A Holistic Approach to Supporting Academic Libraries in Resource Allocation Processes

Lorena Siguenza-Guzman, Alexandra Van den Abbeele, Joos Vandewalle, Henri Verhaaren, and Dirk Cattrysse

ABSTRACT

E-content revolution, technological advances, and ever-shrinking budgets oblige libraries to efficiently allocate their limited resources between collection and services. Unfortunately, resource allocation is a complex process due to the diversity of data sources and formats required to be analyzed prior to decision making, as well as the lack of efficient methods of integration. The contribution of this article is twofold. We first propose an evaluation framework to holistically assess academic libraries. To do so, a four-pronged theoretical framework is used in which the library system and collection are analyzed from the perspective of users and internal stakeholders. Second, we present a data warehouse architecture that integrates, processes, and stores the holistically based collected data. By proposing this holistic approach, we aim to provide an integrated solution that assists library managers to make economic decisions based on a perspective of the library situation that is as realistic as possible.

Amid limited funding resources, libraries strive to efficiently deal with technological advances and the e-content revolution (Bertot 2011). In fact, academic libraries face hard budget constraints due to the global economic crisis (Sudarsan 2006; McKendrick 2011). This dilemma stems from library services usually being "free of charge," but not free of costs, and strongly dependent on public funding (Stouthuysen et al. 2010). As a result, despite cuts, mergers, and budget freezes, libraries must create, maintain, and improve their services (Cox 2010; Guarria and Wang 2011; Cottrell 2012). Furthermore, the latest technological advances and the e-content revolution, such as the growing presence of e-books and the proliferation of tablets and mobile devices, have influenced the manner in which information is disseminated

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and consumed (Allen Press 2012; Brook and Salter 2012). As a consequence, academic libraries are rapidly reallocating budgets from print to digital resources. For example, David Nicholas and colleagues (2010) report that although e-books still account for a small proportion of total spending—approximately 5%—this figure is rising rapidly. Online content facilitates managing information and is often cost-effective and more easily accessible than printed resources; however, it also contributes to increasing the complexity of the resource allocation process (Poll 2001; Chan 2008; Guarria 2009). For instance, one problem with a subscription-based digital library collection is the variability of yearly prices that has evolved over the past few years (Allen Press 2012). Furthermore, in order to provide these e-services, academic libraries have to deal with challenges such as the lack of uniformity in license terms, lease conditions, access restrictions, and librarians' expectations (Walters 2013).

Dynamic components such as the e-content revolution, technological advances, and ever-shrinking budgets constantly force libraries to be more innovative in providing, justifying, and evaluating the effectiveness of their services (Blixrud 2003; ACRL Research Planning and Review Committee 2010). David J. Ernst and Peter Segall (1995) state that institutions in these difficult circumstances are called upon to develop a strategic and well-coordinated budget plan by means of a "holistic approach." The objective of the holistic approach is to help organizations define a set of measures that reflect their objectives and assess their performance appropriately (Matthews 2011). The holistic approach requires interconnecting all necessary components in a way that responds to both shrinking resources and dynamic library services. Unfortunately, interconnecting and analyzing all the heterogeneous data sets are complex processes due to the large number of data sources and the volume of data to be considered. Therefore, the aim of this article is twofold. First, we present a holistic structure and the required set of tools for collecting data from an economic point of view. The holistic structure uses a theoretical framework based on a two-dimensional evaluation matrix (table 1) in which the library system and its collection are analyzed from an internal and external perspective. Second, we propose the design of an integrated decision support system that combines, processes, and stores the collected data.

Theoretical Background

A budget is a financial plan that normally reflects the organization's priorities; through this, managers boost important activities by allocating enough resources to them and ration resources for less important areas of an organization (Linn 2007). Many approaches of budgeting systems have been proposed in literature, such as incremental-line-item, formula-based, mathematical decision model–based, zero-based, and "homemade" resource allocation methods (Linn 2007; Smith 2008). Each budgeting system functions differently and is often used in combination with other methods. For instance, one method can be used externally when applying for funds, and another can be used when distributing those funds internally.

