes (1976).” In fact, the standard journal issue, containing perhaps a dozen articles, is itself a bundled commodity in which articles on different subjects and appealing to different readers are presented as a bundle, which means in effect that the subscriber does not have the choice of purchasing only those articles in which he/she has a particular interest.

It is a fact that a bewildering array of online and paper journals exist, which, depending on the provider or vendor, may be obtainable in paper version alone, online version alone, as a combination of these two, with the subscriber choosing what journal to subscribe to in some cases and being given no such choice in others, each with a different individual and institutional subscription rate. Packages of various kinds are offered to subscribers or members, as the case may be, by universities (HighWire Press), learned societies (Max Planck Gesellschaft), for-profit publishers (Wiley Interscience, Kluwer Online, Elsevier), and not-for-profit organizations (JSTOR, Open Society Institute’s eIFL initiative). The scale of these operations can be seen from the number of articles or journals to which these initiatives provide access (as of July 31, 2001): HighWire Press 1,048,802 articles, Wiley Interscience 300 journals, Kluwer Online 600 journals, eIFL 3,200 journals and 1,300 full-text reference books accessed by some 2,500 institutions in 39 countries, JSTOR 1,301,259 articles or 266 journals.

The advantages of bundling information goods for consumers as well as their producers derives from the fact that different users have different reservation prices for individual journals, depending on the journals’ and scholars’ academic specialization. One scholar might value very highly articles on monopoly pricing and other microeconomic topics but place a low value on one on macroeconomics, while another might have a diametrically opposed valuation. If one assumes that there is a distribution of valuations over journals among consumers and if these distributions are independent of one another and journals are bundled, there will be relatively few consumers who have a very low or very high valuation for the bundle as a whole and many more consumers will have an “in-between” kind of valuation, which has the consequence of changing the demand curve for journals into a demand curve for bundles which has a very flat (elastic) portion at a large
intermediate range of quantity values; thus, setting the price at a level that corresponds to where this flat range of the demand curve occurs tends to extract for the producer most of the consumer surplus (i.e., the excess of valuations that some consumers place over and above the price) and leaves almost no deadweight loss (i.e., the sum of consumer valuations in excess of marginal cost by those who could not afford to buy at the prevailing price) (Bakos & Brynjolfsson, 2000). Bundling therefore appears to be an extremely attractive strategy for producers.

Chuang and Sirbu (2000) have a more elaborate model in which consumer preferences for individual items are characterized by three parameters: the valuation placed on the most preferred items, the rate at which valuation falls off for subsequent items, and an economies-of-scale parameter that describes how the marginal cost of producing the bundled good relates to the marginal cost of individual items in the bundle. Their model reveals that the choice between pure bundling, pure unbundling, and mixed bundling (a situation in which the publisher offers a bundled good and also permits individual items to be purchased) is more complicated. If there are \( n \) goods, pure bundling does not necessarily dominate pure unbundling and, if marginal cost is nonzero, pure bundling is a dominant strategy only if economies of scale are significant enough in producing the bundle and if marginal cost is not too high relative to the readers’ valuation of items. But mixed bundling is always a dominant strategy and is a socially desirable alternative, particularly in cases in which, with pure bundling, consumers might be forced to consume items that they value less than marginal cost.

But not everybody is enthusiastic about bundled scholarly material. The biggest objection raised by Kenneth Frazier (2001) is that once the “big deal” (i.e., the bundle) is accepted, a library can no longer cancel its subscription to a particular electronic journal (although it can cancel the paper version), whereas if it had not accepted the bundle, it could have selectively subscribed to electronically available journals. A second objection to purchasing bundled journals is that it disintermediates serials vendors and enjoins libraries from sharing electronic content with outsiders, although this hardly seems significant. Frazier ends with a clarion call to librarians to invest in “bold new experiments” of a nonprofit variety, such as MIT’s CogNet, Columbia University’s Earthscape (and by implication CIAO), and others of this kind, although a number of these initiatives are both broader in their approach (since they often encompass working papers and other materials in addition to journals) and also narrower in field coverage and may not provide full text for the journals. There is no doubt that there has been considerable interest in starting new, not-for-profit ventures that might compete with the commercial electronic journals, but some of them have been slow to get established, and it is fairly clear that their success will probably be directly proportional to the extent to which they can carve out for themselves a well-defined, unique, and not-too-broad
niche. In any event, creating competition for the existing, commercially produced journals is desirable and some significant attempts in this direction have been undertaken, to wit, by The Scholarly Publishing and Academic Resources Coalition (SPARC) which supports competition among high-priced prestige journals in the belief that

“1) if authors have superior alternatives to existing high-priced journals, they will ultimately move to the outlet that better satisfied their need for both recognition and broad dissemination, and 2) if publishers have market support for bold (but inherently risky) new ventures, they are more likely to make the investment. (Johnson, 1999)”

Full SPARC membership by libraries costs $5,000 in dues, plus $7,500 in purchase commitments for journals, which number fourteen at the present time. SPARC is also affiliated with other, broader scientific information sources such as MIT’s CogNet, Columbia’s Earthscape, BioOne, eScholarship, and Cornell’s Project Euclid. It is further encouraging that LIBER, the principal association of research libraries in Europe, voted to become SPARC’s arm in Europe and will be joined by several organizations such as JISC (Joint Information Systems Committee) and CURL (Consortium of University Research Libraries) in the UK. Public discontent with the existing commercial systems is palpable, and over 22,000 life scientists have signed an open letter stating that “they will publish in, review, and subscribe to only those journals that agree to make the contents of their titles available for free on a publicly accessible server... within six months of publication” (Case, 2001).

Another case in point may be the Electronic Society for Social Scientists (ELSSS), which is in the process of trying to establish itself, but it is difficult to predict whether it will be successful. In particular, ELSSS would pay authors $500 for an article and referees $200–$250, but a typical subscription to its Review of Banking and Finance would sell for an annual $500 in contrast with Elsevier’s Journal of Banking and Finance, which costs an annual $1,066. While it makes good sense for efforts such as SPARC or ELSSS to seek well-defined niches, and SPARC in particular is not neglecting the cultivation of demand for its journals, it is difficult to understand in ventures of this type how libraries would be induced to substitute the ELSSS journal for the established Elsevier journal.

Two significant efforts have been carried out in the 1990s to investigate the technology of delivering journal material to the scholar’s workstation and the usage of electronically available journals. Both rested on a collaboration between Elsevier and a number of universities, among which the University of Michigan was primus inter pares. The first of these, The University Licensing Program (TULIP) started in early 1991 and ended in late 1995 (TULIP, 1996). In addition to Michigan, other participating institutions were Carnegie-Mellon University, Cornell, Georgia Institute of Tech-
nology, MIT, University of California, University of Tennessee, University of Washington, and the Virginia Polytechnic Institute and State University. The objective of TULIP was to provide the participating institutions scanned page images and OCR-based ASCII full text of forty-three journals in material science although another source claims initially forty and ultimately eighty-three journals (Hunter, 2000). The project actually started in 1993 and ultimately some 500,000 articles were produced by the system. It was clearly an early project in this class; the files were provided to the participating universities and they themselves designed the software with which users could access them. It is clear that a great deal of technical information was gained through TULIP and its limitations partially reflected the limited nature of the information infrastructure in place; so much so that eventually Internet distribution of files was replaced by CD-ROM-based distribution. Browsers were not really available at the outset and both hardware and software represented significant obstacles to the effective use of the database. Storage in those days was much more expensive than today and the database was inherently small, i.e., did not have critical mass; as a result, penetration at various universities was rather small. Defining penetration as the percentage of the eligible users who were repeat users, Carnegie Mellon achieved a penetration of 8–12 percent in 1995; Georgia Tech, 50 percent; MIT, 8–9 percent; and the University of California, 1–2 percent. On the whole, the penetration figures were not very impressive. Furthermore, the economic and usage aspects had not been designed with adequate attention to detail and thus relatively little was learned about the economics of electronic journals (Hunter, 2000). But the most important aspects of TULIP probably were the facts that a significant amount of learning took place by Elsevier as well as by the participating institutions and that Elsevier decided, on the basis of TULIP, to scan all its journals and start a commercial subscription service, Elsevier Electronic Subscriptions (EES), at a price of 35 percent of the paper subscription (135 percent for paper and electronic together). EES then spawned ScienceDirect, which had a three-part fee consisting of a “platform fee” (for developing and maintaining the service), a content fee (basically 15 percent of the paper rate or 90 percent of the paper rate for an electronic-only subscription), and a transactional fee: if the institution maintained its level of spending, the content fee declined to 7.5 percent and the institution could get additional articles outside the subscribed titles for free up to a certain allowance, beyond which a transactional fee of $15/article would be charged (Hunter, 2000).

The second Elsevier-University of Michigan project was a bold and complex experiment designed to reveal users’ attitudes toward the costs of electronic access. The project, Pricing Electronic Access to Knowledge (PEAK), provided four and a half years’ of content to about 1,200 Elsevier journals over an eighteen-month period at twelve institutions (MacKie-Mason, Rive
eros, Bonn, & Lougee, 1999; Gazzale & MacKie-Mason). By the end of the
project, it contained 849,371 articles, of which 111,983 had been accessed at least once (Gazzale & MacKie-Mason). Three access methods were provided: (1) Traditional subscriptions, (2) Generalized subscriptions; a single such subscription entitled institutions to have unlimited access to 120 articles from the entire database for a fixed prepayment which would be non-returnable if fewer than 120 articles were actually accessed, and (3) Individual article accesses on a “pay by the drink” basis. The prices were set so that journal issues would be available under Method 1 for $4 (if the institution already subscribed to the journal) or $4 plus 10 percent of the paper subscription rate (if it did not previously subscribe); articles would be available for $4.56 under Method 2 (if the entire allotment of 120 tokens was used up), and would be accessible for $7 under Method 3. In addition, institutions differed in the nonpecuniary costs that were faced by readers for Methods 2 or 3, consisting variously of login and authentication procedures such as passwords and of the requirement to enter credit card information. Institutions were divided into three groups; one group was offered access by all three methods, another group only by Methods 1 and 3, and the third group only by Methods 2 and 3. Some content was available at zero user cost, such as articles published at least two years prior to the experimental period, articles in journals to which the institution purchased an electronic traditional subscription, and articles previously purchased as part of a generalized subscription. While the conclusions from the study, based on careful logs of usage, are detailed, multifaceted, and complex, it is clear that paid usage declined quite dramatically with increases in the marginal cost of access, whether pecuniary or nonpecuniary. It was possible to calculate the optimal expenditures by an institution on the assumption that the actual usage of articles was completely foreseen; the comparison of the optimal with the actual expenditures suggests that forecasting the type of usage in the first of the two experimental years was rather imperfect but improved significantly in the second year. The principal cause of the error was in over-estimating usage, particularly in the category of traditional subscriptions, although six out of nine institutions made the correct adjustment for this type of subscription in the second year. Overall, the study was extremely revealing, particularly in showing that nonpecuniary costs have essentially the same significance as pecuniary ones and that there is a great advantage to users from being able to access the entire database. In particular, the metered, pay-by-the-drink approach places a definite damper on usage and confirms the soundness of the original decision by the designers of JSTOR to make the whole database available for a subscription fee.

Concluding Comments
Since the early 1990s, transmission and storage capacities have become massively greater and the technology of scanning paper and microfilm and making the scanned images available on the Internet has
grown impressively. It is therefore not surprising that the corpus of electronically available materials has grown substantially and it is safe to predict that we are nowhere near the end of this process. The availability of electronic materials has made access much easier and the low cost of distributing these materials has been particularly beneficial for historically disadvantaged countries and institutions.30

There is no doubt that electronic distribution of scholarly materials is less expensive than the distribution of paper, but the prediction that the entire editorial process, particularly for scholarly journals, will be reengineered, so that journals will become available on the World Wide Web for a fraction of the cost of paper journals or even for free is nowhere near realization. University presses and other academic groups are becoming significant players in electronic niche markets in which they are able to achieve self-sufficiency and to provide access to important materials at lower cost and greater convenience than is possible with the traditional methods; but these initiatives typically do not have the financial resources to mount a frontal attack on the commercial publishers’ high-prestige, top-of-the-line journals.31

In addition, the commercial publishers have responded to the low-entry barriers in the field of electronic publication by making their own products available electronically, thus providing the convenience that the paper journals lack. Under these circumstances, it is extremely unlikely that competition from upstart electronic journals will dislodge existing prestige journals from their dominant position in the near term. The situation is somewhat analogous to the provision of public goods: while it is true that, if editorial boards of leading journals all quit and all scholars refused to submit articles to these journals (mutatis mutandis, if all potential taxpayers voluntarily paid for the provision of national defense), new electronic journals could supplant the existing ones, but no single individual has the incentive to defect. Since commercial publishers now tend to provide their journals in both paper and electronic form, the paper versions may well become less important over time, but it is not evident that commercial publishers have an incentive, at least in the short run, actually to terminate production of paper journals. Hence, the predicted demise of the paper journal and, even more so, of commercial publishers, is vastly exaggerated. And while the quality of access to scholarly information will continue to improve substantially, it is unlikely that the increasing dominance of electronic publications will ease the economic plight of libraries in the short run.

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NOTES
1. Richard Ekman, then secretary of the Foundation and a senior program officer, and Richard E. Quandt, senior advisor to the Foundation and at the time Professor of Economics at Princeton University, were asked to provide direction for the program.
2. Somewhat higher prices are reported for 1994 by Carpenter and Alexander.
3. For example, Academic Press Harcourt Ltd. lists the Biochemical and Biophysical Research Communications for an annual rate of $3,999, 2001 Global Print and Electronic (IPL Only) Subscription Rates (Academic Press Harcourt Ltd.).
4. It would have been more appropriate to use the ratio of this difference to the institutional price, which would have proxied the Lerner measure of monopoly power, \( (P - MC)/P \).
5. E.g., in economics, journals such as the American Economic Review, the Quarterly Journal of Economics, or the Journal of Political Economy.
7. See http://www.reed-elsevier.com/.
8. The same rule-of-thumb is employed in Quandt, 1996b. Let \( x_i = 1 \) or 0 indicate whether the \( i \)th journal is or is not selected, \( u_i \) its usefulness or quality, \( c_i \) its cost, and \( B \) the overall budget. Then a library's general optimization problem may be expressed as the knapsack problem in integer programming,

\[
\text{Maximize } u_1x_1 + u_2x_2 + \ldots + u_nx_n
\]

subject to \( c_1x_1 + c_2x_2 + \ldots + c_nx_n < B \)

and \( x_i \) a nonnegative integer for all \( i \).

A heuristic, but not necessarily exact solution to this problem is provided by the rule-of-thumb employed. A similar device is used in Weitzman, 1998, in which species (books) are selected to be included in Noah’s Ark (libraries), given their usefulness, diversity, and probability of survival.
12. But Ginsparg has had substantial support from the National Science Foundation.
14. “A major advantage of such a system is that the journal can be available for free anytime everplace that data networks reach. However, the lack of copy editing that is likely to prevail in such a system may not be acceptable. I expect that what editing assistance might be required will not cost anywhere near what print journals cost, and so might be provided by the authors’ institutions. If that happens, electronic journals can also be distributed freely.” (Odlyzko, 1995).
16. See the next section for a more detailed discussion of bundling.
19. It is not clear what his attitude would be concerning digital scholarly materials that have never had a paper counterpart, i.e., that are originally created as electronic products.
28. A consequence of computing the distribution of the sum of random variables by convoluting the underlying densities.
30. In the first half of the 1990s, various book and journal donation programs were successful in persuading publishers to make their journals available to East European countries either free or at a very low cost. But the number of copies in which these free journals were made available was strictly limited, and it was not conceivable that publishers should offer these in the hundreds or thousands. See Quandt (2002).
31. It is unlikely that JSTOR would have been realized without the substantial resources of The Andrew W. Mellon Foundation, which underwrote its development.

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Library Economic Metrics: Examples of the Comparison of Electronic and Print Journal Collections and Collection Services

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ABSTRACT
This article deals with a framework of library economic metrics including service input and output, performance, usage, effectiveness, outcomes, impact, and cost and benefit comparisons. Examples of these measures are given for comparison of library electronic and print collections and collection services based on a recent cost finding study at Drexel University where the library has converted almost entirely to an electronic journal collection. These data are complemented with recent readership surveys of scientists at Drexel University, University of Tennessee, Oak Ridge National Laboratory, and members of the American Astronomical Society which describe changing information-seeking patterns and use of library electronic and print collections.

BACKGROUND
The introduction of the World Wide Web, electronic publishing, and digital library initiatives has had profound and continuing impact on libraries of all types. The emerging technologies have caused libraries, their funders, and their users to rethink what libraries are and how libraries can best serve their constituents. Sentiments have ranged from the extreme opinions that libraries will no longer be necessary, to explanations as to why the Web is not a library and that the new technologies will actually strength-
en the role of librarians and other information professionals (e.g., Griffiths, 1998). Regardless of how this scenario will play out, it is clear that we must stay on top of these changing events by clearly understanding their economic implications.

This article addresses some economic metrics that can continue to shed light on the evolution of educational, research, and professional communication systems. While these economic metrics have been demonstrated for the scholarly journal system and its participants such as authors, readers, publishers, libraries, and other intermediaries (Tenopir & King, 2000), the focus of this article will be on comparisons of library electronic and print journal collections and collection services. This aspect of the system is particularly important because of the steady shift to electronic collections and the resulting difficult decisions that must be made by librarians in an increasingly complex economic environment.

Librarians continually face the need to make decisions on the selection, acquisition, access, and service policies and procedures related to electronic publications and to negotiate legal and financial arrangements with publishers, consortia, aggregators, and so on (King & Xu, 2003). More specifically, they need to decide whether or not:

- to rely exclusively on electronic journals or purchase both electronic and print subscriptions and, if so, at what price;
- to subscribe to or rely on single article demand for certain journals;
- to discard print issues or rely on them as a backup for archival purposes;
- to negotiate site licenses;
- to deal directly with publishers or rely on intermediary services such as consortia, aggregators, gateways, etc., and if so, at what price;
- to depend, in some cases, on information freely accessible on the Web as a substitute for costly electronic resources.

These complex decisions require a sound economic underpinning as well as good judgment in applying economic information and metrics.

Griffiths (2002) has briefly described the evolution of library performance measurement over the past thirty-five years starting with the Morse (1968) pioneering adaptation of operations research analysis to library performance. In the 1970s and 1980s, the Public Library Association, Association of Research Libraries, Council on Library Resources, National Science Foundation, and others sponsored a series of studies in the U.S. to develop library economic metrics, methods, and models for decision-making and planning (e.g., Baumol & Marcus, 1973; deProspo et al., 1973; Hamburg et al., 1974; Clark, 1976; Palmour et al., 1980; Zweizig & Rodger, 1982; D'Elia & Walsh, 1983; Buckland, 1983; Kantor, 1984; Cummings, 1986; McClure et al., 1987; Van House et al., 1987). Also during this period, Lancaster (1977, 1993) produced books on the evaluation of libraries. More recently, McClure and colleagues (e.g., McClure & Lopata, 1996; Shim et
al., 2001) have focused on measures for library networked services and electronic collections.

The economic framework used in the comparison of library electronic and print collections and services in this article has evolved over thirty some years as a result of what was learned from hundreds of studies. The genesis of the framework was first published in 1971 as a result of a National Science Foundation (NSF) funded study (King & Bryant, 1971; King & Lancaster, 1969) and a similar approach that was being developed in the UK as well (Griffiths, 1977). Many of the studies performed by King Research in the 1970s were founded on this initial framework, including a range of applications such as information retrieval systems (e.g., King et al., 1972), scholarly publishing (e.g., King, et al., 1981), federal clearinghouses (e.g., McDonald et al., 1981), and scientific communication (e.g., King et al., 1976), among others. In the late 1970s, Vernon Eugene Palmour joined the staff of King Research and began to build on the framework (King & Palmour, 1974) with specific applications in the public library community (e.g., Palmour et al., 1980a,b). In the early 1980s, some of the staff that was concerned with public library studies (i.e., Rodger, Van House, Zweizig) moved on and through the years developed one particular approach to library planning and economic assessment. This has led to recent studies of the electronic journals in libraries mentioned above. Meanwhile, the King Research staff took another approach to economic analysis of libraries, which evolved to the most recent version of the framework used in this paper. This economic analysis mostly involves numerous studies of special libraries (e.g., Griffiths & King, 1993), public libraries (e.g., Griffiths & King, 1989), library networks and consortia (e.g., Griffiths & King, 1991), studies of a few academic libraries (e.g., Griffiths & King, 1989; Montgomery & King, 2002; King & Montgomery, 2002).

A FRAMEWORK AND DEFINITION OF LIBRARY ECONOMIC METRICS

One premise of the framework is that metrics are designed to serve the perspectives of library staff and management, library users, the funders of the library, and the higher-order community served by the library. A second aspect of the economic framework is that it is applicable to the entire library, general library functions, specific services, or resources used to perform the services. The framework is described in well-established economic terms such as inputs, outputs, performance, effectiveness, usage and demand, cost-benefit, and so on. It first defines five specific metrics and then derives relationships among these metrics.

A schema depicting the framework of metrics is given in Figure 1. In this framework, one set of metrics involves inputs which include the amount of resources used to perform a service or provide a product where such resources can include staff, equipment, systems, facilities, a library collection,
Figure 1. Conceptual Framework for Library Economic Metrics

<table>
<thead>
<tr>
<th>MEASUREMENT PERSPECTIVES</th>
<th>SPECIFIC METRICS</th>
<th>DERIVED METRICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Library</strong></td>
<td><strong>Inputs (Resources)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Amount of resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Cost of resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Attributes of resources</td>
<td></td>
</tr>
<tr>
<td><strong>Outputs (Products/Services)</strong></td>
<td></td>
<td>Performance</td>
</tr>
<tr>
<td></td>
<td>@Amount of output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Attributes of output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Timeliness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Availability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Accessibility</td>
<td></td>
</tr>
<tr>
<td><strong>User</strong></td>
<td><strong>Usage (Use and Nonuse)</strong></td>
<td></td>
</tr>
<tr>
<td>(Actual and Potential)</td>
<td>@Amount of use and nonuse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Factors affecting use/nonuse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Ease/cost of use (price paid)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Available alternatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Purpose of use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Importance of and satisfaction with attributes of output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Awareness</td>
<td></td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td><strong>Outcomes (Consequences of Information)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Time saved</td>
<td>Impact</td>
</tr>
<tr>
<td></td>
<td>@Improved learning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Improved productivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Improved quality of work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Improved timeliness of work</td>
<td></td>
</tr>
<tr>
<td><strong>Community Served</strong></td>
<td><strong>Value derived</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Effects on organization goals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Higher order effects</td>
<td></td>
</tr>
<tr>
<td><strong>Domain (Environmental Characteristics)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>@Target population</td>
<td></td>
</tr>
<tr>
<td></td>
<td>@User/nonuser population characteristics</td>
<td></td>
</tr>
<tr>
<td><strong>Society</strong></td>
<td><strong>Externalities</strong></td>
<td></td>
</tr>
</tbody>
</table>

and so on. The input resources are often measured in the common measurement unit of dollars. There are also attributes of the input resources that can be measured or characterized. For example, staff attributes include level of education and experience or other indicators of competence. Collection attributes might include comprehensiveness, type of materials, age, and medium (i.e., print, electronic, microform). Outputs include the amount of services provided or number of items produced such as number of items...
loaned, reshelved volumes, electronic journal article hits or printouts. Attributes of output might include quality, timeliness, availability, accessibility, and sometimes, a price or fee charged. Performance is defined as a relationship between input and output that reflects how well a resource or service is performing, such as staff productivity (e.g., output quantity divided by staff time) or unit cost (i.e., cost per unit of service or item provided).

We feel it is important, if feasible, to measure usage in terms of the use of information provided by the library service such as the information content of an article that is read from access to the electronic collection. Too often the service output does not adequately reflect the amount of actual information use. For example, an electronic article hit or printout might not involve a reading and a reshelved issue in a current periodicals room may not have been read or might involve the reading of several articles. For this reason, we depend on a readership survey to provide estimates of the amount of reading from a library collection service and to establish factors that affect the amount of reading from this particular source. Such factors include user effort, ease of use and cost of use; availability of alternative sources of the information and their relative ease of use; purposes of reading; importance of and satisfaction with the attributes of the journal access services; and awareness of the services and their attributes (King & Tenopir, 1999).

Libraries constantly strive to improve their services in order to have a positive effect on the amount of use (reading) and on factors that affect use. Effectiveness is defined as a relationship between service output attributes and usage such as the amount of reading as a function of availability or accessibility of the collection, timeliness and speed of delivery of collection services, and the price required of users in dollars and/or their time. Similarly, usage metrics can be related to the service input costs such as the service cost per article read. In this article we define such derived measures as cost-effectiveness.

Outcomes, by our definition, are consequences of having used the information provided by the service such as a library-provided article that is read. Such outcomes are best determined by relating them to the purposes for which the information is obtained such as for primary research, teaching, life-long learning, consulting or advising others, administration, and so on. Here again, readership surveys can provide evidence of such outcomes that affect one's work (or other endeavors) such as improving the quality, timeliness, and productivity of work. For example, an outcome might be the extent to which the article information affects the quality of research or the effectiveness of teaching. With students, one can demonstrate a correlation between use of periodicals and grades (GPA). It is also useful to consider outcomes that are important to the library funders or community served such as helping achieve the goals of the organization or enhancing the disciplines of science or of society in general such as improving quality of life.

Over the past quarter of a century, there has been much made of the
“value” of information and information services or products. Economists distinguish between two types of value (e.g., Machlup, 1979):

1) *Exchange Value* which is what one pays for information in dollars exchanged and in one’s time and effort (which are usage measures) and,
2) *Use Value* which is measured by the results of having used the information (i.e., outcome measures).

*Impact* is the relationship between (1) inputs, outputs, and/or usage and (2) outcomes. For example, spending more for input resources can improve output attributes which in turn results in more use and, therefore, the possibility of more favorable outcomes. Thus, impacts can be relationships among several of the specific economic measures.

*Domain* metrics are characteristics of the community served by a library service such as number of persons served, how many of them are users, their education, and experience. Such characteristics can have an important bearing on the other metrics. For example, journal publication costs and, therefore, price required to break even or make a profit depend on the number of readers in a discipline (Tenopir & King, 2000) and unit costs of library services depend on the number of users served because of economies of scale (e.g., Cooper, 1979; Griffiths & King, 1993). Level of education and experience of the library’s community can affect who will use library services and the extent to which they will use the services. There are positive and negative externalities inherent in the domain that can also affect the other economic metrics. For example, administration and funder attitudes can tremendously influence the library budgets and even users. In one organization studied by us, potential science users were told not to spend too much time in a company library because the library was thought by a high-level manager to be “recreational.”

The heart of the comparison of electronic and print journal collections and services is a cost-benefit analysis. We rely on Bickner’s approach to cost-benefit, which is a comparison of a service or product with some alternative to it (Bickner, 1971). In this case we will compare the library electronic collection with the traditional print collection, as well as the collection services related to these two media. The comparison can involve any of the metrics previously discussed such as input cost or comprehensiveness of the two collections; output and unit costs of the two collections; input, output, and performance of collection services; amount of articles read or purposes for which the articles are read from the two collections; outcomes from reading from the two collections; and domain number of potential users who can access the two collections.

In such comparisons, if the comparison is favorable to the electronic collection or service, it would be considered a “benefit.” If the comparison is unfavorable, it would be a “cost” or perhaps better termed a “detriment.” Note that the dollar cost of input (or dollar cost of users’ time) could be
either a “benefit” or “cost/detriment” as will be demonstrated in examples given later. For example, publishers could charge libraries less for electronic than print subscriptions in which case the comparison in dollar price paid would be a “benefit” for the electronic collection. On the other hand, if a publisher charges a higher dollar price for electronic subscriptions the comparison with print subscription would constitute a “cost/detriment.” Of course, there are two sides to this coin in that one could compare print collections to electronic collections in which case the “benefits” and “costs” would be the reverse. Other examples of cost-benefit comparisons would be purchase of journal titles compared with use of interlibrary borrowing, document delivery services, pay-per-view, or comparison of a library collection with having no collection at all. Below we provide some recent examples of the cost-benefit comparisons of library electronic collections and services with print collections and services.

**RECENT STUDIES ELECTRONIC AND PRINT COLLECTIONS AND SERVICES**

The examples below are for *cost-benefit* comparisons of the collections and of services, which provide (1) access to electronic journal collections and (2) access to print journal collections. We use the term “access” in a generic manner since a library or its organization may not actually house an electronic journal but subscribe to its use on the Web or have access on a “per view” basis. Similarly, libraries can provide access to their current periodicals collection of issues or bound copies found on the shelves and special libraries often provide access to print journals through journal routing. Libraries also provide access to their collection to other libraries through interlibrary loan (ILL) and obtain copies of articles for their users through interlibrary borrowing (ILB). All of these journal access services are included in the discussion below.

Examples given below are from three recent studies performed by the authors involving economic cost analysis of library collections and readership surveys. The analysis of electronic and print collections includes cost finding for activities and resources associated with inputs, outputs, and performance (unit costs) of collections and services in special libraries and at Drexel University, Hagerty Library. Steps in these cost-finding studies are to identify relevant activities performed, establish all the resources needed to perform the activities, allocate the amount of resources applied to perform the activities, assign a dollar amount to the resources, and sum across the relevant activities to estimate fixed and variable costs of the collections and fixed and variable costs of the collection services. From this, unit costs of the collections and their collection services are estimated.