In the case of academic libraries, collection budgets used to be allocated by taking into account several factors, such as the number of students, circulation of materials, interlibrary loans, number of researchers, and average cost of materials per discipline (Kao, Chang, and Lin 2003). Unfortunately, these indicators to quantify the collection requirements or the usage statistics are not enough anymore. Libraries nowadays must be able to show, on the one hand, their investments and the availability of their resources in producing better results in research and education, and, on the other hand, their effectiveness in delivering library services (Laitinen and Saarti 2012). To do so, library managers must have enough data to ensure the integration of different areas involved in the library system in order to evaluate and decide how to allocate and prioritize resources to each service or material that a library requires. In this respect, a holistic evaluation to obtain a thorough knowledge of the library system becomes an interesting alternative to be used as a means in which to organize the data collected for a resource allocation process.

Holism is a concept that emphasizes the importance of the whole and the interdependence of its parts (*The American Heritage Dictionary* 2011). This means that systems work as a whole and cannot be fully understood by analyzing their components separately. If this concept is translated to libraries, holism can be seen as an analysis that emphasizes the importance of the entire library and the interdependence of its processes, collection, and services. Many resource allocation approaches, based on holistic evaluations, have been proposed; however, the majority focuses separately on the economic allocation for physical or digital collections. For instance, F. Wilfred Lancaster (1977, 1988) establishes evaluation procedures only for traditional library services, and Ying Zhang (2010) and Norbert Fuhr and colleagues (2007) propose a holistic evaluation model for digital library services. In contrast, Scott Nicholson (2004) proposes a theoretical analysis framework to support libraries in gaining a more thorough and holistic understanding of their users and services for both digital and physical services. As can be seen in table 1, Nicholson proposes an evaluation matrix with four quadrants in which columns represent the topics library system and collection, and rows represent the perspectives of library staff and users. Because of the ease of un-

Table 1. Conceptual Matrix for Holistic Measurement

	Topic: Library System	Topic: Collection
Perspective: Internal (library)	1. What does the library system consist of?	4. How is the library system manipulated?
Perspective: External (users)	2. How effective is the library system?	3. How useful is the library system?

Source.—Nicholson (2004).

derstanding, completeness, and applicability to both physical and digital resources, this theoretical framework is adopted as a basis to propose a holistic structure for data collection and, in turn, uses these data sets as an input for an integrated decision support system.

The following items briefly describe the main features of each quadrant proposed by Nicholson:

1. If the library system is analyzed from an internal perspective, the question to be answered is "What does the library system consist of?" This is a traditional type of analysis that can include bibliographic collection aspects, organizational flows, computer interfaces, processes, staff, and resources.
2. The second quadrant evaluates the user's perception about service quality. Aboutness, effectiveness, and usability of the library services are the main aspects studied. The question to be answered is "How effective is the library system?"
3. The third quadrant is centered on "How useful is the library system?" This quadrant allows quantification of the impact of the library collection on its users, thus providing library managers with a better basis for decision making when acquiring new bibliographic materials. By evaluating the current bibliographic collection, libraries may discover possible gaps and plan future collection development (Agee 2005).
4. The fourth quadrant aims to answer the question "How is the library system manipulated?" This quadrant analyzes the use patterns followed to manipulate the library system. For instance, in digital library services, unlike circulation patterns in traditional services, it is possible to track everything users do within the library system, allowing libraries not only to know what users retrieve but also what they looked for and could not receive.

Thus, by incorporating into our model this simple but at the same time powerful theoretical framework to organize the data collection required, this study ensures that evaluating the collection and services in academic libraries is based on a holistic model.

The remainder of this article is divided into three sections. The first section describes the data collection procedure to holistically analyze academic libraries from an economic perspective. The next section proposes the design method and structure of a decision support system based on data-warehouse and data-mining technology. Finally, conclusions are drawn in the final section.

Data Collection through a Holistic Perspective

In this section, Nicholson's conceptual matrix is used as a basic reference to propose a structured data collection that ensures a holistic analysis of an academic library from an economic point of view. Based on this structure, a set of tools is provided to collect data for the specific requirements of each quadrant. An example of implementing the proposed holistic

approach and tools is presented by Lorena Siguenza-Guzman, Ludo Holans, and colleagues (2013). The authors highlight the key benefits, challenges, and lessons learned from the implementation of this holistic approach in an academic library in Belgium.

First Quadrant: Internal Perspective of the Library System

In this quadrant, the traditional library evaluation (i.e., measurements based on library staff, processes, or systems but not users) is the main aspect studied. The internal perspective of the library system largely covers the topics related to processes and services carried out within the library system. From an economic perspective, it refers to the need for analyzing the costs incurred and the resources consumed by library processes. Cost analysis techniques, of which the traditional costing system has been one of the most widely used, have been present in libraries for many years. Jennifer Ellis-Newman, Haji Izan, and Peter Robinson (1996), for instance, describe several studies on library costs that were undertaken in the United States. These studies were carried out with cost allocation models compatible with traditional costing methods. In this type of system, the total cost consists of *direct costs*, such as the cost of consumed resources and direct labor hours, and a percentage of overhead as *indirect costs*, which are specific costs such as maintenance, marketing, depreciation, training, and electricity. Traditional costing systems are adequate when indirect expenses are low and service variety is limited (Ellis-Newman and Robinson 1998). However, in environments with a broad range of services, such as libraries, indirect costs have increasingly become more important than direct costs (Siguenza-Guzman, Van den Abbeele, et al. 2013).

Seeking to remedy these limitations, libraries started employing more advanced cost-calculation techniques such as Activity-Based Costing (ABC). ABC is an alternative costing system promoted by Robin Cooper and Robert S. Kaplan (1988). Compared with traditional costing methods, ABC performs a more accurate and efficient treatment of indirect costs (Ellis-Newman and Robinson 1998). In fact, ABC first accumulates overhead costs for each activity and then assigns the costs of the activities to the services causing that activity. An *activity* for libraries is defined as an event or task undertaken for a specific purpose such as cataloging, loan processing, shelving, and acquisition orders (Ellis-Newman 2003). An extensive stream of literature describes ABC as a system that provides interesting advantages for decision making in libraries (Ellis-Newman and Robinson 1998; Goddard and Ooi 1998; Skilbeck and Connell 1999; Gerdsen 2002; Ellis-Newman 2003; Heaney 2004; Ching et al. 2008; Novak, Paulos, and Clair 2011). However, ABC has great limitations, for instance, a high degree of subjectivity in estimating employees' proportion of time spent on each activity; the excessive time, resources, and money for data collection; and the difficulties in modeling multidriver activities (Siguenza-Guzman, Van den Abbeele, et al. 2013).

Time-Driven Activity-Based Costing (TDABC) is an approach developed by Robert S. Kaplan and Steven R. Anderson (2003) in order to overcome the ABC limitations. TDABC uses only

two parameters to assign resource costs directly to the cost objects: (1) the unit cost of supplying resource capacity and (2) an estimated time required to perform an activity (Yilmaz 2008). For each activity, costing equations are calculated based on the time required to perform an activity (Yilmaz 2008). This time can be readily observed, validated, and then computed by time equations, which are the sum of individual activity times (Kaplan and Anderson 2007). By using these equations, all possible combinations of activities can be represented, for example, when different types of services do not necessarily require the same amount of time to be performed. Siguenza-Guzman, Van den Abbeele, and colleagues (2013) highlight five TDABC advantages: (1) simplicity in building an accurate model, (2) the possibility of using multiple drivers to design cost models for complex operations, (3) good estimation of resource consumption and capacity utilization, (4) versatility and modularity for updating and maintaining the model, and (5) the possibility of using the model in a predictive manner.