Recent readership surveys were conducted with scientists and engineers at the Oak Ridge National Laboratory; scientists, engineers, and medical personnel at the University of Tennessee; and scientists, engineers, and
others at Drexel University. Some economic metrics are based on a survey of users of an electronic journal system developed by the American Astronomical Society (AAS). This remarkable system of core astronomy journals has a number of special features including electronic full text of all the core journals back 150 years, bibliographic links, citation links to and from journal articles, a relatively complete searchable database of abstracts, and links to numeric data and images. The journals are available to individuals and libraries in electronic and print media. Two user surveys with over 1,000 responses provide data and information on reading from library electronic and print subscriptions to these journals. In particular the surveys provide data concerning the relative extent to which library electronic and print versions (as well as other sources) are read and the surveys highlight factors that affect usage such as ratings of importance of system features; awareness of features; time spent by readers in identifying, locating, obtaining, and printing out or photocopying articles; purposes of reading; the age of articles read; and time spent reading the articles.

INPUT, OUTPUT, AND PERFORMANCE OF ACQUIRING LIBRARY ELECTRONIC AND PRINT COLLECTIONS

The first analysis involves the input and output of acquiring library collections, which in turn becomes one of several resources applied to provide journal access services. The input cost of the library print collection resource obviously involves much more than the price paid for the journals. The input to this resource includes staff, equipment, systems, and facilities for collection-related activities such as collection development, serials acquisition, mail processing, serials check in, and collection maintenance. These activities, of course, constitute the components of fixed costs of various collection access services. Some of these activities are common to electronic and print collections, but require a different level of effort. Below we provide some cost-benefit comparisons of the collection resource inputs (e.g., costs of staff, space, equipment, subscription price paid, etc.), outputs (e.g., number of titles acquired in the library collection, comprehensiveness, age, etc.), and performance (e.g., cost per title).

We have performed in-depth cost finding for these activities as they relate to print collections in special libraries (Griffiths & King, 1993) and print and electronic collection at the Drexel University, Hagerty Library (Montgomery & King, 2002). From 1998 to 2002, the Drexel Library migrated from a print collection of 1,710 to 370 titles and from an electronic collection of 200 to 8,634 unique titles. Drexel is not retaining the print counterparts of electronic titles unless the electronic version is not a satisfactory equivalent (e.g., low-quality graphics). The increased comprehensiveness of the electronic collections is a clear “benefit” for them. In comparing the electronic collection resource with the previous print collections, the following differences in the price paid have been observed:
Arguably, we could say that subscription prices paid “on the whole” are less for the Drexel electronic collection (i.e., perhaps a “benefit” for electronic collections). However, this simple statement ignores a complex set of factors that must be considered to make a comparison between electronic and print subscription prices paid meaningful. A “subscription” in the electronic world does not involve a simple payment for the annual content of a journal title. An annual subscription often brings with it several years’ of back files. And the price models and electronic content vary so radically that Drexel has found it necessary to define three electronic journal types by the criterion: How stable is content?

“Pure” Electronic Journals are individual subscriptions or publisher’s packages that may or may not be a part of a consortium “deal” (e.g., acquired by purchase through a subscription agent or from the American Chemical Society, the American Institute of Physics, etc.).

Aggregator Journals come from vendors that provide access to different publishers’ journals with no possibility of content dropping, only adding. The collections started as full-text content and added searching (e.g., JSTOR, MUSE).

Full-Text Database Journals come from many different publishers but with no title or issue-level subject or index access (except ProQuest). Journals are added or removed regularly from these databases according to the database vendor’s contracts with publishers. They often have an embargo on current issues of six months or so (e.g., Lexis/Nexis, INFORTRAC’s Expanded Academic).

Subscription prices vary greatly among the three types: at Drexel, at the beginning of 2002, the average per-title price paid varied from over $300 for the individually subscribed titles, about $90 for the aggregator titles, and $5 per title for the full-text database journals. Most academic libraries do not include the full-text database titles in the journal counts. However, use of the titles in these databases is so high (more about that later) that we feel it is misleading to exclude them from the total picture.

Price comparisons between electronic and print subscriptions will vary from library to library, depending upon the collection choices, agreements with publishers, consortia arrangements, ability to negotiate, choices regarding cataloging and inventory control and, surprisingly, size of library. Two common subscription models favor smaller academic libraries in a “rich get poorer and poor get richer” scenario: (1) access to a publisher’s entire electronic collection for a premium over the money spent on the publisher’s print subscriptions at the time of the “deal,” and (2) access to all of a publisher’s electronic journals held by any member of a consortium for a small premium over the money spent on the publisher’s print subscriptions at the time of the “deal.”
Regardless, libraries are compensating publishers largely for (1) adding value to article information content and (2) distribution through the print version or access to the electronic version. The cost to publishers for adding value to the article information content is about the same for both versions. The publisher's cost to distribute the print version is typically about $30 to $40 per annual subscription and the publisher cost to provide access to the electronic version depends on value-added features provided (e.g., the AAS features mentioned earlier). However, if both versions (i.e., electronic and print) are made available to the library by subscription, the publisher should be compensated only once for adding value to the article information content. Thus, subscribing to both versions should not cost the library much more than the price paid for one version.

In addition to the price paid for library collections, there are input costs associated with collection development; input processing and shelving for print collections; servers and systems for electronic collections; inventory control for both; and subscription maintenance for both. Comparisons of these costs are as follows:

- Collection development costs are generally higher for electronic collections because of the cost of personnel needed for the time-consuming process of negotiating licenses, the additional variables to be considered (e.g., interface, inclusion of visuals, perceived stability of source, commitment to archiving, existence of back files, linking from electronic databases) and the variety of sources from which a journal can be purchased. This is a "cost" for electronic collections compared with the print collections.
- Mail processing, serials check in, and shelving are nil for electronic collections, but even including electronic collection server and systems costs, there is a savings of about $70 per title (i.e., a "benefit" for electronic collections).
- Cataloging or inventory control costs depend on the library's policy. There are two basic approaches with many variations: (1) libraries may catalog all three categories of titles—which is very time-consuming to maintain; (2) catalog only the electronic titles in the first two categories listed above—which gives an incomplete picture; (3) catalog only the electronic equivalents of print titles—also incomplete; (4) maintain HTML lists (created from databases in the more technologically advanced libraries)—far less costly than cataloging to create and maintain but does not provide "one stop shopping" for journal holdings; (5) catalog the titles and provide access via lists—obviously more costly than cataloging only. Thus, the "cost" or "benefit" of electronic journals depends upon the approach taken.
- Subscription maintenance can be higher for electronic collections due to the volatility of the collection (i.e., a "cost" for electronic collections).
The electronic collection at Drexel is more comprehensive than the previous print collection, but the annual per-title costs appear to be much less than equivalent print subscriptions. Thus, on balance these collection-input costs appear to be a substantial “benefit” in comparing electronic with print collections. And since labor costs are higher during the transition, the benefit should increase over time unless subscription prices increase dramatically. Another attribute of electronic journals, the access to back files as part of current subscriptions, makes the economic picture for electronic journals even better at the time of purchase.

**Input, Output, and Performance of Library Electronic and Print Collection Services**

Library print collection services include access to a current periodicals room, access to older journals maintained in stacks, articles provided through interlibrary loan (ILL), as well as journal routing provided by many special libraries. Articles are also obtained from elsewhere through interlibrary borrowing (ILB), document delivery, and pay-per-view. Library electronic access services involve access to internal or external full-text databases from in-library computer workstations and readers’ office desktop computers by means of the campus network and, most importantly at Drexel, from their homes and elsewhere through the public Internet.

Input of library collection access services includes the cost of resources used to provide individual services in addition to allocation of the collection-related resources discussed in the previous section. Outputs of the access services are the quantities of services provided (i.e., hits or downloads and items reshelved) and the service attributes such as timeliness, availability, and accessibility.

The input costs of print collection services include (1) allocation of the fixed costs to each service and (2) the variable costs associated with the service access to the collection (i.e., the costs associated with each use). As shown in the previous section, the fixed costs of print collection services are largely due to the subscription price and processing of journal issues. To that is added the cost of the shelves and space allocated to the current periodicals room, or to older journals in the stack. The variable costs include the costs of activities associated with specific service use. Variable cost includes directional reference to print journals, photocopying of items read, and reshelving issues or bound volumes. ILL activities are ILL processing, photocopying, and reshelving. Journal routing requires such activities as list maintenance, routing processing, and reshelving. Typically photocopying by library staff costs about $2.70 per article (and $1.10 when coin machines are used) and reshelving about $.30 per item reshelved. These costs are estimated with all resources (i.e., staff, equipment, space, supplies, etc.) and overhead included. The total variable cost of the services, of course, depends on the amount of access or use.
There are both fixed and variable input costs associated with electronic collection services as well. There are two kinds of fixed costs. The first kind includes the collection-related resources and allocation of computers, servers, systems, space, and so on. The second kind of fixed cost is more related to the number of users involved. These costs include resources used to train users and to provide promotional and education materials for users. The variable costs associated with electronic access services include directional reference and help to users in the library, as well as support and help services provided to network users. Also, most reading from electronic library-provided journals is done from articles that are printed out. In fact, based on our recent readership surveys, about 80 percent of articles read are printed out. The cost to the library of printing an article obtained from a library computer is typically about $1.00 per article printed including allocation of printer costs (i.e., equipment, maintenance, toner, paper, space, furniture, etc.).

The service output quantities are usually measured by the number of times a service is used. Unfortunately, there are several definitions of use of library collections (King & Tenopir, 1999). For example, access to the periodical room collection and stacks is sometimes measured by counting issues and bound volumes reshelved (i.e., counted by observation or bar code). These measures are not the same as the amount of reading since an issue or bound volume might not be read at all or have many articles in them read. In fact, from exit survey observations, reshelved bound volumes tend to have fewer than two articles read per volume and reshelved issues average about four articles read. The Drexel survey data also indicate that about 25 percent of print journal users regularly use more than one article from a specific volume during a single use.

We have also observed, by survey, the annual number of times users say they have used these two print collections. In academic libraries, it is thirty-five and thirty-one uses per user per year of current periodicals and volumes in the stacks, respectively, and twenty-eight and twenty-five uses in special libraries (Tenopir & King, 2000). At Drexel, annual output metrics are: 15,000 issues reshelved and 8,800 bound volumes reshelved. Output measures also include attributes of the services such as availability and accessibility of the current periodicals room and the stacks. Hours of opening and the distance of the library to readers, of course, limit use of the print collections. ILL attributes include speed of response, quality of photocopying, and fee (if charged). ILB has similar attributes. The most critical attribute of journal routing is the number of persons on a routing list, since this attribute determines to a large degree when the reader will receive an issue.

An example of print service performance is the unit cost per item reshelved. In special libraries, after allocating the print collection (fixed) costs, we estimate the average or unit cost per use as being $13.00 per current periodical issue reshelved, $15.30 per bound volume reshelved, $25.70
per person receiving a routed title, and $24.30 per article obtained through ILB. At Drexel, the recent unit costs of access from the periodicals room is $8.50 per issue reshelved. The unit cost of the stacks tend to be much higher because the amount of use is down due to electronic access, and the size of the bound volume collection is larger than typical special library collections. The access unit cost per volume reshelved is $30.00.

Generally, uses per print title in libraries have increased, largely because of reduced personal subscriptions. Over a twenty-five-year period we estimate this to be about three times more use per title in academic libraries and seven times more in special libraries (Tenopir & King, 2001). This means that the unit costs per use are less than they would be if this phenomenon had not occurred. Of course, the increased prices of print journals have partially offset the increased use, when considering unit costs.

Output quantities of electronic collection services have also been difficult to measure (e.g., Luther, 2000; Shim, et al., 2001; Odlyzko, 2002; Miller & Schmidt, 2002; Goodman, 2002; Kidd, 2002). The metric of service output is currently reported to libraries by publishers, vendors, or consortia providing the electronic journals. These metrics are uses of full text such as hits or downloads of articles, which vary in definition among these sources. Even so, these indicators of reading are probably closer to the amount of reading than counting items reshelved. At Drexel, a full-text use is defined as an HTML, view, PDF download, or print when possible. With an estimated 400,000 electronic uses, Drexel’s estimates of per-use costs are $4 for individual subscriptions, $3 for publisher packages, $2 for aggregator titles, and about $1 for full-text titles. With broader collections available to smaller institutions, ILB will likely decrease and pay-per-view article access is sometimes (not always) available at less than the cost of ILB. All of these reductions in cost are, in effect, “benefits” for electronic collection services compared with print collection services.

Usage and Effectiveness of Library Electronic and Print Collection Services

Usage is measured by the extent to which articles in the library electronic and print collections are actually read. It is useful to make a distinction between type of output metrics of use of library collections mentioned above and metrics of the use of information content provided by the collection access services. We have done that through over 20,000 readership survey responses involving professionals, particularly scientists located in universities, national laboratories, industry, and government. Some of the readership surveys were performed for publishers (e.g., Science).

In recent years (2000 to 2002) we have surveyed readers in four distinct circumstances. Two surveys were performed at sites in which libraries have continued print collections, supplemented with electronic journals. One site is at the University of Tennessee (UT) where scientists and medical staff
were surveyed, and the other involved users of a special library at Oak Ridge National Laboratory (ORNL) where scientists were surveyed. These two sites had been surveyed before electronic journals were on the scene, thus providing before and after observations. Another readership survey was done in May 2002 at Drexel University where most journals were replaced by electronic versions in 1999. Even though all faculty and doctoral students were surveyed, we limit observations here to scientists in order to provide direct comparisons with readership patterns of other scientists discussed here. At the end of 2001, we initiated and conducted a large-scale readership study of the American Astronomical Society (AAS) journal system (under partial funding by NASA). This study, in particular, provided substantial evidence of the readership of both library electronic and print collections. Furthermore, the AAS electronic publishing services are particularly advanced.

All of these readership surveys rely heavily on the critical incident method, where the last reading of an article is the focus of observation. A series of questions concerning the last reading include age of the article read; depth of reading; how the article is identified; where it was obtained (highlighting print vs. electronic sources); the amount of time spent by readers identifying, locating, obtaining, and reading the article; purposes of reading; outcomes from reading; and so on. This method is particularly useful in cross-classifying these observations. Comparison of the information seeking and reading patterns from electronic and print collections is given below.

The frequency with which electronic journals are used varies substantially among the surveyed groups of scientists, partially reflecting access to library electronic collections. For example, at UT and ORNL the proportions of readings from electronic sources are 23 and 32 percent respectively, but 46 percent at Drexel where the current collection is largely electronic.

Because of the early start and sophistication of AAS electronic publishing, the AAS members have come to rely much more on electronic journals than many other user groups. For example, 75 percent of readings by AAS members are from electronic sources. However, only 35 percent of the AAS member electronic journal reading comes from electronic library collections because of the availability of AAS electronic journals to society members and to value-added features.

The estimated annual amount of reading and proportion of reading from library print and electronic collections are given in Table 1. As might be expected, the proportion and amount of reading from the electronic library collection is by far the highest for the Drexel scientists. This electronic access may also account for the fact that less reading at Drexel is done from nonlibrary sources such as personal subscriptions. While we do not have before and after comparisons, it appears that the switch to the electronic collection has, if anything, increased readings from the Drexel library.
Table 1. Proportion and Amount of Reading from Library Electronic and Print Collections by UT Scientists and Medical Staff, ORNL Scientists, Drexel University Scientists, and AAS Members: 2000 to 2002.

<table>
<thead>
<tr>
<th>Survey Respondents</th>
<th>Total Article Readings per Person per Year</th>
<th>Electronic Library Collection Reading (%)</th>
<th>Electronic Library Collection Reading No.</th>
<th>Print Library Collection Reading (%)</th>
<th>Print Library Collection Reading No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT Scientists</td>
<td>201</td>
<td>9.0</td>
<td>17</td>
<td>23.0</td>
<td>46</td>
</tr>
<tr>
<td>UT Medical Staff</td>
<td>322</td>
<td>12.7</td>
<td>41</td>
<td>7.6</td>
<td>24</td>
</tr>
<tr>
<td>ORNL Scientists</td>
<td>113</td>
<td>21.3</td>
<td>24</td>
<td>26.7</td>
<td>30</td>
</tr>
<tr>
<td>Drexel Scientists</td>
<td>214</td>
<td>38.0</td>
<td>81</td>
<td>8.5</td>
<td>18</td>
</tr>
<tr>
<td>AAS Members</td>
<td>226</td>
<td>25.9</td>
<td>59</td>
<td>5.8</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: UT, ORNL, Drexel, and AAS surveys (n = 1,474)

AAS members tend to rely on library electronic collections rather than library print collections, regardless of how the article is identified. For example, if an article is found by searching an online abstracting and indexing (A&I) database (e.g., ADS, PubScience, SPIN) or a Web search engine (e.g., Yahoo, AltaVista, Excite, Google), it will be obtained about 90 percent of the time from a library electronic collection rather than a print collection. At Drexel about 76 percent is from the library electronic collection. When an article is identified through browsing, about 70 percent of the articles will be from an electronic collection, but lower at Drexel (29 percent). Clearly, a library electronic collection is often the source of choice for these scientists. This is not necessarily true for UT/ORNL readers. Online searches (mostly from A&I databases) provide articles that are more often obtained from their library print collections (64 percent of these readings), largely because the older articles, identified by online search, are not yet available electronically. On the other hand, about two-thirds of articles found by browsing are from their library electronic collection as opposed to the print collection.

As mentioned earlier, effectiveness is the relationship between access service outputs (and their attributes) and usage measures. In a real sense, the collection medium (i.e., electronic and print) is an attribute of the collection-related services. Special attributes of the library collection from AAS are the age of articles in electronic medium, forward and backward linkages, preprint access, machine readable data tables, links to the NASA Astrophysics Data System (ADS), and inclusion of images and color. Below we discuss the comparison of the two types of library collections and their services with respect to information-seeking patterns and age of article read.

A survey of Drexel users in May of 2001, after a substantial electronic journal collection had been in place for two years, showed that they prefer electronic journals for many reasons. Four hundred student and faculty respondents responded (on a scale of 1 = no agreement; 10 = strong agreement) to indicators of satisfaction as follows:
Eighty-four percent of the respondents preferred electronic journals to print; and use of electronic journals at Drexel is increasing, a pattern also reported by Guthrie (2000).

Astronomers were also asked to rate the importance of specific attributes or features of their journals. The average importance of these features in order of results are: machine-readable data tables (4.1 average importance rating), links to references (3.9), links to data centers (3.9), links to future citations (3.7), and inclusion of movies and color (3.1). While we do not know the relationship between these features and extent of reading electronic library collections, there well may be a positive correlation.

Time spent by readers (or someone on their behalf) varies substantially depending on how the articles are identified, located, and obtained. When articles have been identified, it takes an average of about nine minutes less time to locate and obtain the articles from the library electronic collections than from library print collections, and time spent browsing a library electronic collection is about eight minutes less per article found. It appears to require about three minutes less to download and print electronic articles than to photocopy print articles. As mentioned, the proportion of readings printed or photocopied is remarkably similar for the two media. While these differences may appear minor, they can add up to an appreciable amount of time with as much reading as scientists do. For example, AAS member use of library electronic collections alone (fifty-nine readings) can save them an average of about ten hours per year. Surveys over the years clearly show that scientists and medical professionals are aware of their time spent and they tend to choose information services and products based on ease of use and minimizing their time. Drexel’s survey data also show that users believe that electronic journal use saves time. These results all point to “benefits” of the library electronic collections.

Since the Drexel Library has JSTOR and other older electronic collections, we observed that 69 percent of readings from articles published more than two years prior to reading were from the electronic library collection. Guthrie’s preliminary usage data from all libraries using JSTOR indicates surprising use of older articles (Guthrie, 2000). He states that the “average age of the top ten articles most frequently printed and viewed was 13 years. More dramatically, in the file of mathematics, the average age of the most used articles was 32 years.” The JSTOR data also show much heavier use of the electronic than print journals. This is confirmed by the Drexel experience. Use of the JSTOR journals is far heavier than the comparable bound
volumes (even when adjusted for number of volumes held in the Drexel collection) and, in spite of the two-to-five-year “moving wall,” it is even heavier than the combined current issue and bound volume use.

The survey of AAS members provided an opportunity to gain a glimpse of information-seeking and reading patterns for older materials since their electronic journals go back to 1849. The age distribution of articles read from astronomy core electronic journals is almost exactly that observed by scientists generally in recent years and even in 1960 (Tenopir & King, 2000). Again, we examined the readings by AAS members of articles published over two years prior to the surveys. Of articles obtained from library collections, 23 percent were over two years old. Most of these older articles were obtained from a library electronic collection (70 percent of readings). Most of these older articles were identified through citations in a refereed journal (35 percent of readings from a library electronic collection) or online search (58 percent). While four percent of readings from this electronic service were found by browsing, 18 percent of readings were found this way from library print collections. Nearly half of older readings from print collections were identified from citations and 27 percent from online searches.

The average amount of time spent by AAS readers (or someone on their behalf) obtaining the older electronic articles was the same as with newer articles. However, the time spent obtaining older print articles was somewhat greater than with the newer ones, thus yielding an additional or greater “benefit” of the library electronic collection. Also of interest is that the average time spent reading older articles is forty minutes per article, compared with twenty-five minutes for recent articles, as might be expected given the purpose of use.

One indicator of print collection effectiveness is the proximity of the collection to readers (i.e., its accessibility). Every survey we have done comparing distance (in minutes) of readers to the print collection shows the overall use of the library, use of its journal collection, and amount of reading are inversely correlated with the distance to the library. That is, those closer have higher use, although it is found that readers further away from the collection tend to read more when they do visit the library. Evidence of the effect of distance on reading is as follows:

- 66 percent of the readings are from library print collections when the readers are less than five minutes away;
- 48 percent of readings are from there when five-to-ten-minutes away; and
- 34 percent of readings are from there when over ten minutes away.

A study by Charles River Associates (1978) for the NSF used a stochastic model to determine the probability that scientists will subscribe to a journal. The two most important factors, of many factors contributing to a low probability of subscribing, were found to be: “availability of the journal in a library frequently used by the scientist” and “convenience of location of the
library to the scientist.” This also accounts for the fact that scientists closer to their library tend to subscribe to fewer journals than those further away.

Thus, one of the clear “benefits” of library electronic collection services is that distance does not affect use of the collection and the extent of reading from the collection. Another is that the electronic collection is available at all hours. Finally, scientists further away from their library tend to subscribe to more journals (incurring additional cost), which would not be necessary with the electronic collection services. Drexel results seem to confirm this since scientists there average fewer personal subscriptions than scientists at UT.

**Cost-Effectiveness of Library Electronic and Print Collection Services**

In an earlier section we discussed the unit cost of several journal access services. The unit costs were based on the fixed costs of purchasing and processing the journal collections and the variable costs associated with provision of the collection services. The average (or unit) costs were based on use measured by issues and bound volumes reshelved for print collections and hits and downloads for electronic collections. Cost effectiveness, by our definition, is a relationship between service input measures and usage measures. Perhaps the most obvious such derived measure is the input cost of services divided by readership resulting from the services. In our special libraries studies the estimated cost-effectiveness measures are:

- Reading from print current periodicals—$4.20 per reading
- Reading from print collections in the stacks—$9.70 per reading
- Reading from routed journals—$4.80 per reading

Note that these unit costs are much less than cost per use of these services. In the discussion of effectiveness of print collections, we mentioned the effect distance has on amount of reading. Of course, special libraries tried to increase reading from their collections by routing journals to their users. This, as shown, has been relatively cost-effective.

Unfortunately, we do not yet have direct comparisons with electronic library collections in special libraries. At Drexel the cost-effectiveness is $3.90 per reading for print current periodicals; $23.50 per reading for print journals in the stacks; and $2.00 per reading electronic journals. Thus, cost-effectiveness is a significant “benefit” for electronic journal collection services.

**Outcomes from Reading Articles from Library Electronic and Print Collection Services**

We consider outcomes as the consequences of having read and used information found in articles obtained from library collections. Since we began surveying readership in the 1970s, we have tried to assess such out-
comes from several perspectives, particularly considering the purposes for which reading is done (i.e., research, teaching, learning, etc.). Examples of outcomes include:

- the importance of the information in achieving these purposes;
- the relative importance of the information, as a resource for performing work, compared with other resources used in doing that work;
- the amount of dollar savings achieved from reading;
- the extent to which reading affects readers' performance such as the quality and timeliness of work, improvement in students' grades, and so on;
- a correlation between amount of reading and productivity;
- other favorable consequences such as initiating new ideas, broadening options in work, and so on;
- achievements of parent organization and societal goals.

Most of these outcome indicators have been observed in special library environments (Griffiths & King, 1993), although below some of them are compared from readings of library electronic and print collections based on the UT, ORNL, Drexel, and AAS surveys.

The purposes for which information is used depends somewhat on the scientists' work setting, field, and type of work. Scientists in universities indicate that about one-half of readings are for current awareness or professional development. When applied to work, they are used to support research (75 percent of readings), teaching (41 percent), and administration (13 percent). Over a period of one year the scientists indicated that twenty-three of the readings from print collections were absolutely essential to their research and thirteen readings were absolutely essential to teaching. Almost identical results were observed from the Drexel survey of scientists when reading from the electronic library collection. For example, 79 percent were read for research and 25 percent of these were absolutely essential to this purpose. Nonuniversity scientists indicated that 30 percent of readings were for current awareness, etc., conducting primary research (17 percent), background research (26 percent), design or other R&D activities (11 percent), administration (19 percent), writing (7 percent), and presentations (7 percent). When compared with other resources (e.g., computing, instrumentation, support staff, etc.), the information found in documents was rated second highest in importance for primary research and rated highest for most other tasks.

Comparing the principal purposes for information read from library electronic and print collections, the purposes given by AAS members are very similar for the two collections: primary research (44 percent of readings from electronic collections vs. 48 percent print); background research (33 percent, 28 percent respectively); writing proposals, reports, articles, etc. (10 percent, 15 percent). Importance of the information to the prin-
Principal purpose is rated from 1—not at all important to 3—absolutely essential. Average importance ratings are almost the same (2.21 for readings from an electronic collection; 2.19 print) and the proportion rated absolutely essential is the same for both collections (22 percent of readings).

A separate opinion survey of AAS members illustrates just how valuable they believe the electronic journals to be for their work, both for keeping up with current developments as well as for obtaining definitive information. For example, 72 percent of them rate electronic journals as either “very useful” or “essential” for keeping up with recent developments. When seeking definitive information, astronomers value the electronic journals even more highly. Virtually all astronomers (96 percent) rate electronic journals as either “essential” or “very useful” for delivering definitive results.

This overwhelming approval rate reflects the effectiveness of the whole electronic information system used in astronomy, particularly seamless links between the electronic journals and the highly effective NASA ADS (an A&I service plus a database of historical full-text journal articles). The same survey indicated that 97 percent of AAS members knew about the ADS, over 50 percent of them use it at least every other day, and 27 percent of AAS members use the ADS every day. ADS usage statistics confirm this level of activity.

We also asked readers if they had previously read the most recently read article and, prior to the first reading, if they knew about the information reported or discussed. The results are similar for proportion of articles that had been previously read (20 percent of readings of electronic, 24 percent print), but less for prior knowledge of information in electronic collections (42 percent electronic vs. 50 percent print). Thus, there may be some “benefit” in provision of more new information read from library electronic collections. One explanation for this phenomenon may be that scientists are observed to read from a broader range of journals than they did twenty-five years ago. That is, in 1977 scientists on average were estimated to read at least one article from about thirteen journals, but that number has increased to over twenty based on observations in the last two years. This broadened reading may be partially due to the easy accessibility of electronic journals and the discovery tools—the abstracting and indexing databases. As a result, more readings from journals not previously read may provide additional new information.

A series of earlier readership surveys (Griffiths & King, 1993) showed that journal reading resulted in saving time and money. In fact, about 32 percent of readings from library-provided articles resulted in such savings compared with 23 percent read from other resources (e.g., personal subscriptions). Furthermore, the estimated amount of savings was $360 per reading and $260 respectively. Reasons given for achieving such savings included avoiding having to do some primary research (49 percent of readings in which savings were incurred), provided confirmation of research (27 percent of such readings), stopped an unproductive line of research (10 per-
cent of such readings), modified research or engineering design (12 percent of such readings), and modified analysis methods (16 percent of such readings). Clearly, one should not interpret the amount of these savings as being “typical” from readings since the average savings are calculated from highly skewed distributions with 25 percent of readings contributing no savings and one or two percent accounting for most of the estimated savings.

In other surveys, we asked how journal reading affected the quality and timeliness of work. For example, respondents were asked the activity for which reading was done, whether the reading affected the quality of the activity and, if so, they were asked to rate the quality of the activity before and after reading with 1 being low and 7 high quality. About 70 percent of readings were for activities in which quality is applicable; 44 percent of all readings resulted in improved quality; and, following readings, the ratings of quality improved from 4.04 average rating to 5.82. About 60 percent of the readings involved activities for which timeliness is relevant and 32 percent of these readings resulted in faster performance or completion of the activity.

In one company, a stated goal was to increase the speed of products from discovery to the marketplace. We identified about twenty major processes involved in going from discovery to the marketplace and asked whether reading affected the speed of completion for each of these processes. About 31 percent of readings of library-provided documents led to the work being completed faster.

We developed five indicators of productivity of professionals in organizations where outputs included number of formal records of work, number of consultations given, number of presentations made, number of written proposals or plans, and number of formal publications written. In all instances the productivity measures were positively correlated with the amount of reading. Higher productivity and improved work performance would suggest the potential of receiving formal recognition of work through achievement or technical awards and other forms of recognition. Our surveys revealed that recipients of such awards tend to read more articles than nonrecipients. For example, such award winners read 32 percent more articles in a year. Persons asked to serve on high-level projects or problem-solving teams or special committees read 21 percent more articles. In one company, the personnel office provided us with the names of twenty-five particularly high achievers. These twenty-five high achievers read 59 percent more articles than cohorts with equivalent degrees, fields of specialty, and years of experience and who performed the same kind of work. This finding holds true for both university and nonuniversity scientists.