Up to now, four important studies concerning TDABC in academic libraries have been applied to very specific processes such as the interlibrary loan (Pernot, Roodhooft, and Van den Abbeele 2007), acquisition (Stouthuysen et al. 2010), circulation (Siguenza-Guzman, Van den Abbeele, Vandewalle, et al. 2014), and cataloging processes (Siguenza-Guzman, Van den Abbeele, and Cattrysse 2014). In these case studies, TDABC is described as a model that offers a relatively quick and less expensive way to design useful costing models. In addition, Siguenza-Guzman, Holans, and colleagues (2013) document the experience of implementing TDABC in 12 library processes. The study highlights three specific advantages: the possibility of disaggregating values per activity, of comparing different scenarios, and of justifying decisions and actions. Two specific challenges are also reported: the significant time required in data collection and the staff discomfort with being observed. However, potential solutions to overcome these challenges are also recommended, for instance, the use of a dedicated software tool to perform TDABC analyses, as well as the need for an appropriate communication strategy among library managers and staff to clearly explain the purpose of measurement. In all the case studies, the authors conclude that TDABC is, so far, the best system to evaluate costs, processes, and services in academic libraries. TDABC provides accurate information on the library activities, which may help managers get a better understanding of how the library uses its time, budget, and resources. Nevertheless, this information is not sufficient for making management decisions in the library. For instance, consider the following scenario. A library manager is asked to reduce staff due to the high cost of salaries. He consults the costing system, and after a "what-if" analysis, he finds that the reference service occupies a surplus of librarians and that by reducing this number, he fulfills the requirement.

Initially, this seems like a good option; however, it provides only a partial solution. The library manager should still consider other aspects, such as the users' perceptions of the service quality falling below the tolerated levels and the impact of the decision on the entire library system.

Second Quadrant: External Perspective of the Library System

Once the library system has been measured from an internal point of view, the evaluation is balanced by introducing the users' perspectives. By doing this, the framework allows library managers to see beyond the system, staff, or processes and to understand what users really need and desire from the services performed by a library. Nicholson (2004) proposes to evaluate the aboutness, pertinence, and usability of a library system, including both physical and digital resources. *Aboutness* refers to analyzing the relevance of library resources and services to their users. It is based on the users' personal judgments of the conceptual relatedness between the users' needs and services offered (Kowalski 2011). *Pertinence* takes into account the user and the situation in which the service is to be used. It assumes that users can make valid judgments only about the suitability of services for solving their information needs (Kowalski 2011). Finally, *usability* refers to evaluating the library system's reliability, meaning whether it can be used without problems.

Libraries have a long history of collecting users' statistics to monitor service quality (Horn and Owen 2009). In literature, different approaches have emerged (Nitecki and Hernon 2000); for instance, one approach is centered on the use of SERVQUAL (short for *serv*ice *qual*ity) measurements. SERVQUAL is a popular tool from the 1980s developed for assessing service quality in the private sector. This model uses the service quality gap theory proposed by Valarie A. Zeithaml, A. Parasuraman, and Leonard L. Berry (1990) to summarize a set of five gaps showing the discrepancy between perceptions and expectations of customers and managers. Danuta A. Nitecki and Peter Hernon (2000) note that by applying this instrument, libraries gain knowledge about the customer conceptualization of what a service should deliver and how well the service complies with idealized expectations. Another approach is based on the work of Peter Hernon and Ellen Altman (1996, 2010), who build their analysis on an extensive set of expectations around the gaps theory to look at the service nature of libraries. They suggest a pool of more than 100 candidate service attributes from which staff can select a subset potentially having the greatest relevance to their library (Nitecki and Hernon 2000). An additional approach, described by Joseph R. Matthews (2013), combines data about library use and library services with other data available on the academic campus. For instance, the author suggests that for university students, library use and services should correlate with either direct or indirect measures of student achievement. Examples of direct measures include the capstone experience, use of a portfolio, or a standardized exam. Indirect measures could include students' grade point averages, success in graduate school exams, and graduate student publications.