Thus, there are several ways of assessing the outcomes of reading journal articles. In our recent surveys we do not have all of these indicators for library electronic collections. However, we observed that a high proportion of readings from library electronic and print collections improved the result of the principal purpose for which reading was done (36 percent of
electronic reading, 41 percent print); inspired new thinking or ideas (36 percent electronic, 33 percent print); narrowed, broadened, or changed the focus (14 percent electronic, 19 percent print); resolved technical problems (9 percent electronic, 7 percent print). Some said that the reading had no effect on the principal purpose, but was valuable nevertheless (17 percent electronic, 26 percent print). It appears, considering outcomes alone, that there is no clear "benefit" or "cost" attributable to electronic collection services compared with print collection services, but both have highly favorable outcomes. On the other hand, readings from library-provided articles almost always have more favorable outcomes (e.g., King & Montgomery, 2002).

SUMMARY AND CONCLUSION

We have provided an approach to assessing the economics of electronic journals in libraries and a description of how this approach developed historically. The approach involves a framework of input, output, performance, usage, effectiveness, cost-effectiveness, and outcome metrics of library services. In this approach, cost-benefit is a comparison of a service and some alternative to it using these metrics. In this article we use, as an example of these metrics, the library electronic collection services compared with print collection services. Such comparisons are considered a "benefit," if favorable, and a "cost" or "detriment," if unfavorable. Some indication of the benefits and costs of electronic over print collections are shown in Table 2.

Examined from the library perspective, it appears that the electronic collection and services will yield benefits in requiring lower prices per-title, less time of staff, and, potentially, substantial savings in space. Thus, these resources can be reallocated into additional or better services to users. Users benefit in flexibility of access; saving substantial time in searching, locating, and obtaining the articles; availability of new and useful features; and broadening the number of journals they use. Library and scientist funders benefit from better utilization of their resources (i.e., library and scientists). Thus, it appears that library electronic collections are highly beneficial to publishers, as well as libraries, readers, and their organizations (whether universities or elsewhere). Despite some turmoil, the scholarly journal system seems likely to continue its important role in research, teaching, and lifelong learning. Electronic journals will continue to grow in acceptance and strength, although some libraries may continue to purchase both electronic and print versions at minimal additional costs in order to provide current periodicals in print for readers who prefer this version.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions to this article by the following persons: Sarah Aerni, Janine Golden, Matt Herbison, Willie J. Johnson Jr., and David Robins, University of Pittsburgh, School of
Table 2.

<table>
<thead>
<tr>
<th>Economic Metrics</th>
<th>Comparison of Electronic vs Print</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collection as a Resource</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td></td>
</tr>
<tr>
<td>Negotiation and system</td>
<td>High costs ($)</td>
</tr>
<tr>
<td>Collection development</td>
<td>Higher cost ($)</td>
</tr>
<tr>
<td>Purchase price</td>
<td>Depends</td>
</tr>
<tr>
<td>Processing</td>
<td>Lower cost ($)</td>
</tr>
<tr>
<td>Inventory control</td>
<td>Depends</td>
</tr>
<tr>
<td>Subscription maintenance</td>
<td>Higher cost ($)</td>
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<tr>
<td><strong>Output Quantities</strong></td>
<td>More titles</td>
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<tr>
<td><strong>Output Attributes</strong></td>
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<tr>
<td>Accessibility</td>
<td>Proximity</td>
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<tr>
<td>Availability</td>
<td>24-hour access</td>
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<tr>
<td>Features (e.g., AAS)</td>
<td>Many features possible</td>
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<tr>
<td><strong>Performance</strong></td>
<td>Lower cost/title ($)</td>
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<tr>
<td><strong>Collection Services</strong></td>
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<tr>
<td><strong>Current Journal (Input)</strong></td>
<td></td>
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<tr>
<td>Collection fixed cost (allocated)</td>
<td>Lower cost ($)</td>
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<tr>
<td>Training, publicity (allocated)</td>
<td>Moderate cost ($)</td>
</tr>
<tr>
<td>Variable cost</td>
<td>Slightly higher cost ($)</td>
</tr>
<tr>
<td><strong>Current Journal (Output)</strong></td>
<td>Some more use</td>
</tr>
<tr>
<td><strong>Older Journal (Input)</strong></td>
<td></td>
</tr>
<tr>
<td>Collection fixed cost (allocated)</td>
<td>Lower cost ($)</td>
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<td>Training, publicity (allocated)</td>
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<tr>
<td>Variable cost</td>
<td>Slightly higher cost ($)</td>
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<td><strong>Older Journal (Output)</strong></td>
<td>Similar use</td>
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<td><strong>Older Journal (Performance)</strong></td>
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<tr>
<td>Collection fixed cost (allocated)</td>
<td>Lower cost ($)</td>
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<tr>
<td>Training, publicity (allocated)</td>
<td>Moderate cost ($)</td>
</tr>
<tr>
<td>Variable cost</td>
<td>Much lower cost/use ($)</td>
</tr>
<tr>
<td><strong>External (e.g., Office) Access (Input)</strong></td>
<td></td>
</tr>
<tr>
<td>Collection fixed cost (allocated)</td>
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<td>Variable cost</td>
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<td><strong>External Access (Output)</strong></td>
<td>More use</td>
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<td><strong>External Access (Performance)</strong></td>
<td>Much lower cost/use ($)</td>
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<td><strong>Usage</strong></td>
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<td>Reading</td>
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<td>Purpose of Reading</td>
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<tr>
<td>User Time</td>
<td>Save user time</td>
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<tr>
<td>User Effort</td>
<td>Less effort needed</td>
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<tr>
<td><strong>Cost-effectiveness</strong></td>
<td>Lower cost/reading ($)</td>
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<tr>
<td><strong>Outcomes</strong></td>
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<td>Importance of Information Content</td>
<td>Similar rating</td>
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<tr>
<td>Provided New Information</td>
<td>More new information</td>
</tr>
<tr>
<td>Other Outcomes</td>
<td>Both high</td>
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</table>
Information Sciences; Katie Brady and Thomas McLaughlin, Drexel University, Hagerty Library; Randy Hoffman, Oak Ridge National Laboratory; and Rhyn Davies, Matt Grayson, Sarah Greene, and Keri-Lynn Paulson, University of Tennessee, School of Information Sciences.

REFERENCES


Cost, Statistics, Measures, and Standards for Digital Reference Services: A Preliminary View

R. DAVID LANKES, MELISSA GROSS, AND CHARLES R. MCCLURE

ABSTRACT

This paper reports on work from two studies in progress related to assessing digital library reference services and developing standards that support such services. The paper suggests that two types of standards—utilization and technical—should be considered together in the costing, statistics, and measures for digital reference services. The digital reference community has the opportunity to embed quality standards and assessment data into software and infrastructure by linking utilization and technical standards early in the evolution of digital reference markets. Such an approach would greatly enhance the collection and analysis of a range of cost data related to digital reference service.

1. INTRODUCTION

This paper outlines the current status of standards (both utilization and technical) in digital reference with special attention given to issues of cost; both costs incurred by adopting standards, as well as means of assessing cost in digital reference. The article represents preliminary results of a study to develop methods to assess the quality of digital reference services and ongoing work to develop technical standards in digital reference.

The Information Institute of Syracuse at Syracuse University and the Information Use Management and Policy Institute at Florida State University conducted the first study. This study is developing digital reference measures; testing and refining these measures and quality standards to
describe digital reference services; and producing a guidebook that describes how to collect and report data for these measures and standards.

This study began at the October 2000 Virtual Reference Desk (VRD) Conference in Seattle, where the growing digital reference community identified assessment of quality as a top research priority. As patrons demand more services online, and as reference librarians seek to better meet patrons' information needs through the Internet, it has become essential to determine common standards quality. Library administrators need strong, grounded metrics and commonly understood data to support digital reference services, assess the success of these services, determine resource allocation to services, and determine a means for constant improvement of digital reference within their institutions. Project information about this effort can be found at http://quartz.syr.edu/quality/.

The second source for this article comes from ongoing work to develop technical standards in digital reference. This work is represented by the development of the Question Interchange Profile (Lankes, 2002) and the newly initiated work of NISO (National Information Standards Organization) Standards Committee AZ (NISO, 2002). This work responds to an increasing call by vendors and technical service staff for clear guidelines to ensure interoperability. Project information about this and related standards efforts can be found at http://www.niso.org/.

While, at first, utilization and technical standards may be seen as separate, this paper argues that both, tightly coupled, are essential for the advancement of digital reference and to truly capture a holistic picture of cost. While utilization standards may determine formulae and approaches to determining the total cost of digital reference, technical standards both impact this cost (through tool development or software acquisition), as well as provide a means of distributing and/or recouping these costs. For example, in a consortia, setting a per-question cost can be determined. Properly developed technical standards can "carry" this cost with the question (for example, by providing a field with a dollar figure), greatly easing accounting and enabling the creation of a "question economy" where consortia members can bid on questions or do automated routing to the most cost-effective answer source. These concepts will be expanded below.

2. A Digital Reference Primer

For the purposes of this paper, digital reference is defined as human-intermediated assistance offered to users through the Internet. Today, libraries are offering a range of human-intermediated reference services over the Internet at an increasing rate. Research by Joe Janes and his colleagues (Janes, 2000) found that 45 percent of academic libraries and 12.8 percent of public libraries offer some type of digital reference service. These services are often ad hoc and experimental. Janes and McClure (1999) found that, for quick factual questions, librarians using only the Web answered a sample of
questions as well as did those using only print sources. Many libraries conduct digital reference service in addition to existing obligations with little sense of the scale of such work or its strategic importance to the library.

This paper does not provide a comprehensive review or analysis of digital reference and digital reference services. Gross, McClure, and Lankes (2002) have published elsewhere a detailed analysis of digital reference literature. Despite this and other such reviews, there is limited knowledge about costs, assessment, and standards related to digital reference services. As the studies discussed in this paper are completed, one product will be a manual to assist librarians assessing digital reference services on a range of criteria and measures (McClure, et al., 2002).

3. DEVELOPING A TYPOLOGY OF STANDARDS IN DIGITAL REFERENCE

The authors divide digital reference standards into two types:

1. Utilization: Those standards that deal with the use and delivery of digital reference services, specifically to determine whether a digital reference service is succeeding. These can include a mix of qualitative and quantitative metrics as well as more abstract statements on best practices or objectives for a service.
2. Technical: The use of hard tools (software, hardware, protocols, and other standards enforced by computers with little or no interpretive room) and soft tools (primarily metadata and organizational schema where aspects of human description are controlled, but still open to interpretation).

These two high-level categories have been further refined in two separate efforts. It should be noted, however, that both of these efforts are ongoing, and these refinements may change.

3.1. REFINING UTILIZATION STANDARDS

The first effort to refine the digital reference typology is the "Assessing Quality in Digital Reference Services" conducted by the Information Institute of Syracuse at Syracuse University and the Information Use Management and Policy Institute at Florida State University (Lankes, et al., 2001). This study is supported by OCLC and the Digital Library Federation and a wide range of library organizations (see Table 1).

This study has compiled a preliminary set of metrics, statistics, and standards for assessing digital reference from a review of the literature and a series of site visits (http://quartz.syr.edu/quality/VRDSiteVisitsummary.pdf). These measures were reviewed by the study’s advisory committee (made up of the primary sponsors and the sustaining members), and revised. As of this writing the revised measures are being field tested in a variety of library types (federal, academic, and public).
Table 1. Members of the Quality Study.

<table>
<thead>
<tr>
<th>Sustaining Members</th>
<th>Contributing Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multnomah County Library (the first public library to join the study)</td>
<td>• McKeldin Library, University of Maryland</td>
</tr>
<tr>
<td>• The Library of Congress</td>
<td>• Mid York Library System</td>
</tr>
<tr>
<td>• Strozer Library, Florida State University</td>
<td>• Bristol University, University Library</td>
</tr>
<tr>
<td>• Cleveland Public Library</td>
<td>• Liverpool John Moores University</td>
</tr>
<tr>
<td>• Pennsylvania Office of Commonwealth Libraries, Bureau of Library Development</td>
<td>• University Library, Syracuse University</td>
</tr>
<tr>
<td>• State Library of Florida, Division of Library and Information Services</td>
<td>• Library of Michigan</td>
</tr>
<tr>
<td>• Reference and User Services Association</td>
<td></td>
</tr>
</tbody>
</table>

3.1.1. QUALITY STANDARDS

Utilization standards can be first refined into performance measures and quality standards. A quality standard is a specific statement of the desired or expected level of performance that should be provided regarding a service or some aspect of that service. A quality standard can be measured to determine the degree to which that standard is in fact being met (Kassowitz, et al., 2000). A quality standard defines the level of performance that an organization is willing to accept for a particular service or activity. Quality standards are important because they:

- Encourage library staff and administration to discuss and agree upon what constitutes “quality” for a specific service;
- Provide clear guidance as to the expected quality that a particular service or activity should offer;
- Educate staff—and especially new staff—as to the expected quality of service that should be provided;
- Recognize that there may be differing acceptable levels of quality for different aspects of digital reference services; and
- Provide a basis for rewards and demonstrating/reporting accountability.

Quality standards are not performance measures. A performance measure might be “correct answer fill rate” whereas the quality standard might be “the digital reference service will have a correct answer fill rate of 65 percent.”

The assessment study specifically states that there is no “correct” standard for any specific digital reference service. The correct standard will rather depend on the goals and objectives of the library, the amount of resources that can be committed to reaching a particular standard, local situations affecting digital reference services, and the relative importance of one quality standard versus another. For one library, an awareness level of digital reference services of 30 percent among faculty (for example) may be acceptable; for another, the standard might be 60 percent.
While not specifically spelling out all possible quality standards, the study proposes six Quality Standards that appear to span specific circumstances and domains:

1. Courtesy: The behavior of the library or institution's staff.
2. Accuracy: The "correctness" of answers provided by a digital reference staff.
4. Repeat Users: The percentage of users that reuse a service after first encounters.
5. Awareness: The population user group's knowledge that the service exists.

It is assumed that each of these standards will have a strong qualitative component. However, to fully define these standards, the study created five types of performance measures that can be used to better determine success in meeting quality standards:

1. Descriptive Statistics and Measures: Statistics and measures to determine the scale and scope of a digital reference service.
2. Log Analysis: Statistics that can be derived from analysis of logs generated by Web and digital reference software packages.
3. User Satisfaction Measures: Statistics and metrics seeking to understand the user view of a digital reference service.
4. Cost: Measures that gage outlay of financial resources to run an ongoing digital reference effort.
5. Staff Time Expended: Measures to determine staff time dedicated to digital reference.

Each of these classes of measures is then further refined into specific metrics and statistics as seen in Table 2.

Further refinement within these measures is also possible. For example, the assessment study has associated data collection methods to each measure, but such refinement is too specific for the discussion in this paper. Nonetheless, special attention should be given to the cost measures and standards.

### 3.1.2. Cost Measures and Standards

The economics of reference is an area that has long been neglected. Indeed, the economics of information in general has only recently received significant attention (Kingma, 2001). Assigning costs to reference service is a complicated task but one that must be faced in order to realistically assess the true costs of doing business, to make assessments about the most efficient ways to provide services, and to determine how to share the costs of this service in setting up and participating in collaborative service models.
**Table 2. Utilization Standards by Class.**

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>Log</th>
<th>User</th>
<th>Cost</th>
<th>Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of digital reference questions received</td>
<td>Number of digital reference sessions</td>
<td>Awareness of service</td>
<td>Cost of digital reference service</td>
<td>Percent of staff time spent overseeing technology</td>
</tr>
<tr>
<td>Number of digital reference responses</td>
<td>Usage of digital reference service by day of the week</td>
<td>Accessibility of service</td>
<td>Cost of digital reference service as a percent of total reference budget</td>
<td>Percent of staff time spent assisting users with technology</td>
</tr>
<tr>
<td>Number of digital reference answers</td>
<td>Usage of digital reference service by time of day</td>
<td>Expectations for service</td>
<td>Cost of digital reference service as a percent of total reference budget</td>
<td></td>
</tr>
<tr>
<td>Total reference activity</td>
<td>User’s browser</td>
<td>Other sources user tried</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of digital reference questions to total reference questions</td>
<td>User’s platform</td>
<td>Reasons for use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital reference correct answer fill rate</td>
<td></td>
<td>Reasons for non-use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital reference completion rate</td>
<td></td>
<td>Satisfaction with staff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of unanswered digital reference questions</td>
<td></td>
<td>Delivery mode satisfaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of digital reference questions received</td>
<td></td>
<td>Impact of service on user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of referrals</td>
<td></td>
<td>Additional services that need to be offered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturation rate</td>
<td></td>
<td>User demographic data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sources used per question</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeat users (return rate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Understanding what it costs to provide reference, the various funding models (and cost-recovery models) under which reference can be provided, and what the effect of supporting digital reference is on other library expenditures, is important for planning, monitoring, and evaluating these services, as well as for performing cost-benefit analysis and measuring the cost-effectiveness of service.

Determining the cost of a digital reference service has many of the same manifold complexities of determining cost of traditional reference. There have been a number of attempts to determine the means of costing reference service, and there have been several estimates of average cost of reference. These estimates have varied widely due to the assumptions under which costs are identified, defined, and operationalized. In many cases staff and resources are often utilized by more than one service area within the library and it is difficult to prorate out costs for any one area. Some resources are utilized both within the library and externally (as in the case of remote access to databases) so it is difficult to ascribe the cost to any one department.

Some of the most costly resources for the provision of digital reference are subscriptions and licenses to online resources and databases. These resources are also available for use by other departments and by the patron from both within the library and at home. Also, different vendors have been varyingly successful or interested in providing meaningful statistics and data about database use. In many cases it is impossible to determine what percentage of costs can be allocated to the digital reference service (especially when authentication is by IP address only). Staff perform the duties of traditional and digital reference at the same time and keeping track of time allocated to either can be problematic. It is important however to make an attempt to determine costs.

Across all sites used in the “Assessing Quality in Digital Reference Study” the collection of cost data was minimally performed and only reported in general terms. Several sites indicate that they expect to be held more accountable for specific cost data in the future, but are unlikely to collect this data unless required. There is some fear that the findings of cost data might not support the continued provision of the service.

The cost for each digital reference transaction is difficult to determine. Two libraries report that cost for outsourcing digital (chat) reference through Library Systems and Services Inc. (LSSI) runs in the $12.00 to $15.00 range per question. How the cost of this service was computed by LSSI is unknown. Digital reference at these sites is not considered separately from traditional reference for accounting purposes, and even where handled separately the costs are not calculated. The per-question cost for traditional reference services, in fact, is also unknown.

There is a major gap in the literature on digital reference services in the area of economic models and accounting. This may follow largely from the fact that the economic and costing models have not been fully devel-
oped in the traditional reference realm. This means that effective measures of cost need to be developed for all types of reference so that each can be assessed and compared in terms of efficiency and benefit.

In the literature of traditional reference services some approaches are offered toward the problem of determining what reference service costs. For instance, the Input/Output Model (Sayre & Thielen, 1989) focuses on measuring inputs and service utilization in small libraries. Functional Cost Analysis (Abels, Kantor, & Saracevic, 1996), a process explored in a variety of reference service environments, seeks to define the various costs of providing a service and then allocates these costs to that service. Hayes (1996) reports on the intricacies of assessing the costs related to the provision of electronic resources in support of reference within the framework of the Library Costing Model (LCM), but does not solve the problem for digital reference services.

Murfin and Bunge (1989) offer four methods for assessing cost effectiveness in academic libraries. They are:

- Method Two: A Reference Service Cost Effectiveness Index Based on Success, Helpfulness, Accessibility and Time/Cost.
- Method Three: Cost (time taken) per Successful Question.

These formulas were tested in academic libraries in a project funded by the Council on Library and Information Resources for research purposes and used in the Wisconsin-Ohio Reference Evaluation Program. There may be value in using this work as a starting point for addressing the current issue of how to evaluate digital reference services from a cost standpoint.

Cost issues also exist in the development and practical management of collaborative arrangements for providing digital reference services. As collaboration models form, the question of how to share the costs of providing 24/7 digital reference services, in what will inevitably be a global forum, has already come to light as an issue that will soon need resolution. In this regard the Library of Congress, Collaborative Digital Reference Services (CDRS) (http://www.loc.gov/rr/digiref/about.html) project will be interesting to watch as it learns how to share the cost of service among its members and finds its place in the information market.

3.1.2.1. Other Considerations of Cost in Digital Reference

While many of the issues of costing in digital reference parallel traditional reference, there are some factors that change. For example, digital reference lends itself to greater and more precise analysis. One of the primary differences between traditional reference and digital reference is the
creation of a document trail. That is to say that while in face-to-face reference recording the reference transaction, including resources used, is at best difficult, in digital reference an auditable record of the whole reference transaction is available for analysis. Be it a transcript from a real-time session or a collection of e-mails, an organization can precisely identify the number of questions asked, the number of responses given to that question, the nature of those questions and responses (their subject, or their depth for example), and the resources used in those transactions (Web pages pointed to, digital assets transferred, etc.). In many cases the output of a digital reference transaction is a knowledge base or FAQ archive that can be either reused in the reference process, or made available to patrons as a new information resource.

3.1.2.2. Coupling Utilization Standards to Technical Standards

It is at this point that the link between utilization and technical standards becomes important. By having the data needed to determine utilization standards provided by (or encoded within) technical standards, the easier the task administrators and evaluators will have. For example, if technical standards record the cost of individual reference interactions, then digital reference software can easily report total cost of service with little or no data gathering on the part of the organization. Similarly, if the technical standards can identify sources (in an XML file, or simply by identifying URL's) used, then the evaluator is saved long tedious hours of trolling through transcripts and/or e-mail records. The point of tightly coupling utilization and technical standards is to have software and systems aid evaluation as part of the reference process. Technical standards allow the opportunity of building assessment into the reference process itself, rather than as a separate, often costly activity.

3.2. Refining Technical Standards

This article will not go into great depth on technical standards. A deeper discussion of digital reference standards can be found in other writing. Rather, this article will discuss the methods of coupling utilization and technical standards, as well as the impacts technical standardization may have on libraries. It is sufficient for the reader to understand that current development activities in digital reference standards fall into three types:

- Question Interchange: The means of encoding reference questions and answers into computational formats and transferring questions form one domain to another.
- Profile: Descriptive information about an organization or individual used to establish a digital reference network that may exist for a single interaction or long-standing relationships. Elements of a profile may in-
• Knowledgebase: The means of encoding questions and answers into a reusable archive.

Of particular interest here are Question Interchange and Profile because they directly relate to the active reference process. Technical standards can encode cost data, institutionalize actions within reference (allowing an audit process to determine what institution did what in the reference process), and track resources used in responding to an inquiry. With this data generated as part of the reference activity (thus minimizing the burden of data collection) software can better report on the full range of resources used, and therefore the true cost of a reference process. Also, by creating an easily packaged format for reference inquiries, a market approach can be brought to bear on the entire reference process (see "Towards a Question Economy" below).

3.2.1. Potential Impacts of Technical Standards on the Cost of Digital Reference

One hope of most standards efforts is to minimize cost. By creating clear technical requirements and ensuring interoperability in software, it is hoped that market forces will force vendors to lower prices, or at least maximize the ratio of cost of software to features or functionality. The concept is that a library can shop a range of competing software vendors, selecting based on local needs without sacrificing interoperability with other libraries and partners. This is the model in today's current OPAC market. Wide-scale adoption of the MARC standard means that libraries are ensured that catalog information can be used in any system; it is simply a matter of features and cost. A vendor, understanding that their competition can handle all the basic functions and standards, must differentiate themselves on either cost or features.

This is, of course, the long-term view. The digital reference software market is still in its infancy. It currently consists of real-time vendors (i.e., LSSI), freeware (such as AOL Instant Messenger), e-mail solutions, and home-grown solutions (i.e., software created by libraries). Since this software market has developed in the absence of technical standards, any introduction and adoption of standards will force new costs in software development and migration of internal data representations to a new standard. In some cases this may be minimal (if an application already stores digital reference data in a structured database, then it may be as simple as renaming fields, or creating new output mappings), but may be quite substantial (for example migrating from low-cost or free e-mail options to systems created specifically for digital reference). While current technical standards are being crafted with the diversity of technical sophistication in mind, a minimal threshold will need to be established (most likely in the form of transferring XML files back and forth).
3.3. TOWARDS A QUESTION ECONOMY

There are larger implications in the creation of a standard way of encoding and distributing questions. In essence these technical standards create an object. That object has certain attributes (e.g., a metadata representation) that can be separated from the original software/system/process that created it. This object-oriented approach allows the creation of a question/answer marketplace in which question objects could be exchanged and bid upon.

For example, an organization could outsource a question, paying some fee to a third-party “answering organization.” This third-party organization could subsist solely by answering questions without a direct user interface (as in the LSSI example mentioned previously). Organizations could use the technical standards as a foundation for cooperative support and reference services (such as the Library of Congress’ CDRS). Originating services (those that receive the questions from patrons) could include minimum requirements in answering questions and a maximum amount they are willing to pay for each answer. Third-party answering agencies could “bid” on the question allowing a sort of supply and demand economy to develop. This bidding could be either automated or human-controlled. Money doesn’t have to be the only resource exchanged. A barter economy (e.g., “I’ll answer one of yours if you answer one of mine”) could develop. Such a system of either resource swapping or fee exchange is essential in the development of cooperative reference services.

In today’s public and research libraries there is a debate over how to support digital reference efforts. How does a public library in New York get reimbursed when it answers a question from California? What is the library’s incentive to offer such services? This becomes particularly problematic when it is nearly impossible to determine a question’s point of origin. With the use of technical standards, electronic IOUs or actual dollars can provide an incentive to these libraries not only to answer the occasional question, but to seek out questions.

3.4. THE FULL DIGITAL REFERENCE STANDARDS TYPOLOGY AND CONCLUSION

Table 3 offers a preliminary digital reference standards typology.

This typology can serve as a starting point for further refinement and development. The point of this article and exercise is not to close the book on digital reference standards, but rather to promote a more holistic approach to developing standards. All too often technical standards are formed with little concern for assessment, and utilization standards (or measures, or best practices) often either ignore the underlying technical standards (often because they are already in place) or do seek to inform technical standards development. This is very evident in the development of the Web, and the HyperText Transfer Protocol (HTTP). Web analysis and assessments
Table 3. Preliminary Typology of Digital Reference Standards.

<table>
<thead>
<tr>
<th>Quality</th>
<th>Utilization</th>
<th>Performance Measures</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Courtesy</td>
<td>Quality</td>
<td>Descriptive (see Table 2 for further refinements)</td>
<td>Note refined in the scope of this article</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Accuracy</td>
<td>Log (see Table 2 for further refinements)</td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Satisfaction</td>
<td>User (see Table 2 for further refinements)</td>
<td></td>
</tr>
<tr>
<td>Repeat Users</td>
<td>Repeat Users</td>
<td>Cost (see Table 2 for further refinements)</td>
<td></td>
</tr>
<tr>
<td>Awareness</td>
<td>Awareness</td>
<td>Staff (see Table 2 for further refinements)</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

would be greatly aided if more user information was passed between computers for logging purposes. One could imagine, for example, being able to determine the number of repeat users rather than making statistical assumptions about repeat use from IP address, or determining the length of time users spend searching in databases. Instead, log analysis is forced into uncomfortable statistical guessing, and Web application must often resort to work-arounds like cookies and login screens. What may have been a desire for technical ease, or even privacy, has instead led to a plethora of incomplete solutions that often threaten both technical ease and privacy.

The digital reference community has the opportunity to embed quality standards and assessment data into software and infrastructure. By linking technical and utilization standards early in the evolution of digital reference markets (software markets, question markets), libraries can advance the field (through technology) and prove they are advancing it at the same time (through utilization standards). Moreover, the resulting improvement in collecting a range of cost data will assist libraries better plan for and deploy digital reference services.

NOTES
1. Coupling refers to the consideration of one type of standard or system by another. Coupling is actually a continuum from tightly coupled to loosely coupled. Tightly coupled systems (standards) are ones with a great deal of knowledge about each other, allowing for a large degree of interaction and customization. Loosely coupled systems are often unaware of each other, and allow only minimal interoperability. Z39.50 is a tightly coupled protocol, for example, versus the wide-open nature of Web searches that utilize no underlying structures (such as MARC).
2. A domain is a deliberately broad term that can be used to describe a single organization, a consortium, industry, or some other differentiation. So a question may be sent from a library to another library, or from the library world to the business world.
REFERENCES


public opinion and the funding of public libraries

bryce allen

abstract
the theory of public choice suggests that high levels of demand for public library services and positive perceptions of the quality of those services should be associated with higher levels of funding for the libraries. this investigation compared self-reported use of public libraries and public opinion about library services with levels of per-capita library funding over time. the results showed a small relationship between self-reported use of libraries and levels of library funding. there was no relationship between public opinion about libraries and funding levels. these results provide little support for the theory of public choice, and suggest that noneconomic factors may have greater impact on funding for libraries than economic factors.

introduction
information agencies such as libraries are frequently established as public agencies. they are funded primarily by tax revenues, and provide most services at no additional direct cost to users. public libraries obviously fit this model. most academic and school libraries obtain funding from the general budget of the institution, and provide services at no additional cost to members of their academic communities. in this sense, they can be considered public agencies, even if their funding does not come entirely from tax revenues. many special libraries are funded as part of administrative and support overhead, and their services are provided to members of the firm or organization without charge to the individual user or his/her department. again, these special libraries fit the public agency model.

private information agencies, on the other hand, can be defined as agencies that obtain their revenues from direct charges for provision of...
services. The best example is an information brokerage, in which customers pay a fee to obtain the information they require. There are other examples. Some special libraries in firms and organizations are established in such a way that the information services they provide are charged to the individual user or his/her department. In addition, there are mixed models, in which some of the agency’s revenue is public in nature, and some is attributed to fees for service.