Stephanie Wright and Lynda S. White (2007) report the top-five assessment methods used in the past by libraries to measure service quality: statistics gathering, suggestion boxes, web usability testing, user interface usability, and satisfaction surveys. Within these methods, the authors mention that locally designed user satisfaction surveys were widely used; however,

they have lately been replaced by surveys developed elsewhere. A detailed description of some of these user-survey methods is provided by Claire Creaser (2006). The author focuses her analysis on the SCONUL user-survey template and the LibQUAL+® surveys. In this article, SCONUL is described as a standard template with a considerable degree of flexibility. SCONUL is offered by the Society of College, National, and University Libraries and can be adapted to suit local circumstances. LibQUAL+®, likewise, is described as a valuable tool for benchmarking because of its uniformity and limited scope for customization.

The LibQUAL+® (http://www.libqual.org) survey is a set of services based on web surveys offered by the Association of Research Libraries. These surveys are based on SERVQUAL measurements, which allow requesting, tracking, understanding, and acting upon users' perceptions of the service quality offered by libraries (Association of Research Libraries 2012). LibQUAL+®, which was initiated in 2000 as an experimental project, has been applied by more than a thousand libraries around the world, and thanks to its great success it is now considered a standard assessment tool for measuring the quality of services based on users' perceptions (Cook 2002). This survey helps libraries to assess their strengths and weaknesses and also benchmark themselves against their peers in order to improve their library services (Saunders 2007; Franklin, Kyrillidou, and Plum 2009). The LibQUAL+® survey consists of 22 items or questions that are grouped into three quality dimensions: services provided, physical space, and information resources (Saunders 2007). The measurement for each perspective uses a scale from 1 to 9. For each question, users give three ratings or levels of service: the minimum expected service quality, the observed or perceived service level, and the desired service level or maximum expectations. Siguenza-Guzman, Holans, et al. (2013) document the experience of utilizing the LibQUAL+® survey to assess library service quality. Their study describes the survey results and the action points that arise from the survey results. The authors state that although LibQUAL+® provides information on the set of services that require additional attention, some considerations must be taken into account, for example, a data preparation period required to define language and population, granularity to provide benchmarking within branch libraries, and the need of strategies to stimulate participation rates.

By integrating the users' satisfaction criteria with the proposed analysis, library managers now have a broader view of the library system, as they have information about their services and the users' opinions on such services. Assessment methods such as statistics gathering, suggestion boxes, web usability testing, user interface usability, and satisfaction surveys (e.g., LibQUAL+® or a locally designed survey) are valuable tools to be integrated into our evaluation matrix. The library manager in the aforementioned example may use LibQUAL+®, for instance, to analyze whether the quality of service provided by the reference librarians still lies within the tolerance zone once the changes have been made. Alternatively, libraries can also devise their own instrument, which can be particularly useful for investigating detailed issues (Creaser 2006). Nevertheless, the selection of the tools to be used in this quadrant depends on

their current availability in the library and the decision of library managers whether to include other measures in the model.

Third Quadrant: External Perspective of the Library Collection

The goal of this quadrant is to evaluate the usefulness of the library collection. This information allows libraries to gain a more holistic understanding of users' needs and to acquire material that complements current holdings, either improving weak areas or enriching strong collections (Agee 2005). To do so, two types of measurement are available: (1) through *direct contact* with the users in order to document which bibliographic materials are valuable to them and (2) through *indirect contact* by the use of bibliometric analysis (Nicholson 2004).

Bibliometrics can be defined as the use of mathematical and statistical methods to analyze the use of library information resources. The main focus of bibliometric analyses is on bibliometric distributions of events, such as the productivity of scientific journals, distributions of words in a text, productivity of scientific authors, and circulation of journals within a library or a documentation center (Lafouge and Lainé-Cruzel 1997). Traditional bibliometrics studies use information about the creation of bibliographic documents, such as authors and documents cited, and the metadata associated with them, for example, a general topic area or the specific material in which the metadata appeared. For these studies, the frequency-based analysis is mainly used; nevertheless, many newer bibliometric studies use visualization techniques and data mining to explore patterns in the creation of these analyses (Nicholson 2006a).