This article focuses on the effects of treating information agencies as public agencies. A comparison of public agencies with private agencies can draw attention to some of these effects. In a private information agency, income is a direct result of the amount of business done and the price charged for services. Both the amount of business a private agency conducts and the price charged for its services depend on supply and demand. Both supply and demand are associated with the quality of the service provided, as perceived by the customer. The success of such an agency can be attributed to existence of a business plan that documents the demand for information services and the agency’s ability to supply such services. If a private information agency is providing information services that are valued by its users and if the magnitude of that perceived value is greater than or equal to the price charged for the services, the information agency will attract customers. Demand will remain at a high level and the profitability of the agency will be limited only by its ability to supply the demanded services. In essence, the nature of the services provided and the quality of the services provided are determined by market forces.

In a competitive marketplace for information services, there may be a number of marketing strategies that private information agencies will find successful. For example, a low-cost, low-quality service may fill a need, while a high-cost, high-quality service may fill an equally substantial (but different) need. The important point to note, however, is that quality of services plays a role in establishing both level of demand and price of services, and accordingly influences the success of the agency.

In a public information agency, political processes such as referenda determine the amount of the agency’s revenue. Similarly, the services to be supplied to the user community are determined (or at least strongly influenced) by political processes. It is possible, however, that political processes are (at least in part) the expression of market forces. The synthesis of political and economic theories is known as the theory of public choice. As developed by Black (1958), Arrow (1951), Buchanan (1968), and others, this theory suggests that supply and demand and the perceived quality of services provided function in public agencies through political processes. In other words, communities demand certain information services. Communities evaluate the quality of services and assess whether the value of the services received is greater than or equal to the total tax costs associated with providing those services.
This theory of public choice is plausible in the public library setting. Many public libraries each year engage in a referendum process by which their communities establish the level of funding they will receive for services provided. This "direct democracy" approach to assessing levels of public demand, and public perception of the quality of information services, is complemented by an indirect approach referred to as the Tiebout model (Tiebout, 1956). In this model, people decide the kind of community they want to live in. It might be a low-tax community with low levels of public services, or a high-tax community with higher levels of public services. As these decisions are made, populations shift and property prices reflect the public choice of the community.

The theory of public choice suggests that market forces operating through political processes influence the nature of services that will be provided by public libraries and the quality of these services. Accordingly, the services offered and the quality of those services will determine the revenue that the library will receive. Clearly, public libraries would have a great interest in establishing and maintaining a reputation for provision of high-quality library services. Such services would, according to the theory, impact the success of public funding initiatives. In addition, high-quality public library services would attract more residents to communities and drive up property values, thus creating a larger tax base from which library funding might be derived.

Although the theory of public choice is widely accepted by economists, others question whether it can effectively explain what goes on in the funding of public agencies. They point out that communities have values that may not be expressed in economic terms and that political decisions may have dimensions that cannot be translated into terms of economics. A skeptic who rejects the theory of public choice could build an alternative view of how public libraries are funded. This view might note that public library revenues depend on the willingness of citizens to be taxed and that in many instances this willingness is extremely limited. The skeptic might also note that public library information services are likely to be influenced by the articulate voices of well-organized pressure groups within their communities and that the resulting services might tend towards the uncontentious and politically correct. Once the political process identifies a service that will be offered, this service is supplied whether or not it is heavily demanded or used. Given limited revenues, libraries might adopt measures (such as overly restrictive bureaucratic rules and regulations) to discourage their user community from making use of the library's information services.

The services are perceived as being "free," because their price is masked from the view of the consumer by public (i.e., tax supported) funding of the services. It follows that the income of the information agency is not related directly either to the services provided or to the price of the services. Within certain obvious limits, the nature, quantity, and quality of library
services provided to the user community have no impact on the income of the agency. It follows that the financial incentives to provide demanded, high-quality services are limited.

Which of these two competing perspectives provides the best explanation for the relationship between public library funding and public library services? Does public demand, and public opinion about the quality of library services influence library funding? This article provides a preliminary approach to answering these questions. The hypothesis tested by this investigation was that public demand for library services and public opinion regarding the quality of library services have an effect on public library funding.

METHODS

To test the hypothesis stated above, measures of public opinion regarding public libraries and measures of levels of public library funding were required. The measure of public opinion was derived from a telephone survey prepared by Lake Research and conducted by Opinion Research Corporation in April of 1996. This survey, funded and sponsored by the Benton Foundation, provided one of the research components for the Benton Foundation’s report *Buildings, Books and Bytes* (Weiss, 1996).

The sample for this survey was 1,015 adults living in private households in the U.S. A random sampling technique was used to select the individuals contacted and the results were deemed representative of the population of the U.S. Comparison of the demographics of the sample with those of the adult population of the U.S. allowed the responses to be weighted to achieve estimates of response percentages that were not biased by age, sex, geographic characteristics, or race.

Three questions posed by the polling organization focused directly on demand for, and public opinion about, public library services. The first was:

How many times did you, yourself, go to a public library in the past year?

Would you say—

Not at all  
1–5 times  
6–10 times  
11–20 times  
21 times or more  
Don’t know.

The second question used in this investigation was:

Let us suppose that your local library needs additional funds to continue operation. Please tell me which of the following you would favor as a possible solution:

Increasing taxes to cover the necessary cost  
The library charging the people who use the library  
Reducing the services the library offers to the public.
The third public opinion question used in this investigation was:

As more and more information becomes available through computers, some people say that public libraries will change. Thinking about the future, as the use of computers continues to grow, do you think public libraries will become more important than they are now, less important, or that their importance will not change much?

More important
Less important
No change
Don't know.

Responses to these questions, used by permission of the Benton Foundation, were clearly representative of national demand for, and public opinion about, the quality of public library services. However, in this investigation, these responses were used for a different purpose: to estimate demand for, and public opinion about, the services of individual public libraries. The assumption that justified this use was that a randomly selected individual from a community is likely to reflect the attitudes of that community. This assumption is, of course, open to criticism. It would have been preferable to use samples randomly drawn from the residents of a sample of municipalities. Future research may adopt that approach. In this investigation, it was considered appropriate to use an approximation of local public opinion to provide a preliminary analysis of the effect of public opinion on library funding.

The respondents to the public opinion poll were identified only by zip code. Using the zip code, it was possible to identify the public library closest to each of the respondents. Having identified the public libraries, per-capita revenue was derived from the American Library Directory. These data were collected for 1995, the year immediately preceding the public opinion poll, and for 1999, the most recent year for which data were available.

There were, of course, a number of difficulties experienced in preparing this data set. Some poll respondents did not provide valid answers to the questions asked. The actual numbers of valid responses to the public opinion poll questions are given in Table 1.

In some instances, it was not possible to identify the local public library serving a poll respondent. There are, for example, substantial areas unserved by public libraries in a number of states. In other cases, the data provided in the American Library Directory was incomplete. Some libraries provided data in the 1995 directory, but were absent from the 1999 direct-

<table>
<thead>
<tr>
<th>Table 1. Numbers of Responses to Poll Questions.</th>
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<tbody>
<tr>
<td>Self-reported number of library visits</td>
</tr>
<tr>
<td>Preference for source of future library funding</td>
</tr>
<tr>
<td>Opinion on future importance of libraries</td>
</tr>
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</table>
tory, and vice versa. The actual numbers of libraries for which financial data were found are given in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Numbers of Libraries For Which Financial Data Were Found.</th>
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<tbody>
<tr>
<td>Per-capita income 1995</td>
</tr>
<tr>
<td>Per-capita income 1999</td>
</tr>
<tr>
<td>Change in per-capita income</td>
</tr>
</tbody>
</table>

Taking into account all of the data available from the above sources, a data set was created that contained 440 unique cases of public opinion responses paired with financial data from the local public library that served the public opinion respondent. The following analysis was based on that set of 440 cases.

**FINDINGS**

Based on the data set of 440 cases, the following summary statistics were derived from the public opinion data. Table 3 reports the responses regarding the self-reported number of library visits.

Table 4 reports the responses regarding the preferred sources for future library funding.

Table 5 reports respondents' views about the future importance of the public library in an era of technological change.

The summary statistics for per capita public library revenues derived from the 440 cases in the data set are given in Table 6.

The objective of this research was to investigate the association of public opinion with public library funding. To test the association of the number of self-reported library visits with library funding, a Spearman's rank-order correlation was used. The results are given in Table 7.

To test the association of preferred future sources of library funding with library funding, ANOVA was used. In no case was there a significant effect of public opinion responses on actual funding levels. For 1995 reve-

<table>
<thead>
<tr>
<th>Table 3. Reported Number of Library Visits in the Past Year.</th>
</tr>
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<tbody>
<tr>
<td>Number of Respondents</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Not at all</td>
</tr>
<tr>
<td>1-5 times</td>
</tr>
<tr>
<td>6-10 times</td>
</tr>
<tr>
<td>11-20 times</td>
</tr>
<tr>
<td>21 times or more</td>
</tr>
<tr>
<td>Total</td>
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</table>
Table 4. Preferred Future Sources for Library Funding.

<table>
<thead>
<tr>
<th>Source of Funding</th>
<th>Number of Respondents</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing taxes to cover the necessary cost</td>
<td>206</td>
<td>46.8</td>
</tr>
<tr>
<td>The library charging the people who use the library</td>
<td>189</td>
<td>43.0</td>
</tr>
<tr>
<td>Reducing the services the library offers to the public</td>
<td>45</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Table 5. Future Importance of the Public Library.

<table>
<thead>
<tr>
<th>Importance Level</th>
<th>Number of Respondents</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>More important</td>
<td>158</td>
<td>35.9</td>
</tr>
<tr>
<td>Less important</td>
<td>90</td>
<td>20.5</td>
</tr>
<tr>
<td>No change</td>
<td>183</td>
<td>41.6</td>
</tr>
<tr>
<td>Don't know</td>
<td>9</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 6. Public Library Per Capita Revenues.

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>$24.21 $0.4</td>
<td>$897.27</td>
</tr>
<tr>
<td>1999</td>
<td>$33.55 $0.2</td>
<td>$1,314.65</td>
</tr>
<tr>
<td>Change from 1995 to 1999</td>
<td>$9.34 $-59.68</td>
<td>$417.38</td>
</tr>
</tbody>
</table>

Table 7. Association of Number of Library Visits with Library Revenues.

<table>
<thead>
<tr>
<th></th>
<th>Per-Capita Revenue 1995</th>
<th>Per-Capita Revenue 1999</th>
<th>Change from 1995 to 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library visits</td>
<td>R = .1412, p &lt; .01</td>
<td>R = .1171, p &lt; .02</td>
<td>R = .0214, p &gt; .65</td>
</tr>
</tbody>
</table>

To test the association of perceived future importance of the library, ANOVA was used. In no case was there a significant effect of public opinion responses on actual funding levels. For 1995 revenue, F(2,437) = 1.1937, p > .3; for 1999 revenue, F(2,437) = .855, p > .42; for revenue change, F(2,437) = .3981, p > .67. Table 8 presents the average levels of public library funding for libraries whose patrons responded in different ways on the public opinion poll.
F(2,428) = .1.062, p > .34. Table 9 presents the average levels of public library funding for libraries whose patrons responded in different ways on the public opinion poll.

Table 8. Public Library Funding Levels, Categorized According to Poll Responses.

<table>
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<tbody>
<tr>
<td>Per-capita revenues 1995</td>
<td>$28.53</td>
<td>$20.50</td>
</tr>
<tr>
<td>Per-capital revenues 1999</td>
<td>$38.76</td>
<td>$29.90</td>
</tr>
<tr>
<td>Change from 1995 to 1999</td>
<td>$10.23</td>
<td>$9.40</td>
</tr>
</tbody>
</table>

Table 9. Public Library Funding Levels, Categorized According to Poll Responses.

<table>
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</thead>
<tbody>
<tr>
<td>Per-capita revenues 1995</td>
<td>$23.26</td>
<td>$20.80</td>
</tr>
<tr>
<td>Per-capital revenues 1999</td>
<td>$29.33</td>
<td>$32.31</td>
</tr>
<tr>
<td>Change from 1995 to 1999</td>
<td>$6.07</td>
<td>$11.51</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Demand for library services, as represented in this investigation by the self-reported number of library visits in the past year, had only a modest association with public library funding. Demand for library services had the largest association with current year revenue. Yet, even in this strongest case, the correlation was only R = .1412. This correlation is the equivalent of a coefficient of determination (r²) of .0199. In other words, less than 2 percent of the variation in library funding could be accounted for by demand for library services. The association of demand for services with subsequent library funding was even more tenuous. The correlation of R = .1171 is the equivalent of a coefficient of determination of .0137. Only slightly more than 1 percent of the variation in per-capita public library funding could be accounted for by previous levels of demand. There was no association of funding level changes with demand for library services.
Proponents of the public choice theory might argue that these modest levels of association between demand for library services and library funding support the influence of public demand on levels of service provided, and on the price of those services. However, other interpretations of these findings are possible. Perhaps higher levels of demand are generated by higher-quality services. In other words, the public may be viewed as reacting to political choices regarding library funding rather than influencing these choices. In any case, the magnitude of the association between demand and funding is so small that differences in interpretation are moot.

Other measures of public opinion regarding library services had no influence on public library funding. It is particularly noteworthy that libraries whose patrons, as represented by poll respondents, supported additional taxes to support library services did not receive a significantly higher level of revenues than other libraries. This result would seem to reflect an important lack of connection between public opinion about library funding and actual levels of library funding.

Perceived quality of library services is an equally important aspect of public opinion about libraries. In this research, perceived quality was best represented by respondents' opinions about the future importance of public libraries. Yet, this variable had no association with levels of library funding. Again, these results provide no support for the theory of public choice as applied to public library services.

These results should be taken as preliminary in nature. A full exploration of the place of public opinion in influencing public library funding would require larger-scale data collection that would include variables that reflect both the quality of the libraries and the services offered, and the political and economic contexts in which the libraries operate. Such a multivariate model would indicate the extent to which quality and demand for services are reflected in a variety of measures of library funding and performance.

**Conclusions**

In the private sector, demand for services and perceived quality of those services have a direct impact on the provision of services and on the price of those services. It would be nice to think that public libraries could generate higher levels of revenues by providing services that generate high demand and that are perceived as being of high quality. The theory of public choice provides a mechanism through which levels of demand and of positive public opinion can be expected to generate higher levels of revenue for public libraries.

Unfortunately, the theory of public choice was not supported in this study. Rather, it appears that higher levels of demand have very little influence on funding levels. In addition, positive public opinion about library
services appears to have no impact on public library funding. These results will probably not surprise many public librarians. They know that political decisions regarding levels of funding are always complex. It may not be enough for the library to be providing good services if other equally good services are deemed to have higher priority in funding. Higher levels of demand may be met with demands for increased cost-effectiveness rather than with higher levels of funding. In many instances, increased public library funding has been achieved through strenuous community protests, rather than through good public opinion. Further, the lack of concern about generating additional demand or being perceived as providing notoriously poor service may be taken as hallmarks of many tax-supported public agencies, and librarians might be forgiven for wondering why their agency should be different.

At the same time, public librarians have a professional commitment to providing high-quality information services to their communities. There may well be intrinsic rewards associated with providing programs and services that are demanded by patrons and in responding promptly and effectively to information needs. But the apparently minimal association between these activities and the levels of funding provided to support these activities can be disappointing. Some may wish to argue that these considerations should provide impetus for privatizing and diversifying information services. However, these findings are too preliminary in nature to support such arguments. This study was intended to provide an initial glimpse at the association between public opinion and public library funding. Additional studies must explore this association further before firm conclusions can be drawn.

REFERENCES
Measuring Outcomes: Applying Cost-Benefit Analysis to Middle-Sized and Smaller Public Libraries

GLEN E. HOLT AND DONALD ELLIOTT

ABSTRACT
THE RECENT DEMAND FOR MORE ACCOUNTABILITY from public libraries has made it essential that true cost-benefit analysis be applied to their operations. With funding from the Public Library Association, the authors developed a cost-benefit analysis methodology and applied it to five large public library systems. The present article describes their ongoing research to modify their methodologies to make them viable for application to public libraries of much smaller size.

OUTCOMES MEASUREMENT IN PUBLIC LIBRARIES
Like it or not, American public libraries have entered the age of accountability. This shift is transforming library statistics and measurements—what statistics are gathered, how they are gathered, and how they are interpreted and applied. To put the matter simply, library assessment, like public school assessment and higher education accreditation, is shifting from measuring outputs to measuring outcomes. The shift marks a transformation in viewpoint. Input-output measurement methodology—the established system of library accounting—follows an industrial production model. The library represents a black box. On one side of the black box, boards and administrators drop in “inputs,” including financial resources to purchase staff, materials, and support services. From the other side of the box emerge “outputs,” which find their principal expression in raw or adjusted counts of circulation and visitation. A whole reportorial culture emerged to address library inputs and outputs. A few professors gained considerable reputation by defining appropriate inputs and outputs

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State libraries hired staff whose principal tasks were (and are) to collect library input and output statistics, ensure their internal consistency, and pass them to officials at the state and federal level. The federal government set up a section in the Department of Education (DOE) to gather the state compilations and turn the forwarded statistics into an annual publication that belatedly aggregated inputs and outputs.\(^1\)

Meanwhile, the Public Library Data Service (PLDS) collected its own sets of input and output statistics using categories and presentation tables often different from DOE (Public Library Association, 2001). Two input-output reporting families now lived side by side, and, because of their different methods for parsing the library world, the two sets of measurements intersected and supported each other only incidentally. Within the framework of input-output statistics, the libraries that circulate the most books and count the most visitors while spending the least amount of money per circulation and visitor are "the best libraries." Implicit in this measurement is the notion that all circulations and all visitations are equal, and that the largest numbers produced at the lowest costs represent hallmarks of efficiency and even quality. Intriguingly, this point of view did not have its strongest exponent until after a decade of life in the networked-computer Information Age and years after civic and political leaders were pushing public libraries to exercise many nontraditional service roles to improve the quality of life in their constituent cultures (Hennen, 2002). Hardly any of these service innovations, however, found their way into traditional counting mechanisms.

The difficulty with these statistical appliances is that they measure what libraries do, not the benefits their constituents derive from them. Politicians, taxpayers, and major donors care about how much the public benefits from the resources provided to libraries, not how many volumes circulated during the last month. When it comes to outcomes, all circulations are not equal (e.g., some represent reading; others represent browsing to find something to read). All visitations do not represent equal consumption of services or equal value to the library customer (e.g., stopping by to use the restroom or copier represents a different benefit from that derived by the prospective entrepreneur whom staff help to get the statistics needed to start a new business). In the age of public-sector accountability, these differences raise questions: What is the worth of a library in the networked-computer age? How do shifts in use patterns reflect changes in customers' valuations of library services, and how would customers prefer that library resources be added or reallocated? What benefits are conferred on different types of library customers by their variant uses of public libraries? And, how can those benefits be measured?

At least two different professional groups in the year 2000 organized meetings that mark a growing trend toward moving library measurement
culture from outputs toward outcomes. The first of these was a gathering of invited participants at a February 2001 conference hosted by the National Information Standards Organization (NISO). The subject was “Issues for Libraries: Measuring the Information Age (NISO, 2001).” Hampered by hideous weather and the seasonal flu bug that deterred travel by many scheduled participants, this conference addressed how networked computing was changing libraries and how library measurements had to change because of this shift. Along with standards, best practices, and electronic service measures, outcome measures played a prominent role in the conference agenda. Participants left Washington, DC, with examples of several different projects that were attempting to measure service outcomes or benefits. One of these was the St. Louis Public Library cost-benefits methodology. The second meeting was a gathering of recipients of fall-2000 grants made by the Institute of Museum and Library Services (IMLS) (2000). The meeting began with the statement of the meeting’s legal context: the passage of the Government Performance and Results Act (1993). This legislation required “every government agency to establish specific performance goals for each of its programs, preferably with performance indicators stated in objective, quantitative and measurable terms (Shepherd, 2000).” Following the mandate of this legislation, IMLS consultants helped grant recipients devise strategies and methodologies by which they would measure the impact and/or benefits of the federal funds they were receiving. A revision of this seminar was repeated in the fall of 2001 for that year’s grant recipients. (Even the granting agencies have entered the age of accountability. Can foundations and charitable trusts be far behind?) Neither the NISO conference nor the IMLS training advocated a dismissal of library input-output measurements. Nor do the authors of this paper. Like other advocates of outcome-based measurement, however, they do believe that the library community can build a strong case for its continued economic legitimacy by measuring the benefits that libraries provide their constituents (Weil, 2000; Rudd, 2000). The social sciences provide a number of these outcome-based measurements. Cost-benefit analysis (CBA) is one of these measurements. CBA has been used by economists to measure the benefits of education, pollution control, and locks and dams—to name only a few applications. The St. Louis CBA project applies the tool to measure library outcomes.

**The First CBA Project (CBA I), 2000—2001**

Responding to a call from large urban library directors and the push of the St. Louis Library Board to “Prove it” (no matter what “it” was), the authors of this paper set out in the mid-1990s to measure the value of public library services. The purpose of this project was to develop a conservative, transportable methodology that large urban libraries could adapt to their own institutional settings. In making estimates of this value, the St. Louis
Public Library researchers utilized the economics-measurement tool of cost-benefit analysis (CBA). With funding from the Public Library Association, the researchers tested the application of this methodology on the operations of the St. Louis Public Library (SLPL). This study demonstrated the feasibility of using CBA to measure library service outcomes. Next, with a grant from IMLS, the SLPL researchers refined the methodology and applied it to four additional library systems: Baltimore County Library System, Birmingham Public Library, Phoenix Public Library, and King County (Seattle) Public Library. They also replicated the earlier study of St. Louis Public Library. The study demonstrated the robustness and sensitivity of CBA methodology in the library setting. The methodology’s reliability could be seen when the reanalysis of St. Louis produced results for general users that were comparable with the earlier study. The sensitivity could be seen when the study showed its ability to detect substantial differences in valuation among libraries based not only on service consumption but also on constituent demographics and ability to pay (Holt, Elliott, Watts, & Holt, 2000).

LAUNCHING CBA II

With these successes, the St. Louis researchers have set out to apply the same methodology to middle-sized and smaller libraries. This study, which the researchers call CBA II, will proceed through 2002 and 2003. The project replicates many of the first project’s goals and adds others as well.

Replication

Like the first study of large urban libraries, this project is designed to develop, apply, and disseminate a methodology to value and communicate the economic benefits of library services, this time in mid-sized and smaller public libraries. Mid-sized and smaller public libraries are those with population services areas ranging from 50,000 to 150,000.

Adaptability

Adaptability is central to this project. In CBA II, the primary goal is to adapt the large-library study methodology to the often very different mission and variant funding of mid-sized and smaller libraries. To ensure institutional adaptability of the methodology, it will be developed in concert with nine very different mid-sized and smaller libraries located in three states in different regions of the United States. After development, the methodology will be tested at each of the nine libraries. The result will be an adaptable, conservative, transportable methodology that will meet the policy needs and cost constraints of mid-sized and smaller libraries.

Research Design

The project will have two phases. In 2002, the researchers will work with nine institutions in three states to develop and test a practical, conservative, cost-feasible, transportable methodology that mid-sized and smaller urban
libraries can use to estimate the value (i.e., the direct return on annual taxpayer investment) provided by their individual organizations. Through 2003, the researchers will disseminate the valuation methodology (i.e., what it is, how it was developed, how individual institutions can undertake their own valuations, and how they can use the tool to communicate their value in the community) through paper and electronic publications, conference presentations, and delivery of training.

Service/User Matrix

After selection of the institutional participants, researchers will meet with the nine test-site libraries to discuss their mission statements and to categorize their library services and users into a service/user matrix. This matrix makes explicit the relationships among the components of a typical library's mission. By identifying major classes of a library's customers (e.g., households, educators, etc.) the matrix is customer-focused. By arraying customers against the library's portfolio of services (e.g., reference and reader's advisory, adult materials, children's materials, etc.) a library's service and user categories become visually explicit. Each of the cells of the matrix represents a stream of benefits from a library service to a particular class of customer.

When arrayed in this way, the matrix becomes the basis for a series of value measurements focusing on how much of which services the library's customers use and customers' valuation of the services. These measurements rely on customer responses in a telephone interview based on the benefit methodologies described below. A simple library service/user matrix and the matrix's explanation can be found in Holt, Elliott, & Dussold's "Framework" (1996). As with other aspects of this study, the service/user matrix is designed conservatively. By intent, some worthwhile but hard-to-measure functions (e.g., the library as a safe place for children, as a neighborhood center, or as a family recreational center) will be ignored. Such benefits are so hard to value that such contestable estimates would obscure the primary focus of the study. The large-library project demonstrated for five major libraries that measurable direct benefits were more than sufficient to prove the libraries' value to their communities. If so, why add explicit suspect measurements to the value-estimating formulae? Furthermore, a major thrust of the CBA II project is to reduce the cost of the methodology so that it is affordable for a much wider range of libraries to use. To reduce the cost of the survey, the measurements in CBA II will omit minor services as well as separately reported benefits to small specialized user groups that were included in CBA I. The service categories and user groups that will be dropped are less important in mid-sized or smaller libraries.

Measurement of Direct versus Indirect Benefits

Benefits can be classified as direct or indirect, individual or collective. Users of library services receive benefits directly, such as the recreational enjoyment from reading a novel or the strategic advantage enjoyed by a
business that researches a new market for its products. Libraries provide many indirect benefits also. Enhanced reading skills of a young participant in a summer reading program may be passed on to her progeny. The community as a whole may benefit from a more informed electorate. Individual users can cite specific benefits that accrue to them through the use of specific library services. For example, a household that checks out and views a video receives direct and individual benefits. Collective benefits accrue to all members of the neighborhood, however, if the very presence of the local library or library branch instills a shared sense of community and pride. Recognizing this difference, this study will estimate a lower bound of the value of library services by focusing on the direct individual benefits provided by the library. To establish this lower bound, the project design focuses on creating a transportable model for estimating direct benefits provided by mid-sized and smaller libraries. The explicit calculation of indirect or collective benefits to nonusers is excluded from the study design.

Multiple Estimations of Benefits to Produce a Conservative Range of Benefits

Using sample surveys, this study will employ two methods of contingent valuation to estimate direct benefits to patrons from using library services. One is a service-by-service approach using the economist’s tool “consumer surplus.” The other approach measures the value of the library as a whole through users’ “willingness to pay.”

Consumer surplus will be used to measure the value that library users place on separately valued library services. Consumer surplus measures the value that consumers place on the consumption of a good or service in excess of what they must pay to get it. Although library services typically are “free,” many substitutes for library services are available in the marketplace. For example, library users can buy novels rather than borrow them from the library’s collections. The willingness of library users to purchase such substitutes if the library service were not available is one indicator of the value that the user places on the particular library service. Such estimates can be made for each service used by each library customer surveyed. These calculations can be summed to provide an estimate of total direct annual benefits for all library users measured in dollars. This approach offers several merits. Respondents are comfortable with the queries’ scenario: most households are accustomed to (or have at least considered) purchasing books, newspapers, magazines, encyclopedias, or even Internet service. Most do not hesitate to respond about what additional purchases they would make if necessary to replace most library services (with the possible exception of staff help). For the library that wishes insight into the comparative contributions of different services, this approach offers a well-grounded method for obtaining detailed estimates. In CBA II queries, the researchers plan to vary the order of services randomly and provide respondents with a running total of their announced purchases to enhance the validity of these estimates.
Contingent valuation measures, though controversial, have been used extensively, even in high-stakes judicial proceedings, to value environmental conditions. The Exxon Valdez damage suit and Superfund (CERCLA) litigation have employed estimates using contingent valuation. Contingent valuation requires a respondent to value a scenario depicting a counterfactual state of the world relative to the existing state of the world. Two alternative approaches are described in the economics literature. In the willingness-to-pay approach (WTP), interviewers ask respondents how much they would be willing to pay to have something that they currently do not have. In the willingness-to-accept approach (WTA), interviewers ask respondents how much they would accept to give up something that they already have. Typically, WTA estimates of benefits are considerably higher than WTP estimates. Also, most experts view WTA estimates as less reliable. In CBA I, interviewers asked respondents how much they would accept to vote to close their public library. The WTA responses were consistent with the literature in that the WTA estimate for those who did respond was much higher than the WTP estimate. More importantly, over 80 percent of household respondents at each of the five sites refused to answer the WTA question. The method provided no reliable quantitative measure of the value of library services at any of the five study sites. Probes of WTA refusals, however, provided exceptionally insightful anecdotal comments regarding cardholders’ views of the library as an irreplaceable community asset. WTA will be dropped in CBA II, however, saving both time and money. In CBA I, WTP produced the most conservative estimates of value and had a consistently small refusal rate. As in the large-library study, the CBA II study will ask library patrons how much they would be willing to pay rather than forego library usage or, if libraries did not exist, how much they would pay (in taxes) to enjoy the library privileges they have today.

Project Objectives

The two major project goals will be accomplished by working through six measurable objectives. These are to:

1) Modify the analytical framework (service user matrix) and survey instrument from CBA I to address the major services and user group(s) that characterize mid-sized and smaller public libraries.

a. Reduce the number of services investigated in the earlier instrument. Focus on those emphasized by smaller libraries and those that produced the greatest contribution to benefits in the earlier large-library study. This step will reduce the length of the survey and cost per respondent completing the survey.

b. Restrict survey queries to provide benefit estimates for consumer surplus and willingness-to-pay approaches. Eliminate willingness-to-accept and value-of-time methods of measuring benefits.

c. Reduce the number of user groups by querying only general users
(households) and, possibly teachers. Eliminate service providers and business users as targeted survey subpopulations. These subpopulations are likely to be too small to add substantially to the public’s valuation of smaller libraries. Focusing on general users and not reporting separate estimates for benefits related to teachers will reduce the number of survey completions required for reliable statistical inference by two-thirds. This change will cut the cost of each library survey.