Of these methods, *citation analysis* is the best known and most often used, and it is also the one that best meets our requirements for analyzing the use of library information resources. Citation analysis is defined by several authors as (1) the wide-ranging area of bibliometrics that considers the citations to and from documents (Diodato 1994); (2) a method often used to generate core lists of journals deemed critical to the research needs of an institution (Wallace and Van Fleet 2001); (3) a technique for counting, tabulating, and ranking the number of times that sources are cited in a document (bibliographies, footnotes, and/or indexing tools) (Edwards 1999); and (4) a method for identifying journals that are often cited, some of which are not from the collection (Feyereisen and Spoiden 2009). Summarizing the definitions and adjusting them in the context of this research, citation analysis is defined here as a technique for counting, tabulating, and ranking the number of times sources are cited to and from documents in order to analyze the use of a collection. Citation analysis is normally based on samples collected from students' PhD dissertations and master's theses. Louise S. Zipp (1996) states that citations from these sources are reliable because they are more easily and comprehensively gathered and because they reflect the interests of local research groups. Nevertheless, K. Brock Enger (2009, 109) recommends caution in the use of citation analysis. For instance, common lists should be created by comparing the library's own results with those of other institutions because students tend to seek only locally owned sources and in many cases

may lack the expertise needed to identify the most appropriate sources (Feyereisen and Spoiden 2009). Likewise, useful information may not be cited or may be cited by professors, postdoctoral students, or researchers in other documents such as syllabi, reports, or books (Feyereisen and Spoiden 2009) or by those who do not publish, such as undergraduate and graduate students (Duy and Vaughan 2006). One solution to avoid these omissions is proposed by Robert N. Bland (1980), who suggests citation analysis of the textbooks used in the curriculum.

Vendor-supplied statistics is an additional bibliometric method for evaluating the usefulness of a library collection. The vendor-supplied statistics, also called electronic journal usage data, are usually collected via publisher websites. These lists are normally supplied by vendors as part of their subscription contract. A case study performed by Joanna Duy and Liwen Vaughan (2006, 515) advocates the use of this technique to replace the "traditional, expensive and time-consuming manual compilation" of reference lists.

In published journal articles, authors include references to articles, books, links, and other resources. These citations describe the sources of some concepts or ideas included in the document. At the same time, they help the reader to find relevant information about the topics that were introduced in the original article (He and Cheung Hui 2002). To measure the value of a journal by the number of citations that a document has had, *citation databases* have been created. According to Robert A. Buchanan (2006), a citation database serves two purposes: (1) to index the literature using cited articles as index terms and (2) to measure the number of times a publication has been cited in the literature. A citation database is a warehouse database that analyzes the impact of peer-reviewed literature. The most famous citation databases are Web of Science and Scopus. The selection of a database depends on the research focus. For instance, Scopus covers more relevant journals of medical informatics than does Web of Science (Spreckelsen, Deserno, and Spitzer 2011).

This study considers that by combining citation analysis, citation databases, and vendor-supplied statistics, library administrators will gain extensive knowledge about the value of their collections. This proposal is supported by several authors who agree that the use of different methods leads to a more robust indication of collection use and users' needs (Beile, Boote, and Killingsworth 2004; Duy and Vaughan 2006; Enger 2009). The early experiences in developing a project combining these methodologies are documented by Siguenza-Guzman, Holans, et al. (2013). The project analyzes more than 1,200 PhD dissertations submitted over a 6-year period (2005–10). In addition, four databases were created to evaluate citation patterns, publishing patterns, journals downloaded, and journals' impact factors. The authors describe several challenges faced up to now, for instance, (1) the amount of time required to collect the information and incorporate it into databases; (2) the need for a defined standard for naming (e.g., journal's abbreviations); and (3) the need for dedicated software to collect the large amount of information and to evaluate the results.

Fourth Quadrant: Internal Perspective of the Library Collection

The final quadrant measures users' behavioral aspects within a library system, namely the users' interactions with the system. This interaction is utilized to study users' preferences and to use this information to personalize services (Agostii, Crivellari, and Di Nunzio 2009).