2) Develop and test programming applicable to most PC software systems that will embed the survey instrument, check for response validity, create a database of responses, and perform most of the calculations that will estimate a lower bound for a library’s annual benefits.
   a. Development of such computer software will substantially reduce the consulting cost to individual libraries in producing benefit estimates from the surveys.
   b. Successful accomplishment of objectives 1 and 2 should permit an individual library to implement the methodology in a statistically valid manner for about $15,000 in external costs ($10,000 in survey costs plus $5,000 in other costs). In contrast, the very comprehensive version like that undertaken in the large-library study might be expected to cost, say, $40,000 ($30,000 in survey costs plus $10,000 in other costs).

3) Demonstrate the methodology for nine mid-sized or smaller libraries (three in each of three states) by completing 500 or more telephone interviews with patrons drawn in a random sample from the active cardholder database for each library.

4) Report results to the participating libraries. Assist them in interpreting the results and communicating those results to internal and external constituencies.

5) Evaluate the demonstration in achieving the following outcomes:
   a. Reduction in cost to apply the methodology to an individual library so that the methodology is affordable for a wide range of mid-sized and smaller public libraries.
   b. Provision of a conservative, meaningful lower bound for benefits and return to taxpayer investment in each library.

6) Disseminate the methodology to other mid-sized and smaller libraries. Develop a training model by which other public libraries may learn about and apply the transportable valuation methodology to estimate their own returns on taxpayer investment.

**IMPACT WITHIN ORGANIZATIONS AND ACROSS ORGANIZATIONS**

Successful accomplishment of the project goals and objectives outlined above will permit mid-sized and smaller urban libraries to engage in cost-benefit studies. As demonstrated in the large-library study, a library’s exe-
ution of such a cost-benefit analysis can impact substantially the institution’s management practices and external relations. Participants in the large libraries’ CBA I study reported the following:

- The construction of the service user matrix leads library personnel to a greater understanding and appreciation of the library and its services from a customer perspective.
- The results of a CBA study help board members and administrators see the relationship between the socioeconomic characteristics of communities and the value they place on library access and service.
- The results of the cost-benefit study help executive directors make more informed budgetary decisions. The study informs resource allocation by quantifying the benefits of particular services for comparison against their costs.
- The results of the cost-benefit study are informative to library staff, help to boost staff morale by demonstrating the value of the library to the community, and impress upon executive directors and administrators the importance of staff training to effective customer service.
- The results of the cost-benefit study are very valuable to the library in its external public relations. The study quantifies the library’s value to the community in a manner that is persuasive to external audiences such as local governments, donors and foundations, and taxpayers.
- The concept of the return on taxpayer investment that is part of the study implicitly incorporates the opportunity to assess the benefits of private-public financial partnerships. Private-sector gift-and-grant programs magnify library service benefits to local patrons beyond those paid for by taxes.
- In some cases, participation in the cost-benefit study may cause the library to reevaluate the effectiveness of its practices in maintaining its cardholder database. Unless cardholding records are updated annually, they do not reflect the library’s actual user membership.

The applicability of the proposed methodology to other educational and cultural institutions is an open question. The central building blocks of the methodology all appear to be applicable to other publicly supported institutions, such as museums or performance arts organizations. The use of a matrix to display mission as an array of services versus subgroups of users is appropriate to a variety of public service venues. Contingent valuation as a means of estimating benefits is also widely applicable. The use of consumer surplus is more problematic, as there may not be readily available market substitutes for services of some public institutions. Return on taxpayer investment and return on invested capital are easily applied to almost any publicly supported institution. Nevertheless, the project’s first purpose is to refine and demonstrate the methodology in the context of mid-sized
and smaller libraries. The methodology may be extended at a later date to serve other institutions, including museums and historical societies.

Steps in Project Research

Each step of the CBA II work plan outlined below follows the project’s research objectives:

1) Construct matrices of patrons and services for each participating library based on the library’s mission. In meetings with the administrative staffs of each of the nine test-site libraries, the researchers will facilitate the classification of library services and patrons into major categories.

2) Consolidate the matrices from the nine libraries into a common framework. Staff from each of the libraries will critique the common framework to ensure its applicability to each of the individual libraries.

3) Design survey instruments, develop interviewing software, and select samples of library patrons to estimate benefits for each of the libraries by using measures of consumer surplus and contingent valuation (WTP). Since the research plan replicates many elements of the large-library study, a comparison of consistency in measuring bigger and smaller systems can be accomplished.

4) Ensure compliance with human-subject guidelines. All research will be conducted in conformity with Federal guidelines for human subject research as applied by the Human Subjects Research Committee at Southern Illinois University at Edwardsville; in compliance with all appropriate state laws protecting the privacy of library transactions; and the highest standards for user privacy articulated in the principles documents of the American Library Association.

5) Complete 4,500 telephone surveys, 500 for each test-site library. This process has several steps. First, computer services staff at each of the nine sites will draw a random sample of 2,500 cardholders who have used their cards within the last twelve months. Second, the director of each library will send a personal letter to each of these cardholders inviting their participation in the survey. Third, university telephone interviewers, trained by the project staff to use the project’s survey instrument, will call those who have not declined the invitation to participate. A sample of 500 completed interviews will allow the extrapolation of sample statistical results to estimate the benefits to all cardholders from the tax investment of each public library.

6) The principal researcher, Dr. Holt, and the project’s principal consultant, Professor Elliott, will write the project report. Prior to any public announcement, the results of the survey will be shared with the directors and participating staff of each library.

7) Develop executive summaries and visual aids for each library that convey clearly, but simply, the conclusions of the study.
The researchers will ask the director of each of the participating libraries to complete an assessment form that evaluates the project and its products. They will be asked to make this assessment based on the project's value as a managerial tool for understanding and communicating the mission of their library, informing budget decisions and strategic planning, and assisting communications with constituencies and the general public. Directors and test-site library staffs also will assess the project and products for cost, practicality, and transportability.

St. Louis Public Library project staff will host a post-project workshop to disseminate the methodology developed in this study to the staff of test-site libraries. Funds from the grant will support the instruction and materials for the workshop.

Participants in the post-project workshop will evaluate the applicability of the methodology to their own libraries and how the materials might be modified to make it easier for other libraries to use them. Several months after the conference, participants will respond to surveys asking whether they have plans to implement the methodology and, if so, when, how, and the expected use of the results.

The principal researcher and the project's principal consultant will prepare articles for electronic and paper publication and solicit appearances at national conferences.

**Anticipated Findings from CBA II**

The methodology of the second (current) study is very similar to that of CBA I. In this section of the paper, the authors report the findings from the first study and suggest differences and similarities in findings they expect in CBA II.

1) CBA I clarified the usefulness of recognized CBA methods of contingent valuation as a basis for calculating a dollar estimate for all five cities. The contingent-valuation methodology is clearly applicable in a large public library setting. The study demonstrated that cost-benefit methodology is a tool well adapted to measuring the direct benefits of library services. The successful application of CBA methodology in the first project will allow the researchers in CBA II to make applications of the methodologies to nine libraries with a greater income range and greater variation in services than was accomplished in CBA I. The researchers expect the methodology to hold up but the range of benefits to vary considerably.

2) Recognizable methods of cost-benefit analysis used in many other kinds of CBA studies were used to measure the direct benefits of library services to each class of patrons. Using data obtained during twenty-five-minute user surveys, the project team calculated direct benefits for general users, teachers, and business users. In carrying out CBA II, the researchers will calculate benefits only for general users and using tele-
phone surveys considerably shorter than twenty-five minutes. The benefits will be stated even more conservatively than in CBA I, but the methodology will be less expensive to apply.

3) When subjected to standard statistical tests for reliability, the study proved to be reasonably valid and reliable. The tests indicated that the survey produced a replicable valuation of services based on voluntary responses by those surveyed. The research team expects CBA II results to be statistically valid and reliable.

4) Based upon their answers to similar questions, the study demonstrated that different user groups receive different levels of benefits from library expenditures. The general user was asked consumer-surplus (CS), willingness-to-pay (WTP), and willingness-to-accept (WTA) questions. Teachers were asked about their professional use of the library with consumer-surplus and willingness-to-accept questions. Business users were also asked consumer-surplus and willingness-to-accept questions. The researchers also initially attempted to query caregivers. Anticipating that the representation of business users and caregivers would be even smaller than in CBA I and to reduce survey costs, CBA II researchers made the decision to focus on general users without reporting separate results for other special subpopulations of cardholders.

5) As in CBA I, the conclusions of CBA II will be defensibly conservative.
   a. The study will capture benefits to cardholders only. No benefit estimation will be attempted for walk-in or virtual visitors who did not hold cards.
Annual local taxes spent for library operations yield substantial direct benefits. Each library returns more than $1 of benefits for each $1 of annual taxes. In the first study, SLPL returned more than $2.50 in benefits per tax dollar; Baltimore County Public Library returned more than $3 in benefits per tax dollar; Birmingham Public Library returned at least $1.30 in benefits per tax dollar; Phoenix Public Library returned over $10 in benefits per tax dollar; and King County Library System returned more than $5 in benefits per tax dollar.

CBA researchers do not yet have sufficient data to anticipate the benefits return for any particular library or library type in CBA II.

Each library studied in CBA I yielded a good annual return on invested capital. SLPL returns a minimum of 22 percent; Baltimore County Public Library returns a minimum of 72 percent; Birmingham Public Library returns a minimum of 5 percent; Phoenix Public Library returns over 150 percent; and King County Library System returns a minimum of 94 percent.

a. Shortly after completing the IMLS CBA study and before publicizing its results, Phoenix Public Library participated in a city-wide bond referendum that will expand its capital assets by 20 percent over five years. The referendum passed with more than 75 percent of voter support. The overwhelming strength of this majority confirms the public's (and cardholders') perception of the high social rate of return to the public's investment in library assets, consistent with the results of the CBA study.

b. The measurement of return on invested capital and return on annual taxpayer investment are both summarized in the seminar casebook, Libraries Are Valuable...Prove It (Holt, Elliott, Watts, & Holt, 2000).

The methodology of CBA I detected differences in benefit streams flowing from different levels of investment. The CBA methodology is sufficiently fine-grained to detect differences in levels of benefits that flow from different levels of support for various areas of library activity. St. Louis Public, for example, had higher levels of benefits from children's services than did King County, which invests a lower percentage of its annual taxpayer investment in youth services. Not surprisingly, differences in cardholder subpopulations (e.g., households, teachers, business users, etc.) in different systems also affect CBA outcomes. Even without the study of library user groups like teachers and business, the CBA II researchers expect that different-sized benefits streams will flow from different levels of investment by the study-site libraries.

In spite of these differences in benefit streams, consistency proved to be the theme of the benefit levels of the studies, especially when calculations were made for categories of library services. In the case of all five libraries, when benefits were calculated, they did so in the follow-
ing order: 1) Materials for adults, on average 35 percent; 2) staff inter-
actions, on average 30 percent; 3) materials for children, on average 20 percent; and 4) library technology, on average 15 percent. Of these, the most problematical was technology, because comments that those surveyed made during their exchanges with interviewers often indicted that they were placing technology benefits implicitly into other categories (e.g., electronic newspaper and magazine databases were thought of as adult materials, not technology). In CBA II, the researchers expect the same consistencies as discovered in the first study.

10) CBA has considerable value as a communications tool. Not unexpectedly, the first persons to utilize the CBA findings were the directors of the systems in which the economic analysis was accomplished. They addressed the CBA findings to diverse audiences. Some used the results to orient staff to the value of their work. Others used them to communicate with individual donors or to the general public through publicity releases (Holt, Elliott, Watts, & Holt, 2000, Sections 2 and 4).

11) Quality of library databases is critical for successful completion of the survey. The most problematical element in the first study was the quality of library-user databases. No library that has not taken considerable care in creating or maintaining its user database should undertake a CBA study of the type described in this report. These techniques require random sampling of an accurate census of active library cardholders. The database used to generate the census must be up-to-date to avoid low response rates and response bias in completing the telephone surveys. In several of the study sites, missing or outdated telephone numbers in cardholder fields lowered the completion rates, and, in other cases, the researchers had to ask that the participating library systems obtain missing telephone data for cardholders before the telephone surveys could be started.

12) Population demographics can affect survey outcome. Phoenix, known for its seasonal residents and diverse ethnicity, presented this study’s most serious challenge in implementing the survey design.
   a. Approximately 30 percent of the cardholders who were active at some time during the previous twelve months had moved or changed phone numbers.
   b. The response rate to an April survey of general users in Phoenix was only 18 percent. Data for the general user survey were weighted in proportion to the frequencies of cardholders by library branch to correct for any possible response bias.
   c. Phoenix households were surveyed again in October to obtain statistically adequate samples of teachers and business users. The response rate again was only 18 percent. To obtain a sufficient number of educator responses, a list of Phoenix public school teachers was matched against a sample of Phoenix cardholders.
In CBA II, researchers will exercise the advantage of the 2000 census reports that will make demographic patterns easier to determine. They still recognize demographic differences as a primary factor in CBA outcomes.

13) At the end of CBA I, the study team cautioned against comparing the benefit estimates across the five libraries studied. The benefit measures are designed conservatively to provide a defensible lower bound to the annual benefits of each library, not an unbiased estimate of each library's annual benefits. For this reason, comparisons across libraries are fraught with problems.

14) Nevertheless, some observations were apparent. For example, average or median family disposable income is correlated with benefits per household across cities: suburban King County and Baltimore County households reported higher benefits per household than the central cities of Birmingham, Phoenix, and St. Louis.

15) With sufficient information, it is possible to measure the nature and extent of economic benefits received by each class of patron for each type of service used. Classes of patrons can be identified by cardholder type and/or by self-identification. No matter what are the means of differentiation, care has to be taken because user types tend to overlap. In CBA II, however, to reduce survey costs for smaller libraries, the survey design will not identify separate classes of users and no such comparisons among user groups will appear.

16) Some CBA measures are more useful than others. As the CBA literature predicts for the whole range of activities, consumer-surplus and willingness-to-pay benefits estimates of library services were more accurate than willingness-to-accept measurements. The researchers also found that the cost-of-time measure that had been considered at the beginning of the project was less useful than other CBA study methods. This methodology, therefore, was not reported in the study results. It will not be included in the CBA II study.

17) CBA I measured the benefits from both public and private dollars. Return on taxpayer investment calculations, in addition to tax-dollar benefits, can assess the benefits of private contributions, foundation grants, and grants from different levels of government. This measure will not change in CBA II.

18) The study produced a replicable methodology, but one that is not without high expense. The biggest expense was the cost of surveys, and this expense was based on the amount of detail that the research team was attempting to capture. Based upon the experience in this project, the researchers recognize that they need less detail to produce reliable results. The costs of future CBA studies at smaller, less complex library systems therefore can be reduced.
CBA AS AN OUTCOME MEASUREMENT

The CBA II research team anticipates that many of the outcome relationships identified in the previous study will hold true in the new study. If these findings do hold up, then the research team will have applied cost-benefit analysis to fourteen different public libraries, large, medium-sized, and smaller, in eight different states. The study already has been replicated successfully when the initial PLA-funded case study was replicated in the first multilibrary IMLS-funded study. Furthermore, the CBA II team expects to be able to conduct the middle-sized and smaller library research far more cheaply per site than the large library study. From a cost standpoint, this project should bring the measurement methodology into the budget range of many more institutions than was possible using the methodology developed in CBA I. Admittedly, CBA II will not measure all of the benefits that libraries confer directly upon all classes of users. The original intention, however, was not to find every benefit but to estimate a conservative lower bound of benefits.

Outcome measurement will become a valued and even necessary tool for library administrators. It will provide a standard, easily understood statement of how their users benefit from a library's services. Museums already have such a tool in their applications of economic impact analysis. IMLS and NISO both recognize the need for libraries to have such outcome-measurement tools. Cost-benefit analysis, now applied not only in the United States but in Norway and New Zealand as well, is recognized increasingly as a valuable outcome-measurement tool. Considerable work remains to be done to perfect the tool's wide applicability to public libraries. Much already has been accomplished.

NOTES
2. For a summary of environmental applications and the controversy surrounding CVA, see Portney (1994).
4. For additional information on the Phoenix study, see Holt, Elliott, Watts, & Holt, 2000, Appendix D.

REFERENCES


Cooperative Game Theoretic Models for Decision-Making in Contexts of Library Cooperation

ROBERT M. HAYES

ABSTRACT
This article starts, in Section 1, with a brief summary of Cooperative Economic Game Theory. It covers the following issues: (1) the nature of utility functions, (2) the representation of a decision problem in terms of utility functions, (3) the max-min solution of a decision problem, (4) the extension to multiple participants in the decision, (5) the context of nonzero-sum games, (6) cooperative decision-making, and (7) the role of transferable utilities.

There then is a more detailed summary of the specific measures identified by John F. Nash, Lloyd S. Shapley, and John C. Harsanyi. It includes a brief discussion of their significance in general economic and social decision-making in which negotiation and cooperation have important roles.

There is then a brief review, in Section 2, of contexts in which negotiation and cooperation among libraries is of special economic importance. They include: (1) sharing of resources, (2) cooperative acquisitions, (3) cooperative automation, (4) shared cataloging, (5) shared storage, and (6) preservation and access.

For two of those contexts—cooperative acquisitions and cooperative automation—detailed applications of cooperative game theory are illustrated, including use of specific utility functions to represent the decision problems and show the results of applying the Nash, Shapley, and Harsanyi measures for optimum decision and equitable allocation of resources. Numerical examples are used to make the illustrations as concrete as possible.

The article concludes, in Section 3, with a brief description of the im-
plementation of the calculations for the two contexts within the LPM—
Library Planning Model.

SECTION 1. GAME THEORETIC MODELS FOR DECISION-MAKING

The crucial reference for game theory is the classic book by John von
Neumann and Oscar Morgenstern, *Theory of Games and Economic Behavior*
(1944).

Understanding a Decision Problem

The starting point for modeling any decision problem must be an un-
derstanding of the problem as it is seen by the decision-maker, a definition
of the objectives of the decision-maker, the identification of alternative
solutions to the problem, and the formulation of means for representing
the objectives in a way that can be used to select among the alternative
answers. All of that may sound self-evident and trite, but each of those steps
is fraught with difficulty.

Most fundamentally, there are likely to be decision-making problems
for the library manager that are not well understood, for which the objec-
tives are by no means evident, and for which the alternative potential an-
swers may not be known. The task in modeling in such cases clearly is comp-
plicated and requires an exploration by the library manager with whatever
professional assistance, such as systems analysis, can be brought to bear.

Fortunately, though, many of the problems faced by the library man-
ger are, in principle, well understood, as are the potential solutions of
them. Even in such cases, though, there still are difficulties in properly
representing the objectives. To resolve those difficulties requires definition
of an appropriate “utility function.”

Utility Functions

A utility function is a means for representing the objectives in a way that
can be used to select among the alternative answers. To represent the ob-
jectives, two aspects must be recognized. One is the relative importance of
the objectives and the second is the scale for assessment individually for each
of them. In this respect, it is important to note that an unweighted mix of
criteria, such as “the greatest good for the greatest number,” is irrational;
one cannot in general optimize two objectives simultaneously. To do so,
there must be a single criterion, and if there are two or more objectives,
that criterion must suitably represent their relative importance. It is that
requirement that makes the utility function necessary.

To illustrate, the library manager may have two objectives in mind: (1)
to decrease the net cost for providing access to materials and (2) to improve
the effectiveness of service in providing that access. On the surface, the two
objectives are likely to be in opposition, since decreases in costs are likely
to result in decreases in services, but the potential solutions may in fact
include some that can to some extent meet both objectives. The utility function is the means for bringing those two objectives into a single criterion for assessing the alternatives.

This example, simple though it is, highlights the difficulties in creating a utility function. First, note that while the first objective is, in principle, quantitative, with net cost measurable in dollars, the second may be essentially qualitative and not adequately assessable in numerical form. Second, note that identifying the relative importance of the two objectives, however they may be assessed, is a near impossibility. Indeed, in any real situation it may shift as the alternative answers represent different combinations of costs and effectiveness.

Despite those difficulties, the process of modeling a decision-making problem requires that there be a utility function, and there are means for resolving the difficulties. First is to translate the problem of comparison among objectives into "quantitative/qualitative" ratios. In the example, that would become a "cost/effectiveness" ratio, a measure of "dollars per service provided." Second is to translate, to the extent possible, the qualitative objectives into quantitative ones. In the example, this might be accomplished by translating "effectiveness" into a combination of measurable characteristics, such as "response time" and "frequency of satisfaction." Third, and most fundamental, is to translate the process of assessment into relative comparisons of alternative options, which might be represented by $U(A) > U(B)$, with $U(X)$ being the utility function, and $U(A)$ and $U(B)$ being the respective "values" for options A and B respectively.

The third means for resolution reflects the fact that the only requirement for the utility function is that it be "order preserving." Specifically, $U(A) > U(B)$ means that option A is preferable to option B (in the order of preferences of the decision-maker). Of course, it may be that two options are of equal preference, and that is represented by $U(A) = U(B)$. The crucial requirement for a utility function is that, for any two options A and B, either $U(A) > U(B)$, $U(A) = U(B)$, or $U(B) > U(A)$. In other words, there must be a means for making the choice and it is not possible for both $U(A) > U(B)$ and $U(B) > U(A)$, so the utility function must preserve the order of preference.

Later, when we discuss the application of game theory to cooperative decision-making among libraries, the specific mixes of quantitative and qualitative objectives appropriate to decisions concerning interlibrary cooperation will be discussed.

### Representation of the Decision Problem

Given the existence of a utility function, it is then possible to represent the decision problem simply by the assessment of the value of the utility function for each of the alternatives available for solution of the problem. Expressed in that way, the decision problem appears to be almost trivial (even recognizing the possible difficulties in assessing the alternatives).
But, of course, real decision problems are not trivial for the very real reason that there are usually uncertainties that must be recognized. To represent those uncertainties, game theoretic models place the decision problem in the framework of potential contexts over which the decision-maker has no direct control. Thus, while the decision-maker may face and be able to evaluate a set of alternative solutions to a problem, each solution must be assessed for its utility in each context and, more to the point, the likelihood of each context must also be assessed.

The game theoretic model is simply a matrix, the rows of which are the options for alternative solutions, the columns are the contexts, and the elements are the utility function assessments:

<table>
<thead>
<tr>
<th>Contexts</th>
<th>Options 1</th>
<th>Options 2</th>
<th>Options 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U11</td>
<td>U12</td>
<td>U13</td>
</tr>
<tr>
<td>2</td>
<td>U21</td>
<td>U22</td>
<td>U23</td>
</tr>
<tr>
<td>3</td>
<td>U31</td>
<td>U32</td>
<td>U33</td>
</tr>
<tr>
<td>4</td>
<td>U41</td>
<td>U42</td>
<td>U43</td>
</tr>
</tbody>
</table>

For example, the assessments of utility might be as follows:

<table>
<thead>
<tr>
<th>Contexts</th>
<th>Options 1</th>
<th>Options 2</th>
<th>Options 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3</td>
<td>-4</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>-5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>-2</td>
<td>3</td>
</tr>
</tbody>
</table>

The usual frame of reference for a game theoretic model is a competitive game, in which the contexts represent the opponent’s strategies for play, and the utilities (if positive) are payments to the decision-maker from the opponent (or, if negative, from the decision-maker to the opponent). Note, that in this case, the player and the opponent each have a utility and that they are negatives of each other: \((U_{ij}, V_{ij})\), with \(V_{ij} = -U_{ij}\).

With utilities as shown above, the decision-maker might prefer option 1 because its utility is 5 in context 3, but there is the risk of a loss of -4 if the opponent plays context 2. How is the best choice to be made?
Max-Min Solution of the Decision Problem

The classical answer to the choice is "maximize the minimum utility"—the "max-min" solution. That is, for each option across the set of contexts, there is a least utility for the decision-maker and the choice should be that option for which the least utility is the largest. In the numerical example above, the answer is option 3, if the three contexts are equally likely. Note that the set of minimum utilities for the four options is (-4, -5, 1, -2) and the maximum of that set occurs at option 3 in context 1.

If the set of contexts are treated as the potential moves of a competitor, that person is similarly trying to maximize the minimum utility for him (which would be the negatives of the values shown), and the minimum utilities would be (-1, -2, -5), the maximum of which again occurs in context 1, option 3. In either case the result, G, from the game is payment of 1 from the competitor to the decision-maker.

In the example, as a game, the best strategies for the two competitors produce the same solution, option 3 and context 1. Such a game is one with a "saddle-point."

Mixed Strategies. There are games without saddle-points and determining how best to decide for them requires introduction of what are called "mixed strategies" which entail basing the decisions on relative frequencies rather than fixed choices. For example, in the children's game "paper, scissors, rock," the best strategy is to make the choice among the three options as randomly as possible (unless the opponent reveals an evident bias). Using such mixed strategies, the decision process always will have a solution in the form of relative frequencies for each option that will produce at least the minimum expected return (as a counterpart of the max-min solution).

Determination of the best mixed strategy (i.e., best set of relative frequencies for selection of each option by the decision-maker and of the contexts by the opponent) entails solution of a set of linear equalities and inequalities. First, each set of relative frequencies must sum to 1:

\[ A_1 + A_2 + ... + A_n = 1, \text{ and } B_1 + B_2 ... + B_m = 1. \]

Second, each player wants the results, G, from the game to be the best possible for himself:

\[ \sum A_i U_{ij} \geq G, j = 1, 2, ..., n \text{ and } \sum B_i U_{ji} \leq G, j = 1, 2, ..., m. \]

The need is to determine the values for the set of frequencies, A, and B, and the value, G, of the game. In general, the solution of a set of linear inequalities (called "linear programming") is an iterative process of searching for values that are potential solutions and then finding the best among them. It is beyond the scope of this article to go into details about that process, and the reader will need to go to a standard text for operations research or linear programming to find them. However, to illustrate the results, consider the following game which does not have a saddle point (i.e.,
max-min for the options is at option 1, context 2 but min-max for the contexts is at context 1, option 1): 

<table>
<thead>
<tr>
<th>Options</th>
<th>Contexts</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>-3</td>
</tr>
</tbody>
</table>

The inequalities for the decision-maker are:

\[ 2A1 - 3A2 \geq G, \quad -2A1 + 5A2 \geq G, \quad 3A1 - A2 \geq G, \]

Those for the opponent are:

\[ 2B1 - 2B2 + 3B3 \leq G, \quad -3B1 + 5B2 + B3 \leq G, \]

The solution is:

\[ A1 = 2/3, \quad A2 = 1/3, \quad B1 = 7/12, \quad B2 = 5/12, \quad B3 = 0, \quad \text{and} \quad G = 1/3. \]

The result from each of the inequalities except the third one for the decision-maker is equal to G, but for that one it is greater than G. That means that the opponent does not want to select option 3 under any conditions, which is why B3 should be zero.

Multiple Players

So far, the number of players has been just two—the decision-maker and the opponent. What happens if there are more than two players, say N of them? The crucial point in such games is that players may form coalitions with the objective of gaining advantages by doing so. Of course there is the implication that there will be mutual agreement among the players forming a coalition with respect to the division of utilities among them and that the utilities can be transferred among the participants in a coalition in accordance with that agreement (what are called “transferable utilities”).

The representation of an N-player game is essentially parallel to that for the two-player game, except that there will be N components to the payoff vectors instead of two. That is, instead of simply \((U_{ij}, V_{ij})\) as a pair of utilities, there will be \((U_{ij}^1, U_{ij}^2, \ldots, U_{ij}^N)\) as an N-fold set of utilities with, for the moment, the sum of the utilities being equal to zero. Again, each player has a set of options among which to choose, with a coalition entailing agreed-upon choices among the options for the players forming that coalition.

The question at hand is then, what the value of such a game is as represented by the expected returns for each player, given the possibilities for
forming the entire range of coalitions among the players. The answer is a
bright formula, developed by Lloyd S. Shapley (1953). Consider $S$ as one
among the possible coalitions, with $s$ players joining in it, and let $v(S)$ be
the sum of the payoffs to the members of the coalition if they cooperate
(and do not cooperate with any other player). Then, the payoff that each
player can expect from the game is given by:

$$U_i = \sum_{i} [v(S)*(s-1)!*(N-s)!/N!] - \sum_{i} [v(S)*s!*(N-s-1)!/N!]$$

where the first sum, $\Sigma_i$, is taken over all possible coalitions that include
player $i$ and the second sum, $\Sigma_i'$, is taken over all coalitions that do not in-
clude player $i$. The sums together include all possible coalitions.

**Nonzero-Sum Games**

Note that, in the matrix representation of the game theoretic model
for the $N$-person game as shown above, the sum of the utilities equals zero.
In particular, for the two-person game, only one utility function has been
included and, in the numerical illustration, there are only single numbers
in each element of the matrix. Further, in the discussion above, the utility
function for the competitor was taken simply as the negative of that for the
decision-maker, with the view that the results of the game were simply the
transfer from one person to the other.

Clearly, it is possible, even likely, that competitors can have fundamen-
tally different utility functions which cannot be expressed simply as the
negatives of each other. If so, the matrix representation must consist of
two values in each cell. To illustrate with a two-person game, let $U_{ij}$ be the
utility function for the decision-maker and $V_{ij}$ the utility function for the
competitor:

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<tr>
<th>Options</th>
<th>Contexts</th>
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<tbody>
<tr>
<td>1</td>
<td>$U_{11}$, $V_{11}$</td>
</tr>
<tr>
<td>2</td>
<td>$U_{21}$, $V_{21}$</td>
</tr>
<tr>
<td>3</td>
<td>$U_{31}$, $V_{31}$</td>
</tr>
<tr>
<td>4</td>
<td>$U_{41}$, $V_{41}$</td>
</tr>
</tbody>
</table>

The sum of the two utility functions, $U_{ij} + V_{ij}$, would then represent
the total value of that combination of options and contexts for both players to-
gether. If $V_{ij} = -U_{ij}$, as the prior illustration represented, the game is called
a "zero-sum" game. If the two utility functions are not simply the negatives
of each other, the determination of strategy by a given player would still be
based on maximizing the minimum utility for that player.