Transaction log analysis (TLA) is one of the most important and well-known techniques that has been utilized for this purpose. *TLA* is defined by Thomas A. Peters (1993, 42) as "a form of system monitoring and as a way of observing, usually unobtrusively, human behavior." Marcos GonÇalves, Ming Luo, Rao Shen, Mir Ali, and Edward Fox (2002) describe log analysis as a primary source of knowledge in how digital library users actually exploit digital library systems and how systems behave while trying to support users' information-seeking activities. In the context of web search, the storage and analysis of log files are mainly used to (1) gain knowledge of users and improve services offered through a web portal without the need to bother users with the explicit collection of information (Agostii et al. 2009), (2) assist users with query suggestions (Kruschwitz et al. 2011), and (3) study the use of online journals and their users' information-seeking behaviors (Jamali, Nicholas, and Huntington 2005). Measures of usage analysis can include the number and titles of journals used; number of article downloads; usage over time; and a special analysis of subject, date, and method of access (Nicholas et al. 2006).

Many studies have been conducted to corroborate the use of logs analysis to analyze users' behaviors in a digital environment. For instance, deep log analysis (DLA) is a technique employed by Nicholas and colleagues to demonstrate the utility and application of transaction log analysis. The authors conducted a series of studies, such as a comparison of two consumer health sites, NHS Direct Online and SurgeryDoor (Nicholas, Huntington, and Williams 2002); a comparison of five sources of health information (Nicholas, Huntington, and Homewood 2003); and a study of the impact of consortia "Big Deals"[1] on users' behaviors (Nicholas, Huntington, and Watkinson 2003; Nicholas, Huntington, and Watkinson 2005). Nicholas and colleagues state that web usage logs offer a direct and immediate record of what people have done on a website. Some of the outcomes of DLA include site penetration as the number of items viewed during a particular visit, time online or page-view time, type of users identified by IP addresses, academic departments' usage, differentiation among on-campus and off-campus users, and user satisfaction measured by tracking returnees by IP (Nicholas et al. 2006).

Another example of user behavior analysis is presented by Philip M. Davis and Leah R. Solla (2003). The authors report a 3-month analysis of usage data for 29 American Chemical Society electronic journals downloaded from Cornell University. They demonstrate that although

1. For detailed information on this subject, see Peters (2001).

the majority of users limited themselves to a small number of journals and article downloads, a small minority of heavy users had a large effect on total journal downloads. They conclude that a user population can be estimated by knowing the total use of a journal because of the strong relationship between the number of downloaded articles and the number of users. Nevertheless, the authors use IP addresses as a representation of users, which is not necessarily accurate and might lead to biased results.

Moreover, log analysis can be supported and validated by other types of user studies such as eye-tracking systems to understand users' behaviors in different situations. Eye-tracking systems are devices for measuring eye positions and eye movement (Mehrubeoglu et al. 2011). Hitomi Saito and colleagues (2009) analyze search behaviors and eye-movement data to conclude that different tasks and levels of experience affect the behavior of students searching for information on the web. In general, user studies and logs are used separately because they are adopted with different aims in mind (Agostii et al. 2009). For instance, Robert Capra and colleagues (2009) describe the use of log data from the online public access catalog (OPAC) to develop a set of grounded tasks. At the same time, through the use of a remote eye tracker in a controlled laboratory setting, they collect eye-tracking data to examine users' behaviors in developing exploratory search tasks. The authors report that data collection using the eye tracker was a difficult process, as was using the log data to develop the search tasks.

Gi Woong Yun (2009) differentiates two types of methods for collecting log files: servers and clients. The server-side method is a low-cost, nonintrusive way of collecting data from a large number of individuals with minimal staff involvement. This method uses web log files to identify users' accesses to files in a certain web server. The client-side method requires some contact with study participants because of the need to install a monitoring program on the users' computers. Client-side methods are very invasive, require high staff involvement, and have high costs due to users' recruitments. Gheorghe Muresan (2009) states that data captured by server-side and client-side logging are complementary and typically used to answer different research questions.