As a principle, game theory assumes that the players in a game are "ra-
tional," in the sense that they will each make decisions that are best for their individual interests, as expressed by their respective utility functions. That implies, in particular, that the relative frequencies of the options and contexts (as defined above) will be determined by the optimal strategy of the player whose plays they represent. It is further assumed that both players have complete knowledge of the utility functions for each.

There are good reasons to question either of those assumptions in any context more complex than a game. Furthermore, the facts are that while the choice of a play in a game may well be made randomly so that the opponent in making the opposing play is not sure of what it will be, the choice in virtually any real situation is likely not to be based on any element of randomness but instead will be made as directly as possible.

Cooperative Decision-Making

In particular, there are applications of game theory for which the assumption of maximizing individual interests, with max-min as the resulting criterion for choice and with the use of randomization as the means for creating mixed strategies, may be changed. The means for doing so is called "bargaining" and the resulting games are called "cooperative games."

Basically bargaining is a process of making offers and demands with the objective of achieving total, joint results that are better than can be obtained from simply the competitive game. In such bargaining, of course, the competitive game sits in the background as the fall-back position in the event that bargaining fails and there is no cooperation in arriving at the solution.

Cooperative games are of special importance for libraries for which cooperation in joint solution of operational problems is part of the underlying ethic as well as an economic and operational necessity. These kinds of applications therefore will be considered in the context of national information policy decisions and of library cooperation within them. As the background for that discussion, the following is a brief review of the theory underlying cooperative games.

The basis for the theory of cooperative games was developed by two quite remarkable individuals, each a combination of mathematician and economist—John F. Nash and John C. Harsanyi—who (together with Reinhard Selten) jointly received the Nobel Prize in economics in 1994 for their work. The seminal articles, though, were by Nash, and the following description draws primarily from them, supplemented by material from Harsanyi (Nash, 1950, 1953; Harsanyi, 1977).

Utility Functions in Cooperative Games. As was discussed above, to develop any game-theoretic model, one first needs a measure of utility, a means by which one can express the decision-maker’s preferences. While such a utility function normally need only represent and preserve the order of preferences, there are two further requirements for application to cooperative games.
The first added requirement is "transitivity": If A is preferred to B and B is preferred to C, then A is preferred to C. Expressed in terms of the utility function, if \( U(A) > U(B) \) and \( U(B) > U(C) \), then \( U(A) > U(C) \). The second added requirement is "linearity": Given a value \( p \), \( 0 \leq p \leq 1 \), with a possible option represented by \( C = pA + (1-p)B \), then the utility of C is the same linear combination of the respective utilities of A and B. Expressed in terms of the utility function, \( U(C) = pU(A) + (1-p)U(B) \). Note that the linearity requirement necessitates that the utility function be quantitative.

The Mechanism of a Cooperative Game. The theory developed by Nash treats situations involving individuals whose interests are neither completely opposed nor completely coincident. Decision-making in such situations is expected to require mutual discussion and agreement on a rational plan of joint action.

It is assumed that each participant has a set of possible mixed strategies (i.e., weighted combinations of simple strategies) that represent the actions that can be taken independent of the other participant. Typically the weights for the mixed strategies may be determined by a random process with specified averages.

For each combination of strategies, say \( (S_1, S_2) \), there will be resulting utilities \( U(S_1, S_2) \) and \( V(S_1, S_2) \) for the two players. Each utility is a linear function of \( S_1 \) and \( S_2 \) (because of the assumed property of linearity for the utility function).

Now, the issue in cooperation is to make a joint decision concerning the choice of \( S_1 \) and \( S_2 \) that would maximize the joint utility. Nash identifies a process of negotiation by which that joint decision is made and then identifies the properties that any "reasonable" solution must have.

Specifically, (1) there should be a unique solution, (2) any other potential solution cannot be better, (3) order preserving transformations of the utility functions will not change the solution, (4) the solution is symmetrical with respect to the two players, (5) if, for some reason, the set of pairs of strategies should be reduced but still contain the solution, it will continue to be the solution, (6) restricting the strategies for one player cannot increase the value of the solution for that player, (7) there is some way to restrict the strategies for both players without increasing the value of the solution for a given player.

Based on those axioms, Nash proves that there is a solution to the game that will maximize the total utility. The bottom line is that the solution to the game is that pair of strategies that maximizes the product of the possible gains over the fallback positions:

\[
\text{Maximize } (U(S_1, S_2) - X_1)(V(S_1, S_2) - X_2)
\]

where \( X_1 \) and \( X_2 \) are the expected pay-offs for the respective "fallback" positions of the two players (i.e., the results from the strategies which would be
used without cooperation). The following table (the example used by Nash in his article) illustrates a set of choices and the two utility values for each.

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<tr>
<th>Choice</th>
<th>Cost to A</th>
<th>Value to B</th>
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<tbody>
<tr>
<td>1</td>
<td>-2</td>
<td>4</td>
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<td>2</td>
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<td>2</td>
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<tr>
<td>5</td>
<td>-4</td>
<td>1</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Choice</th>
<th>Value to A</th>
<th>Cost to B</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>10</td>
<td>-1</td>
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<tr>
<td>7</td>
<td>4</td>
<td>-1</td>
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<tr>
<td>8</td>
<td>6</td>
<td>-2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>-2</td>
</tr>
</tbody>
</table>

The crucial point is that by cooperation, the players can do much better, both individually and together, than their respective fallback positions would yield. As Nash identifies, the optimum combination of choices is (1, 2, 3, 4, 6, 7, 8). For that combination, the payoffs are 12 for A and 5 for B, with the criterion product \((12 - 0) \times (5 - 0) = 60\). (The values of zero representing the fallback position of noncooperation.)

One might ask why not include all of the choices except number 5 (in which it is evident that there would be a net loss)? Well, note that the values of the combination (1, 2, 3, 4, 6, 7, 8, 9) are 14 for A and 3 for B. Although the total, at 17, indeed is equal to the total for the optimum choice, it is clear that B is subsidizing A and is not getting all that should come from the collaboration. The criterion product is \((14 - 0) \times (3 - 0) = 42\) and reveals the inequity by being much less than the 60 for the optimum answer.

**Risk Factors.** In the bargaining process, a crucial element is the relative degree of risk faced by each player at any given point. It is measured by the “risk factors” for each player:

\[
R_1 = \frac{U(S_1', S_2') - U(S_1, S_2)}{U(S_1', S_2') - X_1},
\]

\[
R_2 = \frac{V(S_1', S_2') - V(S_1, S_2)}{V(S_1', S_2') - X_2}
\]

If \(R_1 > R_2\), then player i should prevail over player j in the choice between \((S_1', S_2')\) and \((S_1, S_2)\), since player i has relatively more to gain and player j has relatively more at risk.

**Transferable Utilities**

However, this does raise the possibility that one might do better. To illustrate the possibilities, in the example given above, let’s change the values for choice 9 from \((2, -2)\) to \((3, -1)\). It turns out that there are then two
combinations of options that have equal values for the Nash criterion: (1, 2, 3, 4, 6, 7, 8) and (1, 2, 3, 4, 6, 7, 8, 9). The criterion product for the first is still $12 \times 5 = 60$, but that for the second is $15 \times 4 = 60$. In other words, the Nash criterion for each is 60, but the total utility of the second is 19 versus 17 for the first.

There are two reasons for looking at this new set of values. First, it serves to highlight one of the crucial features of the axioms that underlie the Nash solution. Specifically, the remarkable contribution that Nash made was not only to provide a simple criterion but to prove that it would provide the optimum answer and that it would be unique. How then can we have two options with the same Nash criterion value? The answer is that given two values there are linear combinations of them, lying between them, that are also potential answers.

Thus, let $(X_1, Y_1)$ and $(X_2, Y_2)$ be two options. Then $[a \times X_1 + (1-a) \times X_2, a \times Y_1 + (1-a) \times Y_2]$, $a \leq 1$ is also an option. The linearity of the utility function then allows us to calculate the Nash criterion function:

$$N = [a \times U(X_1) + (1-a) \times U(X_2)] \times [a \times V(Y_1) + (1-a) \times V(Y_2)].$$

To maximize $N$, set to zero the derivative of it with respect to $a$:

$$2a[U(X_1) - U(X_2)] + V(Y_1) - V(Y_2) + V(Y_1) - V(Y_2) = 0$$

Then, $a = (1/2)(V(Y_1)/[V(Y_1) - V(Y_2)] + U(X_2)/[U(X_2) - U(X_1)])$.

In the example given above, $U(X_1) = 12$, $U(X_2) = 15$, $V(Y_1) = 5$, and $V(Y_2) = 4$. In that case,

$$a = (1/2) \times [4/(5 - 4) + 15/(15 - 12)] = 1/2.$$ 

The Nash criterion value is then:

$$F = (.5 \times 12 + .5 \times 15) \times (.5 \times 5 + .5 \times 4) = 13.5 \times 4.5 = 60.75,$$

and that is the unique maximum value.

The second reason for looking at this example, though, is that it highlights the potential for bargaining between the players with respect to the distribution of the total maximum utility. For them to bargain, the utilities must be transferable, so that player A would be able to give units of utility to player B as an incentive to cooperate in such a way as to increase the total utility.

In the example, player A might agree to give player B one and a half units if they can cooperate on the option that gives 15 units to A and 4 units to B. The result would be that A winds up with 13.5 units and B with 5.5 units. Each is ahead of the option that gave only 12 units to A and 5 units to B.
Later, we will use this example to illustrate the application of cooperative games in the context of decisions concerning library cooperation.

Optimization over Total Utility

So far, the optimization has focused totally on criteria that relate to the individuals separately. But as the discussion just above should demonstrate, there is great potential value if the optimization can consider the total utility, combining those for each of the two players.

Here is where Harsanyi provides another beautiful answer (1977, p. 192). Without going into the details (as given in the reference), the bottom line is to maximize the Harsanyi criterion function:

\[
H = [U(S_1, S_2) - X_1] [V(S_1, S_2) - X_2] + [U(S_1, S_2) + V(S_1, S_2) - (X_1 + X_2)].
\]

But beyond the Harsanyi criterion is that of Shapley, as described earlier, which provides the basis for maximum collaboration among all of the participants.

Section 2. Libraries within Cooperative Structures

We turn now to the potential for use of cooperative game theory in support of cooperation among libraries. Of course, libraries have a long history of cooperation, perhaps best exemplified by the system for interlibrary borrowing and lending. It has been a continuing theme for library management for decades. Today, though, there is an expansion of that tradition into a variety of contexts and purposes and into formalized structures.

Reasons for Library Cooperation

There are several specific reasons for cooperation among libraries:

Sharing of Resources. This is certainly the starting point for library cooperation. It is explicitly represented by the process for interlibrary borrowing and lending that has been formalized for decades. But it has generated a number of supporting tools in the form of union catalogs, union lists of serials, and other cooperative means for determining where desired materials may be available.

Cooperative Acquisitions. This is a means for cooperation that obviously depends upon the sharing of resources, but it goes further by formalizing agreements in which specific institutions take responsibility for identified areas of acquisition. This implies some degree of sharing of funding as well as responsibility, and some formal arrangements include provision for pooling some portions of the acquisitions budgets of the participants.

Automation. The development of automated systems has frequently been a focus of cooperation among libraries. The joint contracting for acquisition of a system, the sharing of costs in implementation and in operation, the sharing of experience and staff expertise—these have been typical ways in which cooperation with respect to automated systems has occurred.
**Shared Cataloging.** The largest concentrated effort at cooperation among libraries certainly was the development of systems for shared cataloging. That effort is now represented by the international bibliographic databases of OCLC and RLIN. It grew out of the need for cooperation among libraries in the conversion of bibliographic records—catalogs especially—to machine processible forms. The result, of course, is that now virtually every major library has the catalog for its entire collection in an online public access catalog (OPAC).

**Shared Storage.** The growth of library collections, whether exponential or linear, leads to the problem of allocating materials to alternative places for storage. The costs of storage facilities, though, is great enough that efficiency requires that they be shared by groups of cooperating libraries. Shared storage has therefore been another of the success stories in library cooperation.

**Preservation and Access.** Perhaps the most dramatic context for library cooperation has been that of preservation and access. The underlying problem is the literal disintegration of the paper in books, especially those produced in the years since the introduction of acidic paper that self-destructs. It has been estimated that as much as 25 percent to 30 percent of the holdings of major research libraries are at risk (Hayes, 1987). To deal with this problem, the Council on Library Resources established the Commission on Preservation and Access as the focus for management of a major cooperative effort. The objectives were identified in testimony at a March 17, 1988 hearing of a Congressional committee: "Commission President Pat Battin proposed a model for a national cooperative microfilming program. A goal of filming 150,000 volumes a year would require 20 institutions to commit to filming 7,500 volumes each. At the 150,000 annual rate, it would take about 20 years to film 3 million volumes—the estimated number of volumes it would be important to save in order to preserve a representative portion of the 10 million or more volumes that will turn to dust by that time" (Commission on Preservation and Access, 1988).

**Utility Functions for Library Cooperation**

We turn now to the potential for application of cooperative game theories to library cooperation. As was discussed above, to represent a decision-making problem as a game requires that there be a measure of utility for each participant in the game. What are the elements of such a utility model for library cooperation?

**Capital Investments and Operating Costs.** We start with the most measurable elements, the capital investments and the operating costs associated with alternative options for solution of the decision-making problem. Normally, they will be measured in dollars, or equivalent, and can be readily accumulated.

Sometimes the context for possible cooperation may affect existing
capital investments. For example, an effort to cooperate in the development of a joint automated system may need to recognize that a participant already has a system in place and that cooperation might entail changing that system, losing the existing capital investment, and incurring additional capital costs.

Sometimes the context may affect current or future capital investments. An effort to share acquisitions will usually entail a decision by one of the participants to eliminate the capital investment in acquisition and technical processing of materials in a specific subject area, under the assumption that needs for materials in that subject will be met by another participant. This concept underlay the Farmington Plan, as a national effort in which responsibility for collection development in specific subject areas was to be assigned to specific institutions. The other institutions could then, in principle, count on coverage of the subject fields and concentrate their own budgets on their more specific needs.

Sometimes the context may affect operating costs. As an example, any system for interlibrary borrowing and lending or for document delivery entails substantial costs in both the borrowing and lending institutions. Those operating costs need to be included in any decision concerning shared acquisitions.

A major operating cost in library cooperation is the commitment of the time and energy of the library management and professional staff in negotiation and in governance. Probably the most successful example of library cooperation in the past several decades has been the development of the international bibliographic utilities (as represented by OCLC and RLIN). The impact on both library costs and library effectiveness has been immense. But these efforts have necessitated intense involvement of directors of libraries, catalogers, and reference staff. The expenditures of time by exceptionally valuable persons have been immense. At some time in the process of evaluating options for library cooperation, those costs need to be considered.

Cómo. Any utility function for assessing options in library cooperation must consider the effect on users and on the overall productivity of the library. Unfortunately, these effects are not easily quantifiable. Of course, some may be, such as “response time” or “frequency of satisfaction.” But others, such as “browseability” are not.

Governance. The utility function will need to recognize issues involved in governance. They relate to centralization versus decentralization of decision-making in operation of cooperative enterprises, to the structure for control of policies, and to the relationships of the library to its parent institution. These issues are even less amenable to quantification than those for effectiveness.

Profeccional Ethics. Underlying all of the contexts of library cooperation is an ethical commitment of librarianship to the very concept itself. It is em-
bedded in the profession and is evidenced in the long-standing commitment to interlibrary borrowing and lending despite the costs and inequities it entails. The major net lenders periodically will complain about the costs they incur and the adverse impact on services to their primary constituencies, but when the decision finally must be made, invariably it is in favor of cooperation.

In a sense, there is an underlying rationale for that professional commitment in the recognition that no library can be all-encompassing and that sharing is the only way to ensure preserving the record of the past and providing access to that record. But there appears to be something more than simply that pragmatic rationale in the view of librarianship that information indeed is a public good.

The Consequent Utility Function. Would that one could readily identify the utility function that will properly weight and combine this combination of quantitative and qualitative factors. In lieu of that, the utility function for application to library cooperation must be an individual assessment of the relative utility of options and, perhaps, a jointly agreed-upon combination of those individual assessments into a mutually acceptable criterion for the group of libraries participating in library cooperation.

Illustrative Applications of Cooperative Games

Two examples will serve to illustrate the potential for use of cooperative games in decision-making concerning library cooperation. One considers cooperative acquisitions and the other considers library automation.

Cooperative Acquisitions. As a start, for simplicity, let's suppose that there are just two institutions considering an agreement to share acquisitions. If one of them will assume responsibility for acquisition in a subject field, the second will save the costs of acquisition and technical processing for that subject. However, each will incur operating costs in meeting the needs of users in the institution served by the second library who need materials in that subject field from the first. The utility measure to be used will be quantitative and based simply on the total costs represented by any given choice.

In Section 1, above, a numerical example was presented to illustrate the choice of optimal mixtures of choices, and the following repeats the table of values but now interprets them as reflecting the net costs or benefits if the options are interpreted as acceptance of subject responsibility.

The interpretation of this table is that there are nine subject areas being considered for cooperative acquisitions. Library A is renowned in the first five fields, and library B, in the last four. If library A were to accept responsibility for one of the first five fields, there would be estimated costs in fulfilling that obligation. Those costs might consist of increased levels of acquisition to meet the joint needs; it definitely would include costs in providing materials to borrowers from library B. On the other hand, library B would save substantial costs in acquisition and technical processing, though
there would be counterbalancing costs in borrowing from library A. The values shown are interpreted as the estimates of those respective costs and benefits.

As was described above, this cooperative game has a solution: Library A accepts responsibility for subject fields 1 through 4 and library B for fields 6 through 8. The remaining fields are left out of the agreement. The net gain both to the individual libraries and in total would be substantially greater than if there were no agreement to cooperate.

Now let's complicate the example by including three institutions and ten fields.

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<tr>
<th>Table 7.</th>
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<tbody>
<tr>
<td>Choice</td>
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This numerical example will be interpreted as follows: There are three libraries (A, B, and C) that are considering a program of cooperative acquisitions. They have identified ten subject fields (choices 1 through 10) as potential candidates. For each choice, if the value for a given library is negative (such as for library A in choice 1), it will be responsible for that subject field. The
value is negative for that library because they will now incur, perhaps, additional costs in added acquisitions and, surely, additional costs in providing lending services to users from the other libraries. The values for the other libraries (library B and C in the case of choice 1, for example) are positive because they will now save costs in acquisition in that subject field because they can depend upon the host library (library A for choice 1).

Parenthetically, it should be noted that underlying the choices shown above might be more basic choices reflecting the potential for two-party agreements. For example, choice 1 might be the sum of two more basic choices: \((-2,2,2) = (-1,2,0) + (-1,0,2)\). In this way, if additional libraries were to participate, perhaps without even serving as hosts for subject fields, their impact on costs would be directly represented in a parallel fashion.

But, returning to the example as shown, the options available are essentially the several combinations of the choices, of which there are 1,024 (i.e., \(2^{10}\)). The task is to determine the best among those combinations and the resulting distribution of benefits (or costs) among the participants. In general, it would appear that every choice for which the total of values was positive ought to be included, since the group of libraries as a whole would experience a net gain. Whether or not a choice for which there was a total of zero should be included is clearly debatable, but let’s see what happens.

For this example, it turns out that the maximum Nash Value occurs if all of the choices are included, including that for which the total of values is negative as well as those for which it is zero. The total individual values are then \((11,4,8)\) with a total for the group of 23 and a Nash Value of 352.

However, the option that excludes choice number 3 has total individual values \((13,3,8)\), with a total for the group of 24 and a Nash Value of 312. It is therefore the option that should be selected if the goal is to maximize the total for the group as a whole.

The Shapley Values are \((11.33, 4.33, 8.33)\), so there would need to be transfers from library A to libraries B and C to provide equity, otherwise, there would be no reason for library B to agree to that option since it would lose in comparison with the Nash Value maximum option (i.e., getting only 3 instead of 4). The Shapley values are calculated as follows:

\[
U(A) = \frac{1}{3} \cdot 11 + \frac{1}{6} \cdot 15 + \frac{1}{6} \cdot 19 + \frac{1}{3} \cdot 24 - \frac{1}{3} \cdot 4 - \frac{1}{3} \cdot 8 - \frac{1}{6} \cdot 12 = 11.33
\]

\[
U(B) = \frac{1}{3} \cdot 4 + \frac{1}{6} \cdot 15 + \frac{1}{6} \cdot 12 + \frac{1}{3} \cdot 24 - \frac{1}{3} \cdot 11 - \frac{1}{3} \cdot 8 - \frac{1}{6} \cdot 19 = 4.33
\]

\[
U(C) = \frac{1}{3} \cdot 8 + \frac{1}{6} \cdot 19 + \frac{1}{6} \cdot 12 + \frac{1}{3} \cdot 24 - \frac{1}{3} \cdot 11 - \frac{1}{3} \cdot 4 - \frac{1}{6} \cdot 15 = 8.33.
\]

**Cooperation in Automation.** Let’s suppose that there are several institutions considering an agreement to cooperate in the installation of a common system for automation in their libraries. If they can agree upon a com-
mon system, there should be significant benefits in cooperation. For example, as pointed out earlier, there may be savings from joint contracting in acquisition of the common system, savings in costs in implementation and in operation (such as in shared maintenance and replacement parts), efficiencies in sharing of experience and staff expertise, greater effectiveness in adding later improvements, and easier sharing of common data files.

Of course, balancing such benefits from cooperation may be the fact that each institution has a substantial investment in its current system. Part of that investment may be the residual value in amortization of the initial investment in the system. Another part, one likely to weigh even more heavily, is the fact that the existing system is well-entrenched in the operating procedures of the library and the usage by its patrons.

All in all, the potential is that the benefits from cooperation will be sufficient enough to warrant at least careful evaluation of alternative systems.

There are thus at least four factors to be considered in the utility function for this application of cooperative game theory: (1) existing capital investments at each institution, (2) the costs for installation of each potential candidate for a replacement system, (3) the net benefits (i.e., difference between benefits and operating costs) to be anticipated from each potential candidate for a replacement system, and (4) the benefits to be anticipated from cooperation (which may vary from systems to system) by selection of a common system.

To apply cooperative game theory, it is assumed that those four factors are commensurate, both across factors and across institutions, so that they can be combined by simple arithmetic operations. It is also assumed that each factor is measured by a linear function of the size of the institution so it is expressible in the form \( V(i,j) = A(i,j) + B(i,j) \times \text{Size}(k) \), with the parameters \( A \) and \( B \) varying by factor \( i \) and system \( j \) and the size varying by institution \( k \).

Finally, it is assumed that the parameters for benefits from cooperation are a linear function of the number of institutions selecting a common system so they are expressible in the form \( A(4,j) = N(j) \times A'(j) \) and \( B(4,j) = N(j) \times B'(j) \), where \( N(j) \) is the number of institutions selecting system \( S_j \) and the parameters \( A'(j) \) and \( B'(j) \) are given for each system \( S_j \).

The following numerical example will illustrate the model for just two institutions (see Table 8).

In this example, the existing investments are, respectively, 6 (for institution \( J_1 \) in system \( S_1 \)) and 3 (for institution \( J_2 \) in system \( S_2 \)). The potential third system, \( S_3 \), does not provide sufficient benefits to overcome the loss of the existing capital investment at \( J_1 \), but the values in cooperation are sufficient to warrant installation of \( S_1 \) at \( J_2 \). However, there needs to be compensation for the loss of investment at \( J_2 \), and the Shapley values, as shown, provide the basis for such compensation. If the net operating benefits for \( S_3 \), are increased from 8 to 10, the results are as follows (see Table 9). Note that both institutions lose their existing capital investments,
Table 8.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Size</th>
<th>Existing Investment</th>
<th>Current System</th>
<th>Best Choices</th>
<th>Net for Best</th>
<th>Shapley Values</th>
<th>Needed Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>27</td>
<td>24.00</td>
<td>-3.00</td>
</tr>
<tr>
<td>J2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>13.00</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Table 9.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Size</th>
<th>Existing Investment</th>
<th>Current System</th>
<th>Best Choices</th>
<th>Net for Best</th>
<th>Shapley Values</th>
<th>Needed Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>22</td>
<td>23.00</td>
<td>1.00</td>
</tr>
<tr>
<td>J2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>16</td>
<td>15.00</td>
<td>-1.00</td>
</tr>
</tbody>
</table>

but the benefits from both S3 and from cooperation more than compensate. The Shapley values in this case recognize the greater investment loss of institution J1.

SECTION 3. IMPLEMENTATION IN LPM

Processes for solution of cooperative games have been implemented in a program, called LPM—The Library Planning Model. This program is in the form of a Microsoft Excel spreadsheet with extensive Visual Basic macros. It provides a structure within which several models related to library operations and services, management, and planning can be interrelated and easily brought together for application to operations in specific libraries and to several policy contexts.

In particular, LPM provides means for entry of data about the populations served, materials acquired, services provided to the populations served, processes involved in acquiring, cataloging, and preserving materials, and facilities related to both users and materials. From those input data, LPM then derives an estimation of the staff required, both for each category of service
or process and in total. Staff estimates are in two categories: direct FTE and indirect FTE and for three levels of personnel (professional, nonprofessional, and hourly). To calibrate the staffing estimates from the LPM, means are included to compare them with actual staffing, distributed both by administrative units and functional areas (using the categories of the model).

LPM also provides means for assessing the needs for facilities to serve users, to store the materials acquired, and for comparing them with the input data for facilities already available. It includes means for applying models for allocation of materials to alternative means for storage and for decisions about the choice between acquisition and access elsewhere.

And LPM includes means for using the cooperative game theoretic models presented in this article.

Implementation of Cooperative Games for Shared Acquisitions

One process is in support of the model for shared acquisitions, representing options (i.e., strategies) that are either independent or are based on combinations of possible choices, such as in the example for shared acquisitions as given above. Note that in the first example there were $2^9 = 512$ possible combinations for two institutions; in the second example, $2^{10} = 1,024$ for three institutions. A given option then is one of those combinations of the nine or ten possible choices. The implementation within LPM will allow up to nineteen choices and up to five institutions. The Nash, Shapley, and Harsanyi criteria have been included in the implementation in LPM.

Implementation of Cooperative Games for Shared Automation

The second process is in support of shared automation or similar contexts. Provision has been made to include up to five institutions and up to six systems. For each institution and each system, the parameters shown in the above illustration need to be entered. That being done, LPM will then determine the optimum selections. In principle, different systems might best be selected by different coalitions, so LPM then determines the Shapley values for that optimum by assessing the optimum choice for all possible coalitions of institutions and combining them as has been discussed in the definition of the Shapley measure.

CONCLUSION

Game theory has become a powerful tool in decision-making for business and government contexts in which competitive motivations are paramount. Even when "cooperative games" are involved, they are typically seen in the framework of bargaining for best individual advantage.

The value of looking at the potential use of this tool in library contexts is that cooperation is a part of the ethos of the profession. In that respect, it is representative of many kinds of non-profit, non-governmental organizations for which what is good for the group of participants and even for society at large has great weight in decision-making.
The intent of this paper has been to identify some potential applications of cooperative game theory that would illustrate those kinds of values. In doing so, it raises questions about the nature of the utility functions and clearly those questions need to be explored; this is especially the case for those elements of the utility functions that are essentially qualitative. But the framework of game theory provides a context in which such questions can be properly posed.

Beyond that basic intent, the paper has also presented two specific examples of those applications with the objective of showing how some of the questions might be answered in specific situations. The extension to other applications would require developing utility functions appropriate to each. Once that is done, the measures (such as those of Nash, Shapley, and Harsanyi that are discussed in this paper) provide the means for making effective decisions.

NOTES
2. It is important to note that game theory fundamentally represents a means to reconcile or combine simultaneous objectives, as represented, for example, by those of the players in a game. The solution of the game is that mix of meeting the simultaneous objectives that is called "Pareto-optimum," meaning "the best that could be achieved without disadvantage for at least one objective." In other words, no objective can be bettered without reducing another objective. There is extensive research on the implications of the criterion of Pareto-optimum and alternatives for it. (See, for example, Schmid, 1987. Reviewed by Boulding, 1979.)
3. It is important to recognize that optimization of a cost/effectiveness measure usually is in the context of boundary conditions (such as "the cost must be less than some maximum" or "the effectiveness must be at least some minimum" or both).
4. Churchman, Ackoff, & Arrow, 1957. (The numerical examples presented in the text above are taken from this textbook.)

REFERENCES
Financial Management of Libraries: Past Trends and Future Prospects

STEVEN A. ROBERTS

ABSTRACT
The growing alignment of information service management to business-based models of management since the 1970s is evident. The impact of the information and communication technologies (ICTs) on all areas of information service management is bringing about further structural changes and adjustments to practice. The financial environment within library and information services is reviewed and a structure for financial management is presented based on funding source and level of commercial activity. A set of criteria for library resource and service management based on Maurice Line's proposals is reviewed and these are critically appraised against the parameters of the business and financial models discussed. A good fit between Line's principles and business and financial parameters is found. A discussion of macroeconomic factors and contemporary trends is offered. A set of objectives for financial management of library and information services is developed and reviewed in the light of future trends and stakeholder perspectives.

INTRODUCTION
During the last twenty years there was a growing trend to align library and information service management to business models of management. In the late 1970s business conditions were rapidly evolving in response to changes in economic thinking. Monetarism and its political children Reaganomics (in the U.S.) and Thatcherism (in the UK) reinvigorated the debates about taxation, investment, and public spending. Market forces, the role of markets, and competition were given new prominence and interpretations. The roles of the consumer and customer in society and in com-
merce were highlighted. Efficiency, the elimination of waste, and quality delivery were new watchwords. The role of central government, economic intervention, and balances between public and private sector activities were analyzed, criticized, and redefined. In short, the deregulation of economic activity was to be the favored means of ensuring growth and wealth creation. This cycle of change would inevitably come to affect every sector of economic activity including library and information services.

The recent historical record, and indeed contemporary events, show that the library and the information sector has had to face a changing and ever more turbulent environment since the late 1970s. Rising library materials price indices were amongst the first indicators (e.g., well summarized in Cummings, 1992). Mid-1970s inflation—a symptom of rising oil prices—affected all economies tied together by global trade and against this background the new ‘economics of the right’ found its moment arriving to challenge the post-1945 Keynesian consensus.

Today’s economic and business climate is still influenced by these changes observed first during the 1970s in the U.S. and UK. The substantial dependency of the professional library and information area on public sector funding was to prove a considerable disadvantage. The virtual entirety of public libraries in the U.S. and UK were then, and still are, dependent on local or central public finance. These major sources of revenue were constrained as a result of these political and economic changes because the reduction of public spending was one of the major goals advocated. Likewise, academic and research libraries in the UK were and are virtually all publicly funded; in the U.S. private funding plays a greater role for research libraries, even though public funding is very significant for many.

In a perverse way, with hindsight, and from a library and information standpoint it could be said that the economic environment over the last twenty years has been both a negative force and a stimulus at the same time. Constraint on public funds and a shift to an enterprise culture undermined the welfare tradition of social provision. But it also encouraged a climate of innovation and so gained new potential and momentum. Little by little these library and information services have begun to explore markets and commerce, new customer sectors, added-value services, and new managerial responsibilities. They have discovered, albeit through a painful process, that public obligations can be sustained and innovation and adaptation engendered at the same time.

Against this background lies the justification for this paper. Given that financial management can be considered as a body of principles and practice with a close relation to applied economics, a review and discussion of financial management is an appropriate theme for this special issue on the economics of libraries: theories, measurements, costs, and related issues. Our period of study unfolds against a background not only of new economics but also of new technologies.
We can also observe that the post-1980s applied economics of the library sector is now giving way to a new economics which has to reflect the incorporation of the information and communication technologies (ICTs). Fresh organizational responses requiring business models hitherto unfamiliar are now indicated. What was public not-for-profit enterprise is not yet really (and perhaps never will be) private enterprise, but it has nevertheless undergone some radical rethinking and real changes in practice.

In the 1980s the author was an advocate of a more vigorous approach to the use of financial management tools (especially cost measurement and management) in library and information service (Roberts, 1985). By then, especially in the U.S., there had been a strong injection of business thinking applied to libraries but it met with some apathy as much as resistance in professional practice. This paper will make a review of progress over the last twenty years and look forward in a strategic manner to the future. Whilst the alignment of library and information service management to business models of management has continued, the rate of innovation has been uneven. Yet, there was enough impact in the 1980s to soften the blow for the adaptation that was to come in the last decade. A review may reveal trends and practices which still have to be absorbed and addressed.

With the arrival of the digital environment in the mid-1990s and the emergence of the hybrid library model, new managerial and financial needs have arisen as the environment of library and information service has become more complex. To what extent has current practice learned the lessons of the past so that it is well equipped to deal with future needs? Digital collection management, access policies, information marketing, public-private sector relations, converged services, and paradigms such as knowledge management provide areas of case study for a continued debate about library and information economics and financial management.

The paper will seek to clarify and reaffirm theory, but will also try to elicit the practical consequences and indicate how managers and other stakeholders can respond. Some observations regarding contrasting trends and practices in the United Kingdom, Europe, and North America will be made. The wider impacts and ramifications in other regional settings will be noted.

**The Context**

In delimiting the scope of financial management, the operational context and setting of application play an important part at any and every level. Historically, the organizational setting of library and library-derived information activities in society has been both a characteristic and a potent financial delimiter. Professional growth and identity have been formed around the emergence of characteristic sectors of library and information activity. The public library emerging in the mid-nineteenth century was a social and civic activity deriving legitimacy and resource from public taxa-
tion and expenditure. Mass education at all levels expanding in the same moment shared this heritage, and even where private initiative and charity played a significant part, the welfare motivation was strong. Private benefactors endowed personal resources for some ultimate public good. Only a very small proportion of library-based activities were developed as commercial, risk-bearing enterprises that sought private gain through profit (commercial lending libraries had a certain heyday in both the U.S. and the UK in the first half of the twentieth century).

Although industrial and commercial enterprises established and promoted library and information centers to meet their needs (special libraries) they did so as an internal diversification of their organizational activities. They could be regarded as a fixed-cost overhead and their financial implications and needs were limited. Commercial activity in the information sector (as defined today) was confined to publishing and the emerging mass media of press and magazines, whose survival was determined by profit and loss.

The core of the emergent library sector and profession was firmly in the public sector. The financial goal of these agencies was to spend money raised by some other agency (public taxation filtered through treasuries nationally or locally) for public good. Their great financial distinction and saving was that they were noncommercial and not-for-profit. Their financial responsibility was to be able to control and account for their spending. They were essentially welfare dependents.

The history of library management and its financial component was considerably determined by organizational status. In turn this seems to have shaped library manager needs for financial management technique and governed the nature and pace of practice and innovation. Four basic sectoral types can be identified presently: the library sector, the diversified library and information sector, the emergent markets for information and knowledge management (with an organizational and technological basis), and the wider applications of ICTs. These four can be regarded as the professional business models, to distinguish them from the managerial (enterprise/commercial) business models. These professional sectors have each generated new needs for financial management techniques and developments in practice have indeed taken place. These movements and trends have had a part to play in forming the present discussion.

If professional librarianship emerged in the 1850s there was a period of 80 to 100 years before a major transformation occurred. Between the 1930s and the 1950s professional librarianship was slowly coming under the sway of scientific management, most notably in the U.S.. This trend had barely arrived in the UK by the 1950s but then it too accelerated there. Professional writing on costing, accounting, and related matters for library and information services started to appear in the 1950s and 1960s.

When the author published Cost Management For Library and Information
Services in 1985 (Roberts, 1985), there was much to write about, papers to read and cite, as well as a context for activity in the U.S. and the UK as well as Germany. An analysis of the 485 references listed in the expanded second edition of this work (Roberts, 1998) provides an indication.

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<tbody>
<tr>
<td>Broader Financial</td>
<td>21</td>
<td>178</td>
<td>61</td>
<td>(260)</td>
</tr>
<tr>
<td>Management</td>
<td>9</td>
<td>111</td>
<td>105</td>
<td>(225)</td>
</tr>
<tr>
<td>Total</td>
<td>(30)</td>
<td>(289)</td>
<td>(166)</td>
<td>(485)</td>
</tr>
</tbody>
</table>

The 1985 study was based on a thorough search for material published in English up until then (core studies of methodology and well-reported and disseminated case studies). There is a sharp rise in published studies after 1967 up to 1984. In the period up to the second edition there is a marked decline in like-for-like studies. Broader studies (planning, budgeting, financial studies in general) continued with similar prominence. No definitive bibliometric claim is made from this evidence (although inclusion criteria were similar in both editions) but it could indicate a steady concern and interest in the general theme, which is not backed up by a growing number of published empirical studies. It could suggest a need for further empirical studies, although there is no good way of assessing the numbers of in-house studies carried out but not reported. In reality the number of “broad” studies is likely to be much more, because financial matters are increasingly referred to in policy and macro-studies (e.g., charging and pricing, impact of the ICTs, networking, and cooperation). The information and economics literature is probably outpacing that on financial management more specifically.

Over the last twenty years some tentative theory and empirical evidence have been developed. An intellectual pattern for the study of financial management in the library and information sector has at least emerged. Just how adequate a basis this provides is the next theme to discuss.

Financial Managerial Environment

What is financial management? Essentially it is one of the functional processes of the managed organization. At the root of the definition are the three aspects of sourcing, deployment, and utilization of monetary resources in direct or surrogate form. As such it is a formal responsibility likely to be undertaken as a specialty or generally by managers and related staff. The ways in which they undertake these functional processes in the organizational context constitutes the financial managerial environment. This managerial environment has a specific internal organizational setting and a wider setting (external to the organization).

The concepts and aspects of sourcing, deployment, and utilization provide a basis for defining specialized managerial roles. These aspects show
operational variation under different conditions. The different conditions are represented by different managerial business models and their professional counterparts (discussed in the next section). Part of the analysis must be to look at the appropriateness of different managerial business models for fulfilling library and information service goals (within the overall professional business model with its four main sectors). In strategic organizational terms there should be a general fit between the appropriate managerial business model and professional service goals. This is proposed as a working hypothesis.

Nevertheless, a consideration of the evidence of practice indicates a need also to consider the nature of adjustments and realignments between the business and the professional models. There is a view that the last thirty years of practice have seen substantial change and adjustment in the financial and business models of library and information services. The question to be put is whether or not the financial managerial environment has reached a state of optimization with respect to the interplay between the business and professional aspects of the model? In the light of likely anticipated developments (most of all in the shift to a hybrid and digital information economy) it may be prudent to regard existing arrangements as suboptimal. Hence, the concern with likely future developments. Is the future model likely to be the continuing evolution of present models or is something radically different likely to emerge? Put another way: will the professional models have to transform more radically than the business models?

To return to the financial responsibilities, sourcing of capital, current revenue, and income streams is the classic responsibility of the financial manager (the director of finance in the commercial organization; often a professional postholder in a library). Assuring income and capital is to assure the survival and growth of the organization and provides the key to establishing and maintaining its value. This is a strategic function operating at Board and CEO level. Much of the detail in the sourcing function is the concern of financial accounting drawing on systems of responsibility accounting. Being publicly grant-funded does spare the library/information manager from the difficult and risk-laden tasks of sourcing capital from the market; so much the better some think, if they too have few revenue-raising responsibilities.

Deployment of finance is essentially the task of planning and budgeting. In the commercial organization these functions are rooted in financial strategy (debt/equity ratio, debt structure, and dividend policy) and interrelate with sourcing. Budgetary planning and management are classic responsibilities which cross over the strategic and substrategic levels. A strong managerial economic aspect is exercised in the deployment function to deal with the analysis of choices and economics-influenced decision-making. Ideally, the library and information manager should be as deeply
involved as his enterprise counterpart in this function. In reality this may not be mandated by the role itself or the host organization. Examination of the professional literature has indicated that the tools are less well-developed and applied than they might be. Professionally, the U.S. practitioner tends to be better equipped to perform the task than the UK counterpart. An enterprise and market tradition, preference for analysis over pragmatism, professional norms, and bigger and more managed organizations may explain some difference. These themes would make worthwhile and interesting inquiries!

Utilization is the operational phase of the planning and budgeting cycles. Financial process management is devolved to operational levels and control and performance tasks take on great importance. Cost measurement and cost accounting are primary concerns and management information is generated through process systems. Information is collected together for fuller responsibility and financial accounting and is then redeployed to the strategic level of management for review and action. The two most detailed monographs on accounting and costing for libraries originate in the U.S. (Snyder & Davenport, 1997; Smith, 1998). The author’s own UK work (Roberts, 1998) covers the ground under the overall rubric of financial management. Historically, the key works of this literature came from the U.S. Nevertheless, more specialized work was undertaken in Germany (Beyersdorff, 1978; Koch, 1985) and the practical tradition of management-based empirical studies within Aslib in the UK need mentioning. It can be argued that financial utilization runs on into studies of performance and evaluation. Both the U.S. and UK have been innovators, although the U.S. provided much inspiration (King & Bryant, 1971; De Prospo et al., 1973; Lancaster, 1977). Cost-efficiency, cost-effectiveness, cost-value, and cost-benefit studies also feature in all these studies. Questions of financial resource and value will remain high on the agenda. It is perhaps ironic that professional interest in these aspects has not always run to improving the organizational and managerial foundations of costs, data, and management information on which such studies rely.

Financial management and physical resource management in the modern managed organization are inextricably bound together. Physical resource management (e.g., document collections, technology-based systems, equipment, accommodation and estates, as well as human resource management) all require their own levels of speciality [often related to logistics (allocation, storage, movement), safety, social, legal, political, human, and cultural factors]. Nevertheless, the managed physical resource usually has a financial or economic consequence and/or value which may be explicit or implicit.

The interplay of financial and operational conditions is very familiar to library and information service managers, and especially with reference
to document and information collections. It poses characteristic questions of prices, costs, and values familiar to these professional managers in libraries. Acquisition costs and collection operating costs may bear little relation to information content value and/or user valuations of the same physical stock, which when unresolved lead to classic disputes over weeding and relegation.

Within the new digital information economy the finance and economics of the material forms (a one-to-one relation between materiographic formats and content) is giving way to one-to-many and multiple forms of content and service with no need to transfer format for access, or ones which dispense with format/content boundaries altogether. Information is reduced to digital data which can be reconfigured through software to provide the information in the same, enhanced, or varied form, which can also be linked to other data and information and redistributed.

New forms of ‘classic dispute’ are emerging with the new information media having to do with rights to intellectual property, reprography, copyright ownership, seller and buyer rights, access regimes, subscription value, and licensing of access. Behind these ‘new classic’ disputes are the old economic and financial constraints in a new guise. Some already believe they may pose a threat to information access. If this is true, then a good understanding of the economic and financial environment is essential for future managerial success.

BUSINESS MODELS AND FINANCIAL MANAGEMENT

A business model is a set of structures, processes, and behaviors which constitute the predominant means of achieving organizational goals. In this section we leave behind the contrastive definition of the business enterprise model and the professional sectoral model. Instead we cross the range of public to private domains, and offer a typology of possible business models (A)–(J) based on financial resourcing as the dominant criterion. The business enterprise (commercial managerial) model is concentrated almost entirely on the final class (J) (commercial for profit/loss), although some privatized public utilities operate commercially with public subsidy.

Library and library and information sector organizations operate substantially within the first seven classes (A)–(G). In theory and practice information and knowledge management services can be undertaken in all classes. The ICTs have a similar range of classes but in practice their extensive use has depended on commercial innovation for rapid leading-edge exploitation. The typology helps to clarify the direction in which financial management has to have a distinctive priority as the range is crossed. If this typology is applied in practice (another future research study) it will be observed that some library information providers need to bolster financial management, especially at the deployment and utilization stage.
Business Models

Grant-funded (A) organizations are entirely dependent on their (external) grant provider as the source of revenue. Grant-funded through internal allocation/overhead (B) organizations depend on their host organization as the source of revenue.

Grant-funded with simple revenue earning (C). The grant provider—of either type (A) or (B)—is by far the dominant source of revenue, but allows the organization to earn marginal revenue without loss of grant income.

Grant-funded with internal market (D). The grant provider or host organization still provides the bulk of funding, but internal users may pay variable overhead contributions according to levels of use or need. This model allows some scope to make efficiency gains; it provides the delivery of a basic level of service and differentiated/added value services at additional cost.

Grant-funded with commercial trading (E). As a development of model (C) this type of organization may set increasing revenue-earning targets. At certain levels of earning more rigorous financial managerial conditions are required.

Business unit (strategic overhead in commercial organization) (F). This type is model B in a commercial setting. As a strategic overhead the unit is vital but at the same time has to pay its way in terms of efficiency levels and corporate value added.

Business unit (market tested) (G). Model (D) can be developed to provide service to an internal market and to move towards free-standing operations. Grant and overhead revenues are bid for through internal competition. This model could operate in a zero-based budget environment. Sources of income are released in exchange for specific service commitments. This type of unit is, in effect, the internal unit 'contracted out'; it implies that the unit is competitive and could be substituted by another provider (offering the same service for less money or better service for the same money).

Commercial with public subsidy (contracted out) (H). In the UK and some Western European countries this model has been the end result of privatizations of public corporations. For example, privatized rail services have operated under this model notably in the UK, but with opinions varying as to their success. The commercial provider is contracted to meet a public service obligation. The model has also been used for highway infrastructure provision. The model also underpins the discussion and politics of public/private partnerships, where the objective is to regenerate public services using private sector expertise and the financial markets. In the UK this approach is sometimes viewed as the evolution of the Thatcherite—New Right model. It is sometimes referred to as the "Third Way," implying the delivery of social provision (combining equality, compassion, and obligation) with efficiency and best value delivery.
Commercial for profit (and loss) (J). This is the model associated with market freedoms and enterprise: it is the traditional business/financial model of the private sector. Between the financial independence it portrays and full dependency (type A) there are seven variations.

Application of Models

How do the financial deployment and utilization aspects fit into any given sourcing model? Essentially there is no difficulty incorporating these two aspects, once it is realized they are dependents of the sourcing regime. In practice the development of these aspects increases in intensity and scope along the spectrum of grant-funded to commercially funded. It is the intensity of commercial (and managerial) activity that drives the financial management regime in any given setting.

As the necessity for financial management theory applied to library and information activity increases, the greater the level of commercial and market activity. In the commercial and market environment the base assumption can only be one of total uncertainty: financial management technique seeks to reduce uncertainty. Financial sourcing in this setting is derived from borrowing (under conditions of risk of default on loan) or current and future revenue streams (dependent upon market success). Reputation and competitive strength are clearly important in balancing likely risk and reward functions, and determine financial soundness and probity of the organization. Market economists hold these conditions to be stimulating and the best drivers in allocating scarce goods to ends. Even if information is sometimes economically nonscarce the resources that permit its managed distribution are scarce. The economics of information is conceptually problematic (see Boisot, 1998, for example) but its transfer from source to user is a transaction more akin to mundane commercial activity, whether publicly or privately financed.

But the application of financial management theory is affected by another decisive element: that of private goods versus public goods. The same information can be both a public good (available to a wider number at marginal cost) and embodied in a product as a private good (with a scarcity value reflected in cost and price). And the same piece of information can be maintained socially as a private good and also commercially exploited (see Kingma, 2001, for an accessible discussion).

The commercial enterprise has evolved in such a way as to become associated with the markets for private goods and products. Profits can be made as a reward for negotiating and overcoming uncertainty and risk. Normally, welfare/public goods supply has been associated with public agencies who have not had to operate commercially for profit, and who are able to operate outside the tightest discipline of the market; they can survive on financial losses if there is a public interest to be served and an ultimate source of funds. Needs and equitable distribution are the operational criteria. Any
loss is considered for subsidy should it still be desired. The public agency and treasury is the provider of last resort. Of course in the real world public agencies have more and more come to understand the value of respecting market disciplines (in the interests of efficient and stable government).

The consequences of information itself (and by extension information service) as potentially both public and private goods is a condition that somehow has to be squared with economic and financial reality. The nine business models (of financial sourcing) reviewed above reflect this problem quite clearly when real library and information organizations are matched against the model types. Grant-sourced organizations almost exclusively carry out public/welfare good provision whether for social, cultural, or economic reasons. On the continuum of grant-sourced to commercial organizations we can observe the gradual introduction of trading activity to replace public grant with market-derived revenues. In the last thirty years the number of gradations of models necessary to accommodate the variety of settings has increased as a response to structural and secular change as well as political preference, new opportunities, and technologies.

As the ICTs are now the most potent source of change in the library and information environment it will not be a surprise to implicate them as a driver of future financial managerial changes. But there is a history to consider too. In the U.S. and UK in the 1980s there were many debates about the future of public libraries and their function as much as their financing. Facing up to this debate was very important even if at the end the historical principles of public libraries as public goods seem to have been maintained. The purpose and funding of academic and research libraries has been similarly debated in the U.S., UK, Germany, and Australia to name but a few centers. The similar public good and welfare status was maintained.

But will it always be like this? A debate followed by a reaffirmation of the tradition? The debate on the financial managerial impact of the new technologies has been going for a decade at least. In collection management, the impact of electronic journals and now of digital and hybrid libraries are becoming clear (Cummings et al., 1992). We reserve this discussion for the closing part of this paper, but its kernel may focus around the relative aspects of information as public and/or private goods.

**Past and Present Philosophies**

So far the discussion has evolved around a conventional management axis. An analysis of organization development and financial management has resulted in a typology of business models by revenue sourcing. Future reform of practice could be achieved by locating a given organization within the typology (on intensity of need for and practice of financial management) and deciding to intensify (or possibly relax) the processes applied. First of all, to what extent has this taken place in the past?
Over the last fifty years an erratic yet persistent reform has been taking place. Library and information services seem to have been working towards a future model of rational organization and management. But the ‘normalization’ of library and information service management has been a game of catch up. Experts are more, rather than less, certain of the forms of rationalization, although the impact on practice and the academic discussion are still ragged and unresolved.

The predominance of grant funding has protected services from market rigor and shielded them from the stimulus of the market although often keeping them short of revenue. This may have been entirely good political economy. But, if it had been otherwise, society may not have enjoyed the obvious benefits delivered by great library resources and high levels of welfare provision. But, can the trend be continued when the future seems to promise so much change?

But pivoting around the infant years of the twenty-first century makes it pretty clear that a new economic (if not financial) perspective is being unveiled. Financial management (and its microeconomic environment) is largely focused on the inner world of the organization and its essential links to external reality. However much the inner world is perfected (by matching the business to the financial model) it is the external world/environment that provides the challenge. Where organizational financial management was once seen to provide a summative paradigm, the determinant in the future is going to be external and economic and more specifically macroeconomic.

A sufficient understanding of financial management in the organization is going to have to be matched with an enlarged understanding of the external environment and market. In essence, the well-founded library and information service has to fully comprehend the variety and complexity of its enlarged (even global) information marketplace. Striving to understand user behavior was once mainly a task to understand local users who had few choices other than to use your immediate offer to satisfy their needs. Now users not only have potential global access to information content but also to competing alternatives and services. Your service monopoly has been undermined or reduced. Now you have to compete and retain users by virtue of your offer and attraction. Because sooner or later their desertion to other providers will show up very clearly within your strategic financial model and at every point through the process model (by declining usage figures, poor performance and evaluation ratings, higher unit costs, and a weakened case for further funds from the grant sponsor). Later we will look at how the emerging trends are shaping the new macroeconomics. But first is it possible to identify a solid line of practice to give a firm foundation for the new outlook?
CRITERIA FOR RESOURCE AND SERVICE MANAGEMENT:
PRINCIPLES

Maurice Line (Line, 1986) set down some very useful principles which academic libraries should take into account in increasingly difficult operational times. By definition these are times of resource scarcity and encapsulate the need to behave and manage economically. These principles were quoted extensively in Roberts (1998) and are restated now (at the risk of repetition, but also out of respect for Line’s views) because the message seems as valid now as it was then. And perhaps because it does not seem that it is always heeded! Some questions which still seem relevant now and may still be largely unanswered are added. What goes for grant-funded academic libraries can go for others too in the public, scientific, and voluntary sector. These precepts for resource management are as follows:

On suggested principles for running a library, Line states:

the following are suggested as sound and defensible principles on which an academic library might be run.

(1) The library/information services required by the institution should be provided in the way that is most cost-effective for the institution. Nothing should inhibit the optimal use of resources made available to the library (as charging for selected services would, and as departmental control of the budget probably would). This implies that the institution (with the librarian’s guidance) should work out precisely what facilities and services are required to support the work of the institution, and what resources are required to provide these facilities and services. A similar principle should apply to every academic service.

Line’s stress on costing and financial context are as relevant now as then. Charging in the public sector remains in check and is confined to added-value services for individuals. A basic platform of service is defined and libraries strive to maintain it. The library bears the users’ costs. Libraries which are well-used are valued by users who may seek further increments of value—this may pressure up library costs and grant requirements. But financial resources devoted by hosts to service are tightly controlled. Cost-effectiveness is usually for the institution rather than for the user! But, good financial management does contribute to optimization.

(2) Within the library deployment of resources—of money, staff and accommodation—should be optimized. (This requires that the librarian should (a) explore alternative ways of giving each required service, (b) calculate the cost of alternative ways, including the existing one, (c) calculate the effectiveness of alternative ways. If the results of these exercises are to achieve full usefulness, the librarian must have the freedom to deploy his resources for optimal cost-effectiveness. This requires a quite different budget structure from what is the norm.)

Rarely are library managers the paragons of virtue that Line implies. However, they do consider alternative means of service, but usually when pressed by events. Costing is still a weakly developed area of technical ex-
pertise, which limits the knowledge base for action. Line implies the value of program budgeting which is far from the norm in the UK, but possibly more widespread in the U.S.

(3) The valid use of library resources—stock, staff, equipment and accommodation—should be maximized. (This minimizes unit cost per use and helps to provide a justification for the operation—or not, as the case may be, depending on how low minimal is. The same principle should of course be applied to other academic facilities.)

No one would argue with this assertion. But with converged library/computer services systems emerging some redefinition of which resources belong to whom may be needed. Old models of ownership and possession are less meaningful now. Networking and sharing require their specific legal basis. Understanding the value of resource inventories and asset registers is part of the financial management picture too.

(4) Abuse of resources should be minimized. (Where this conflicts with the principles above, it should normally be subsidiary to them. For example, heavy penalties or deterrent charges may minimize abuse at the expense of reducing valid use.)

This proposition should remind of the value of appreciating scarcity and giving the reduction of waste of all kinds high priority: waste of money, waste of time spent because of poor operational technique, and waste of resources through poor utilization. Efficient management and financial management go hand in hand.

(5) Individual members of the institution should not pay for facilities or services that they need to fulfill their function in the institution. This has been argued above under ‘Earning money’ (see the actual paper for the argument).

Line restates the primary reason for public grant funding, but there is a wider implication. Members and employees need at the very least adequate information support to fulfill their task needs. There is a gap between professional idealism and practice, and the levels of financial sourcing needed have to be considered.

(6) Whether the library should carry the cost of a facility or service or require departments to pay them should be determined according to cost-effectiveness. (As where the term is used elsewhere in this paper, ‘cost-effectiveness’ is to be interpreted broadly and in the longer term.) This criterion seems the only sound one on which to select activities for charging of all elements in library expenditure to departments, but this is very unlikely to achieve optimal cost-effectiveness (principle 1 above).

This principle shows that the library has to consider its business model. Categories (D) through (G) are relevant here and the strategy of creating internal markets has been tried for several decades. There is still no certain
answer as to whether collective provision is more cost-efficient and effective in practice. In theory it could be, but it will tend to push up the level of grant required. In some cases internal markets are expensive to set up and run, but in doing so can provide the institution with a workable management information system to supply the necessary costing and accounting data.

(7) The library should not transfer its costs to users. [Although the library may not charge users directly, and although it may not even charge departments, the reduction or cancellation of some services (such as personal assistance with manual bibliographic searches) can make the user incur costs, if only in time, that he cannot recover from the institution.].

This principle firmly places a strong social and economic public duty on the service.

Libraries have to face financial and economic responsibilities and consequences. To do so they need the clearest vision and mandate upon which to operate. To support the achievement of Line's principles, financial management in all its aspects has to be present and ever strengthening.

Line then goes on to outline some solutions to economic pressures:

if the reasoning above is sound, the following are the measures that might reasonably be taken to mitigate economic pressures.

(1) Services can be provided to external users, particularly industry, for payment. (This can range from allowing external users and institutions access to the stock, to the provision of specially tailored services which recover more than they cost. Pump-priming may be needed. This could be a highly attractive course; some industries (as noted below) are contracting out their library and information services, and there is no fundamental reason why academic institutions should not make a bid. The extent to which staff attitudes may need to be changed—in the direction of entrepreneurship and giving value for money—should not be underestimated.).

(2) Economies can be sought in fulfilling existing functions. (This requires a radical scrutiny of every function, an exploration of different ways of achieving it, and a choice of the least costly. All costs should be taken into account.).

(3) The use of the total budget should be optimized (This requires: (a) an adequate costing system, which calculates regularly the cost of all activities and services, including unit cost. (b) a financial control system, to ensure that expenditure is properly controlled from month to month. These can be implemented with any budget structure, though they require, certainly initially a good deal of effort. More fundamentally, optimization requires: (c) a budget structured by function, cutting across staff, acquisitions, equipment and other recurrent expenditure (and possibly accommodation also). Virement between these expenditure heads would be necessary. The budget would be divided into: (i) Information services; including cataloguing, database searching, reference services, SDI etc. (ii) Document provision; including acquisitions, interlibrary document supply, electronic text access etc. Although virement may be hard if not impossible to achieve, a mere
paper exercise along these lines will be very revealing; for example, if acquisitions and interlibrary access are seen as part of the same budget, an optimal balance is much more likely to be attained.

(4) What is required to provide the institution with the information it requires to fulfill its functions should be determined. (This is a longer-term exercise, but it should put the library/information service on a far sounder footing than has been customary. A similar exercise should of course take place for every function and activity of the institution: the library should not be the only operation exposed to this kind of zero-based budgeting. The exercise would include the development—and use—of performance indicators.)

(5) A forward plan should be constructed, taking account of the likely pressures, technical developments, changing needs etc., to try and ensure that appropriate future provision is made.

Line’s advocacy of program budgets is significant, as is the insistence on the centrality of cost information, and his view that performance measures have a place in a wholly integrated budgetary and resource planning cycle. More than fifteen years later Line’s analysis seems as valid as when it was first presented. Now, features which were embryonic are commonplace (the Internet, the World Wide Web, the diffusion of personal computing, mobile communications, multimedia, and integration) with all their impacts of user behavior and communication. Is library and information service management really dealing with these challenges?

**FINANCIAL ESSENTIALS: PRECEPTS AS THEORY**

Roberts (1998) surveyed the resource management process and outlined the requirements of contemporary library and information managers. These are: planning and programming; delegation and devolution to internal business centers; explicit budgets and budgeting; rich information bases for action and decision; modeling and quantification; behavioral awareness; and, costs and other decision tools. The requirement for physical and financial resources was treated as implicit then, but is stated explicitly here. From the viewpoint of the three aspects of financial management (sourcing, deployment, and utilization) these requirements can be configured to fit the model of financial management.

Physical resources are an implied given although differentiated by characteristics and circumstances. The existing and currently available resources are assets which can be represented by monetary values which have depended upon past and present financial sourcing. To maintain them and expand them will require future access to financial resources.

Planning and programming (reflecting the purpose of the service and its goals), explicit budgets and budgeting, and the use of costs and other decision tools are the three requirements which constitute financial deployment.

Delegation and devolution to those responsible for operations is the requirement which enables financial utilization to take place. The effective
use of financial resources has to take place in its managerial context, in order to achieve both efficiency and effectiveness. Of course, this does not always happen in practice. Lack of supporting and enabling systems mean that managements tend to retain central controls over operational details by default.

Quality information systems enable managers to have strategic oversight of operations whilst at the same time enabling confident delegation to those closest to operations through the creation of business centers as autonomous and sustaining centers of activity. Devolved budgets can effectively enable operations but there must also be a mechanism to link together devolved elements for oversight.

There are three underlying managerial requirements: rich information bases for decision and action, processes of modeling and quantification, and behavioral awareness in the social as well as the technical domain. These requirements underpin financial sourcing, deployment, and utilization.

Can these requirements be translated into financial management principles to correspond with the practical operational principles Line has offered (for academic libraries in the first instance, but possibly for the range of library and information management activities)? The following interpretation is now suggested.

A. Actual and potential resources have to be financed from a source. This embodies Line’s (1) “The library/information services required by the institution should be provided in the way that is most cost-effective for the institution.” A largely publicly funded educational institution (a grant receiver) is thus likely to fund its library and information service in the same fashion. If the library information unit is not commercially freestanding, the host institution is the determining financial source. The principle implies that the information service resource (of whatever kind) has to have a visible and viable financial source. There has to be a clear way to answer the question: who is paying for/supporting the costs of this information?

Library and information development and service should stem from clear policies reflecting user circumstances and needs. Proper consideration of needs will identify the scale of requirement and the best source (of funding) to match the needs. If there is no policy, little can be expected and ultimately less will be achieved. If the service is to be open and public then public grant sources are a rational solution. If the product of the service is for private gain (rather than for a collectivity of individual gains) then public grant sources are not indicated.

Line’s (5) “Individual members of the institution should not pay for facilities or services that they need to fulfill their function in the institution” is best linked within this precept since it is a consequence of his precept (1) (above). Meeting user requirements is an institutional responsibility: this is very clear in a public/grant-funded setting. Therefore, the financial consequences have to be recognized and borne. The public library rate
precept and the spend-per-student capita are direct reflections of these principles and are used to define financial revenue targets.

B. A financial planning process (within overall planning) has to be effected with programming concordant with the purpose of service and the relevant goals, aims, and objectives. Line’s (2) is covered in this principle “Within the library deployment of resources—of money, staff and accommodation—should be optimized.” The principle of optimization is rooted in recognition of the mission, goals, and aims of the service. These features reflect fundamental needs as expressed in policy (strategically and operationally).

C. The planning process provides the basis for explicit budgets and budgeting. Line’s (3) states “The valid use of library resources—stock, staff, equipment and accommodation—should be maximized.” Policy provides the rationale for the planning process and the allocation of resources. Budgets and budget processes provide the structures for maximizing the use of resources. Modeling and quantification are the tools to enable this process, but require rich bases of information for decision and action.

D. Systems are necessary for the collection of costs and the development of other decision tools. Financial management is a type of information management. Cost collection and other parametric information systems have to be in place to carry out the information management function. It is only within an information rich environment that Line’s (4) “Abuse of resources should be minimized” can be achieved.

Optimizing and maximizing processes are ways to minimize “abuse”—that is to say, inappropriate and wasteful allocation of financial resources. But in reality, library and information services may have little precise idea on the rates of financial wastage in their systems. Accounting systems merely record the flows in a context and value-free manner. Accounting data have to be used managerially, in a sense incorporating quality and behavioral judgments.

E. Financial utilization takes place in various stages and conditions through delegation and devolution to those responsible for operations. The most autonomous realization comes through the creation of business centers as autonomous and sustaining centers of activity. Line’s (6) is reflected in this precept: “Whether the library should carry the cost of a facility or service or require departments to pay them should be determined according to cost-effectiveness.” This can be translated into “whether the library and information function is a social/institutional overhead or a commercial business center.” The decision to accept the financial consequences at a given point on the welfare-to-commercial scale stems from policy, once again underlining its importance in financial management.

Line’s (7) “The library should not transfer its costs to users” is a consequence of his (6) but it is open to variable practical interpretation. Policy could come to the rescue here. Service to a small group may not be cost-effective, but policy could be used to justify a subsidy. In practice there is con-
siderable margin to be exploited. A subsidy may be justified now on grounds of opportunity costs (it represents the best use of money) and it can be discounted against future benefits and value added. But making the linkage between present costs and financial conditions of service provision against the future benefits and values of information provision is one of the most taxing issues in the realm of information management and economics. At the moment financial management practice does not usually make the synthesis, although the academic literature discusses the theory substantially.

There are three underlying requirements, which are not directly related to Line’s principles, but are clearly important for effective financial management:

F. Rich information bases for decision and action, and G. Processes of modeling and quantification have appeared in their context especially in C. and D. The application of cost measurement and cost-finding techniques provide the basic information for constructing budgets, resource deployment, and monitoring the transformation of resources into service and product. Equally, a good knowledge of resource prices, inventories, and value of resources in process is essential. Furthermore, cost control, budgetary control, measures of output, and performance measures in general contribute information for decision and action. The ability to model options quantitatively (using price, cost, and performance information) is also vital in the consideration of resource allocation and detailed budget construction. Lack of information and an ability to manipulate it creatively will reduce the reach of financial management.

H. Behavioral awareness in the social as well as the technical domain. Sensitivity to the impact of human factors, social processes, and the consequences of undertaking an activity (using professional techniques and technologies) implies a need for behavioral awareness. For example, time and cost measurement of work processes is straightforward as technique, but requires skill and sympathy to carry out with a working group. Measuring the work process may be interpreted as a threat or criticism. The work process needs to be measured as part of effective financial management but has to avoid negative social disturbance.

In general this precept implies the recognition and incorporation of a whole range of human, political, and psychological factors into the financial process. These are nonfinancial factors with a bearing upon the financial process. They are difficult to quantify and therefore difficult to formally evidence in the management process. But they are nevertheless evident and present. These behavioral requirements underpin much of the policy and organizational context for example in precepts A and B.

Aligning Line’s principles to the requirements for financial management identified by Roberts suggests a good fit between the two. At the gen-
eral level it would be worrying if they did not, but it is what is evident in specific bodies of practice that is the real concern. From the analysis made, the application of a high level of cost management and budgeting processes would seem to be an essential requirement.

If this paper serves as a commentary on the author's attempt to produce a synthesis on the topic, a search of the post-1998 literature reveals relatively little advance in academic interest or practice. It is difficult to rewrite the conclusion posted in 1998 about essentially limited innovation and improvement in practice in the central concerns of cost measurement and budgeting. But, the debates on essentially macroeconomic topics have continued to grow. We move on to review these issues before attempting a conclusion for 2002.

**Emerging Trends: Macroeconomic Environment**

So far the discussion, although complex enough, has been of a linear character looking at financial affairs through a microeconomic perspective. Now we must acknowledge reality and introduce dimensions of complexity through a macroeconomic perspective. This allows the incorporation of the external environmental features which constitute much of the real working environment of library and information provision.

The concept of the user has come to occupy a central position in library and information service theory and practice. The user studies movement has provided some intellectual backbone with a focus on information needs and requirements.

This has provided some theory to underpin practice developing the notion that all information service should be user-centered. A greater understanding of the user has helped to sharpen and prioritize service policies. It is from this that the connection to financial management can be made and reflected in precepts A and B.

User needs provide the focus for resource allocation and studies of use and demand have supported this. The user aspect has to be understood since financial sourcing is justified through the user (more accurately, the consumer/customer in a commercial setting). This leads to a fundamental financial question: how much to spend on behalf of each user and who should bear the burden in each setting—the user/consumer/customer (private and commercial) or the institution (public and welfare)? Spending per-capita figures can be elicited historically but are difficult to predict in terms of need. In a fully commercial environment, market opportunities and demand determine resource and production levels. Perceptions of user need (from a welfare stance) are the equivalent of market opportunities and demand in the grant-funded public sector.

The library and information sector has grown steadily in terms of its professionalism; few would doubt this assertion. But a question is often posed about the actual or potential conflicts generated between the pro-
professional and the managerial role and perspective. Professionalism is foremost a social construct imbued with aspirations and ethics. These aspects are not easy to negotiate financially. It is usually wiser to entrust the financial responsibility to those who can best balance the professional with the managerial. This has opened up divisions in library and information organizations as professionals feel that materials funds are inadequate, technology budgets limited, staffing levels insufficient to deliver service, and so on. Is the sometimes-felt lack of financial clout of the library and information service field due to this professional/managerial conflict?

The library and information profession, however defined, has become accustomed to taking on new responsibilities. Many identity and boundary crises have been addressed and often resolved beneficially. Technology has pushed and pulled each professional generation. But new responsibilities carry financial obligations and consequences. Competitively and strategically the information sectors most closely allied to the ICTs, the private sector, and the commercial world generally have been more successful financially (although corporate libraries have been closed and their functions dispersed). When the public sector of library and information activity has wished to respond to new opportunities it has found it difficult to do so from the grant-supported base. The funding of new technologies has been an Achilles’ heel, to which funding agencies and grant providers have had to respond ultimately with new money. In UK academic libraries the Follett report and the Joint Information Systems Committee have addressed responses to the ICTs with new money, and similar developments have been required for public libraries and the New Library Network. In the U.S. there have been similar initiatives.

The ability to innovate in times of rapid change has become a test for the library and information profession and especially for its public sector/grant-funded agencies. For financial management the consequence is clear: more capital spending and new operational money are required. If this is not forthcoming there has to be some deregulation and engagement in commercial activity for which they are not naturally well-suited. Corporate sponsorship and joint ventures may be a way forward to overcome difficulties and disinclination.

Converged services were an early response to technological change. A converged service results from the integration of computing-based and computer services activities with traditional library and information services. It has been a common occurrence not only in academic libraries but also in business organizations where it is sought to bring all information functions together strategically. Apart from the hunger for more funding necessitated by restructuring, converged services present challenges for governance and for planning, budgeting, and accounting. Convergence increases the mass of the information-related overhead expenditure, the complexity of operational tasks, and their management.
The hybrid library does not necessarily have to form part of a converged service, but in practice it usually is, and the convergence itself creates the conditions for the maximum exploitation of digital resources. The hybrid library concept has initially become associated with academic library provision as part of the creation of the digital campus. It is essentially a delivery mechanism to acknowledge and ensure the continued service of the traditional paper/document-based library combined with the provision and exploitation of digital resources. In the longer run the hybrid library concept will spread to all library and information sectors. Hybridization and convergence are powerful influences in the personal sphere where PCs, hardwired telecommunications, and wireless and mobile technologies are changing the relations between individual users and the whole range of information and media provision and use in the widest sense.

In some ways the hybrid library defines a fault line with the historic library. The dematerialization of information (no longer delivered through a physical document format) has radical consequences for the financial management of library and information service (Roberts, 2000 and various papers in Gorman, 2000). In buying a document, the library constructs a certain ownership which it combines with the duty of user access. In the hybrid collection, digital resources are bought (under a range of vendor-buyer arrangements) or payments made for access to them. The simplicity of purchasing a document and retaining it is replaced by purchasing access and/or the need to maintain the digital resource. The financial requirements of managing and maintaining technology-based access are demanding.

Digital collection management has emerged to complement document collection management. The financial impact of digital collections in academic and research libraries is a topic of much recent interest and professional writing (Roberts, 2001a). Financial pressures had been felt very keenly in the management of traditional collections. The new media provided novelty and opportunity, and perhaps offered a release from historic pressures of collection funding. In reality digital resources are not likely to be cheaper to acquire or lower cost to operate, since relatively high capital costs are involved and regular maintenance charges are a feature. Nevertheless, digital collections offer vastly increased (and possibly more efficient) access to information. Coupled with the flexibility and manipulability of digital media such resources may offer good value for money.

In traditional collections there are one-to-one relationships between units of spending, acquisition, and use. In digital collections one spend usually gives multiple acquisitions (in the form of access) and use. In the future this may lead to user-access funding instead of collection funding as a major financial priority (Roberts, 2001b). This may have serious implications because, despite all its problems, collection spending does lead to the acquisition of physical and durable assets. If the library is grant-funded its income will be spent on subsidizing access through user charges with-
out increasing assets in the form of collection materials. Digital publishing initially would seem to strengthen the hand of publishers and weaken the power of library consumers. Publishers continue to have a strong interest to protect their intellectual property and maximize its economic exploitation through access charges (Roberts, 2001a); and furthermore, the environment is a real time one. Digital media can be updated easily and publishers naturally wish to protect their rights of exploitation. Libraries have responded by negotiating licensing agreements and developing library networks and collaborative arrangements to strengthen their buying power. Licensing provides a compromise between pay-per-use and unlimited use for a segmented user base.

In the sense that financing collections has been at the core of library finance, the arrival of digital media is likely to be one of the strongest influences on future financial management. On the other hand, publishers and library and information services do have many mutual interests which can be managed to achieve mutual success (see Roberts, 2001a, for a further discussion).

Access policies are a traditional professional concern and a consequence of the growing importance of digital resources. These policies form a response to the macroeconomic environment. In grant-funded institutions user members’ access to information was implied and subsidized. But as the range of sources has grown, many are located outside and distant from the institution. This raised the financial question of who was to pay for such external access, for if no one paid, users were denied access. The access to external services theme arose in the 1970s with online database access, but was well-established before within the scope of interlibrary lending and borrowing. External access has created a financial burden, and a consequence of it has been the development of commercialization across the information sector.

Information markets and marketing naturally emerged as a theme from the growing external sourcing and commercialization of information. Information services in a commercial environment had little difficulty with this as they simply incorporated the costs of information access into product prices. But grant-funded welfare operators were faced with a tough problem. At first the response was to ask for more from their sponsors, but this rarely led to extra finance to meet growing user demand (e.g., online bibliographic access). Changes came about by the adoption of the business model in the direction of commercialization.

The gradation of business models considered earlier in the paper is in some ways the response to this problem. Commercialization and income generation was the only way to move ahead. But all the while, this promoted a conflict among professionalism, markets, and user needs. Over the last thirty years the information service markets have become more diverse and specialized. Grant funding has remained more or less constant and inno-
vation has increasingly been funded by commercial activity. This is a financial managerial truth that cannot be baulked, but one that hurts the public sector and its users.

Public-private sector relations emerged as a theme as a result of these developments in market diversification. The new economics of the 1980s evolved a preoccupation with this theme. Certainly in the UK it became a major issue, on the one hand sometimes carrying negative connotations and on the other hand, more positive ones. In the 1990s UK, the theme became an orthodoxy and an avenue for encouraging managerial creativity. Financially, it has opened up new sources of funding through commercial sponsorship: creative dealings are no longer entirely frowned upon. But new money also has to be shown to be clean money. Good accounting systems are increasingly needed to assure information to guarantee political transparency. “Partnerships” could provide a politically correct vehicle to resource what the public purse cannot or will not do, and the idea of ethical businesses helps to keep a favorable public image. The financial and the political go hand in hand!

If we are to look ahead, virtual information environments may become the dominant information systems. This will be a combined technological, professional, and economic macroenvironment. To look to the future is one task of this paper to try to see what implications lie ahead for financial management. Hitherto, the financial and business models have been largely organizationally based. The need to meet the requirements reviewed above will not diminish, because library and information providers will still operate within this model. But the virtual environment will provide a framework for multiple transactions between users and providers and the mechanisms of e-business and m-business will facilitate trading.

Knowledge management is a current paradigm in the information and library sector and is a shaping force in future economic and business activity. It has been extensively discussed and reviewed in terms of its importance to private and public environments (e.g., Stewart, 1997; California Management Review, 1998). It is likely to evolve into forms which allow greater convergence and integration of information sources, delivery systems, user needs, and contextual environments (occupations, tasks, etc.). Virtual and digital environments are ideally suited to knowledge management but are far from being an exclusive domain. Information, knowledge, social action, learning, change, and adaptation form a strategic macroenvironment of great complexity and power forming a matrix for the digital virtual environment. What will be needed are economic and financial tools which can assist the management, measurement, and control of these processes.

In the short to the medium term, the conventional financial, budgeting, and accounting tools are necessary and adequate. They are standardized and durable and should be adopted by organizations: the benefits from application will outweigh the costs. In the longer term, digital and electronic
technologies will manage processes as well as provide a means of control through transaction processing. It is not too soon to look ahead to see how new financial and accounting technologies could be exploited for better financial deployment and utilization. A line of evolution from swipe cards to stored value cards and on to PDAs and wider corporate transaction systems and automation will open further potential for resource management.

**FUTURE PROSPECTS: PRACTICE**

A number of lines of development can be identified. But first some assumptions have to be stated.

- For the commercial information provider (types (H) and (J)) standard business financial practices have to be employed for sourcing, deployment, and utilization. In this environment all the objectives outlined below have to be achieved.
- For the grant-funded providers (types (A) to (D)) the limitations of fixed funding and limited sourcing flexibility have to be understood. Clear service policies are needed to determine spending priorities. For types (E), (F), and (G) the requirement to meet these financial management objectives is more intense and exigent.

The objectives for financial management are as follows:

- Financial sourcing in accordance with organizational, user, and access policies.
- A planning and review mechanism is required and used in conjunction with an explicit and workable budgeting system.
- Resource and asset inventories are required and a system of cost finding developed and maintained.
- Proper financial deployment structures and techniques are required. These have to be reviewed and deficiencies dealt with as necessary.
- Process and unit costs should inform budgeting.
- A program-activity budgeting system is required, and although grant-funded operations have tended to make do with line-item budgets, some reform is required.
- Budgeting has to develop an informed managerial style without compromising professional standards.
- Budgeting systems have to provide a foundation for cost and management accounting as well as more conventional stewardship accounting.
- Implementing these deployment processes will enable effective financial utilization. Cost finding and measurement systems are required for deployment but have to be maintained through the utilization phase.
- Financial utilization has to be developed to incorporate systems of budgetary, cost, and operations control. Throughput and output processes are to be monitored through the construction and use of performance measures.
These are basic assumptions that have to be fulfilled in every information service provider organization. With these in place, future challenges can be faced. A number of challenging themes can be identified which require financial management responses.

Organizational Financial Management. It is safe to assume that there is scope for improvement in every organization: in securing funding streams, cost measurement, budgeting processes, management information, and in cost efficiency especially where commercial activities are concerned. Each organization needs to review and define explicitly its financial management requirements in the areas of sourcing, deployment, and utilization. As providers came to see the value of written collection and user services policies, so should the same be done for financial management.

Financial management policies and techniques need to be visible and explicit as the core of microeconomic management. Only in this way will the growing need to master the external macroeconomic environment be achieved.

Electronic and Hybrid Resources. The expanding production and growing market distribution of digital resources is likely to have the greatest impact on macroeconomic financial management. The coverage and integration of digital resources will be a significant resource cost, but will also raise new service costs. Although libraries may increase their contribution to content production and engage in commercial activity, the cost burden will be generated by continued needs to make effective content management a focus of service. The information center will therefore remain a consumer of content and in a welfare setting will have to cover the costs of consumption for their clients. Grant-funding budgets will be challenged by this and centers will have to demonstrate value gained through cost and financial measures. These service costs will not have the added advantage of generating asset values through collection spending and materials accumulation.

Clear financial management strategy and good technique will be essential to assure grant funders that the best value is being achieved. Digital providers and publishers will exploit their intellectual property aggressively to maximize returns on investment. But, Roberts (2001a) has argued that the symbiotic relationship between publishers and information service providers may show the value of collaboration rather than competition and exploitation as the best mutual response.

Collective versus Individual Responsibilities

The association of welfare provision, public service, and grant-funded financial sourcing is a solid manifestation of collective responsibility for individual needs. Historically, information and library service financial management practices can be seen to have evolved to support this association.

When funding provision is adequate, or even generous, the relationship works well. However, the financial stresses which have become widespread
in the sector since the 1980s have led to some adaptation and innovation. There has been little alternative to adopting a more commercial market orientated approach and to consider selectivity and differentiated service levels as concomitants. When grant-funded budgets are perceived as less than adequate to meet needs, commercial and market activities are seen as a way to either generate income or transfer consumption costs from the collective to the individual. This may, of course, be at variance with the prevailing professional ethic which historically is towards public service, which when adequately funded can be economically efficient. In these settings financial management enters a political realm as much as an economic one. Just where the line lies at the moment is an important question. If the line moves towards the individual and the market it is clear that financial management is both more central to the process and has to be more evident and stringent.

User Consumption Models. The professional service environment has always presented a mixture of welfare and commercial aspects and within each strand a working equilibrium is usually achieved. But problems arise at the boundary of the strand: for example, when a free at-point-of-use service introduces a user charge. The impact is usually greater on the welfare service user than on the private sector commercial user.

Under an equilibrium condition of public support for individual social needs, existing financial management technique in the welfare sector may be adequate even if capable of improvement. In the commercial sector, market mechanisms and financial discipline are largely homeostatic anyway. When adjustments seem to be necessary in the welfare sector it is the individual user in the collective who feels the impact and who senses the aggressive intent of financial adjustments. Pay-per-use and explicit individual consumption models are the most common sources of disturbance, because they undermine the consensus of collective provision.

Offering Service and Added Value. Where the macroeconomic conditions require greater financial managerial discipline, the professional response is to stress the relation between service and value. Claims are made that users tolerate charges because they can be associated with service efficiency and added value. Users have to define their needs more clearly; the service provided may be better targeted and they value what they have to pay for. This inevitably highlights issues of cost and price, and poses a question about ideal levels of resource support and where that support comes from.

Charging for services has been a highlighted feature of the information sector for more than thirty years. For-profit services have seen their markets grow and new services have been developed using the technologies; appropriate financial management has underpinned the exploitation of opportunities. In the welfare sector greater tension has been created as conflicts between public and private good have arisen. Services have thus found themselves operating across both sectors, but often with insufficient
financial management experience or apparatus. In spite of an extended period of learning, these tensions remain. More formalized financial management may be the only remedy: it can support commercial activities and at the same time enable more rigorous justification of welfare spending. Public sector efficiency is no longer politically incorrect!

Information and Knowledge Life Cycles. The information and library sector works with a unique asset: information itself. The profession has long been fascinated (as much as perplexed) by the nature of information. Historically, the information service product has been transacted and exploited through the physical embodiment of information—the document. Like any other physical asset this is subject to depreciation and obsolescence, which may necessitate capital replenishment. In the digital environment the life cycle of information can be prolonged, with reduced (physical) depreciation, albeit with maintenance costs. With the ability to extend the information life cycle, assets can be conserved, but a corollary is that review and weeding may become more important to ensure relevance; this may incur additional costs.

We can envisage some consequences for financial management as a consequence of the shift to digital media. Expenditure on access and maintenance will increase, and that on physical document assets may remain stable or decline. Editing and review in managing content may turn out to have strong financial consequences since expensive human assets are required for the task. The patterns of these changes are likely to become much clearer in the next few years. Certainly, operational patterns of activity will change and these will have internal financial consequences requiring rebalancing of deployment and utilization.

Within the emerging knowledge management paradigm these features will be intensified. In general, knowledge production and life cycles are more complex than for the information component alone. They pose the problem of financial management and accounting for implicit and intangible assets. We can predict that information and knowledge operations will account for more expenditure and require even greater financial vigilance. We have yet to make the links between information and knowledge accounting and its financial side, but this should provide a research agenda in the coming years.

Intellectual Property. The growing visibility of information and knowledge assets and their communication and transaction has led to the increasing realization of their value. These assets form intellectual property, whether or not embodied in any particular media. This perception should really be welcomed by information professionals who for many years have campaigned around the value, resourcefulness, and purpose of information. But its commodification has to be rationalized with other professional and ethical values and this creates angst for some in the process. Whilst intellectual property embodies a moral and legal component at its base, the
economic component is realized through the communication implicit in the cycles of information and communication activity.

Values and Ethics. Professional values derive from and represent the social conscience of those active in the world of information. The development of the professional and occupational group has been associated with a consideration of such values: professional obligation, public duty, access to information, information and citizenship, privacy, confidentiality, security, and so on. Financial management itself has its value framework of accountability, transparency, reporting, audit, and review. In reality these technical and professional issues, however different, have to be dealt with under the same common framework.

Weak financial procedures are not only a technical and operational threat, but may hinder the realization of the wider framework of values which ideally bind service professionals to their clients. Financial procedures do not create the system of values but they do positively help to maintain it. For the future, financial managers must strive not only to be technically competent within the organization but must ensure that these tasks are conducted in the spirit of the collective values required by the profession. Herein lies the ethical dimension which maintains the system of values. Equality of access and equity of provision are key issues with clear financial consequences: greater accountability will generally assist greater equality.

Resource management inevitably encompasses a political dimension. Scarcity of resources necessitates consideration of priorities, interests, and choices. Decisions have to be informed by direction, by policy, or by political desire or need. The political aspect may be more or less explicit. Grant- or tax-funded public libraries often incorporate political policy in resource and financial decision-making. In a commercial setting, information sourcing decisions should reflect business purpose, but this might imply a political element as one view prevails over another. Political processes incorporate values and may also maintain a strong ethical element. Clear financial managerial models play a part in mediating the political dimension as much as they do the economic one and thus have some effects on the values culture. In the organization, decision-makers have to balance resource allocations and may use the principle of equity as much as need. A decision one way rather than another may require a compensating explanation.

Fuzzy Environments. From the foregoing discussion it must be clear that the macroenvironment of financial management is not only diverse and complex, but also fuzzy and indistinct. That is to say that relativities play as important a part as absolutes. At first perception some see financial management as quantitative and numerical; this may be to confuse the accounting with the managerial purpose. In reality financial management is substantially qualitative, social, organizational, and political. Seeing what should be done is as important as the actual doing of it and this vision should always be clear at the first stage. But fuzziness and complexity are not an
excuse for lack of clarity or any other half-hearted views of action. Financial management is strategic management in which once the course of action is set, the need is for excellent technical systems for implementation, operation, and control.

**Practical Consequences for Stakeholders**

Financial managers need to recognize a number of issues in practice. They need to recognize their stakeholders and try to maintain policies for decision which uphold stakeholder interests.

Users should be seen at the heart of the financial management of the information service. Financial management is a means to achieve proper ends. The user and customer need has to be incorporated in the strategies and policies from which operational and financial goals, aims, and objectives will be developed. A key question to ask is to what extent and how these user interests are met in practice. To provide quality service free at the point of access has its financial consequence most keenly felt by users when charges are introduced and costs are transferred. This may be exigent financial practice but not good financial management from a user perspective. Service costs should aim to minimize user costs for a given level of service specified through a policy.

Information professionals are not always the financial managers so they need to be separately distinguished as a stakeholder group. In giving service, this group is at the sharp end, having to mediate financial decisions through the customer interface. The financial manager, in considering the overall requirements of the organization, needs to think in terms of the power (or lack of it) that expenditure delivers to the working information professional: this has a capital as well as a current context. A financial manager has to see the capitalization of service professionals as a serious measure of success in the same way as an automobile production manager sees machine investment per line worker as a measure of standing. There is much scope for financial managers to sensitize around these stakeholder issues. In practical terms, program and output budgeting helps to realize these perspectives by enabling the calculation of useful measures and ratios to inform decision-making, and to relate resource inputs to outcomes.

The financial manager may enjoy considerable power and influence, but in the organization, he is also another stakeholder interest. Managers have to work within the power role, but they also need friends so as to exert influence! Multiple-way communication thus takes on significance in financial management because command and control rely upon compliance. Those injured by poor financial decision-making tend to comply less willingly, although they may be compelled by duty and contract.

Financial managers have to develop effective relations with stakeholders to achieve their performance goals. In effect they play the role of the banker and have the power of the bank, but this must be tempered by good
customer relations which encourage good business behavior and conserve and increase customer capital. Anyone with financial managerial responsibility would do well to consider these points in practice.

CONCLUSIONS

The delivery of information services (of whatever kind) can take place over a broad spectrum of organizational and business settings. Resource requirements and their financial management (financial sourcing) show variation over the same spectrum. How much is to be spent is, to an extent, governed by who provides the resources reflecting user needs and demands. What is the trend? In the public sector the collective has the initiative and the power to determine the relationship, and resourcing is a matter of policy foremost. In the market sector the consumers enjoy considerable power through their desire to purchase or not; all managerial decisions however distant have to follow these trends. These two boundaries determine the trend. Balancing public and private interests in the information market was and still is the question to be resolved. There are still any number of answers! But professional as much as managerial judgment will provide them.

Questions formulated and papers reviewed some fifteen years ago (Roberts, 1985) were more recently reviewed by the same author (Roberts, 1998). Has any variation in the trend occurred since then? It appears that the environment is still changing more rapidly than the techniques and the lags in practice noted above still seem to be maintained. Financial management (and deployment in particular) is still cottage industry rather than industrial and managerial.

The technical response to financial management can be advocated and achieved, but is nothing without the context of need and policy. Furthermore, a range of organizational competences can be developed to provide a basis for services. But, beyond that, the effective management of the information resource component is still challenging. Experienced information professionals know that information and library activities are substantially complex: as complex as any medium-range business enterprise. Managers thus have to increase their command over their microenvironment in order to have any chance of dealing with the wider macroenvironment.

This then is the proposition: each professional and manager must ensure that the financial management basis is as well-ordered as it can be. Assume the future to be more complex and turbulent than the past. Hopefully, this review can stimulate thought, debate, and even action. By offering some checklists, discussion points for debate are presented. Line's principles seem as sound as ever and echo a wider and continued interest in the subject of managing library and information services. These principles can and have to be adapted to the new hybrid and digital environments of information and knowledge work. The paper has tried to highlight the financial subtext within Line's general principles. The practical objectives
of financial management need to be checklisted and addressed through policy and action points by every provider so that clear lessons for practice can be drawn.

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