To enhance the results of log analysis and test findings, other data-gathering methods can be applied, such as questionnaires, surveys, interviews, or observation studies (Jamali et al. 2005; Agostii et al. 2009; Black 2009; Kostkova and Madle 2009). Combining quantitative data—for example, log analysis with qualitative data—allows researchers to cross-check the analysis and fill in knowledge gaps. In addition, this combination provides a much more in-depth picture of how a digital library may be impacting its users' community and their work, and it also explains the information-seeking behavior of the users discovered in the logs. One specific example, presented by Maristella Agostii, Franco Crivellari, and Nick Di Nunzio (2009), concludes that when implicit methods such as users' interaction logs and explicit methods such as users' questionnaires are combined, the results are more scientifically informative than those ob-

tained when the two types of studies are conducted alone. Thus, by incorporating log analysis into our holistic matrix, library managers gain important input on users' behaviors and the possibility of identifying potential failures in the library system at the time of delivering services to their users.

The Proposed Holistic Evaluation Matrix

By combining the methodologies discussed in the preceding sections and the conceptual matrix defined by Scott Nicholson, this article proposes a holistic view of the processes, resources, and activities present in libraries from an economic perspective (table 2). We strongly support the idea that information must be collected from many separate sources, such as library information systems, library statistics, observations, surveys, and users' inquiries, in order to have enough input and different points of view for an adequate decision-making process.

The approach for implementing this matrix starts by identifying the services or activities involved in libraries and by calculating the costs of different resources (staff, equipment, facilities, collection, etc.). In order to do so, qualitative mechanisms for assessing library effectiveness should be included—for example, observation, interviews, surveys, expert opinions, process analysis, organizational structure analysis, standards, and peer comparison. Quantitative techniques are also required to evaluate efficiency, usefulness, and manipulation of the system. Citation analysis, log analysis, statistics gathering, and stopwatch techniques are useful methods that can be included.

To collect these data, typical sources could include the following: (1) integrated library systems, which contain information about process performance in the library, circulation data, acquisition, and so on; (2) the library portal used as a front end for the different types of

Table 2. Methodologies Proposed to Economically Evaluate a Library through a Holistic Perspective

	Topic: Library System	Topic: Library Collection
Perspective: Internal (library)	Service analysis: Processes Time Resources	Usage analysis: Implicit data Explicit data
Perspective: External (users)	Quality analysis: Statistics gathering Suggestion boxes Usability testing Satisfaction surveys	Collection analysis: Citations patterns Publishing patterns Journals downloaded Journals' impact factor

electronic resources; (3) the OPAC as a system to support digital reference services; (4) the interlibrary loan system from consortiums (Nicholson 2006a); (5) the LibQUAL+® survey system; and (6) information systems for demographic information.

However, some considerations must be taken into account when collecting data from these heterogeneous data sources (Poll 2001). These factors include (1) lack of well-defined standards for some specific analysis, such as the abbreviation of journal names, access to electronic collections, and e-lending; (2) the need for a common understanding of what sources and data must be considered; (3) the need for integrating multiple data sources from the library, university, consortiums, and suppliers; (4) differences of requirements between traditional and digital collections (for example, digital libraries require licenses for a certain time period, links to remote resources, or prepaid pay-per-view); and (5) the large volume of data generated by different sources, for instance, web logs. To develop a structure for a holistic analysis, data generated by multiple data sources must be integrated. Unfortunately, such integration presents a big challenge because these different sources normally use dissimilar formats and access methods (Ying Wah, Hooi Peng, and Sue Hok 2007). To overcome these shortcomings, Scott Nicholson (2003) proposes the aid of a data warehouse to integrate, filter, and process all the information extracted from many different systems based on the holistic matrix.

Data Warehouse Architecture for Library Holistic Evaluation

A *data warehouse* is defined as "a repository of integrated information from distributed, autonomous, and possibly heterogeneous, sources" (quoted in Bleyberg et al. 1999, 546). Based on the measures proposed in this study and the typical structure of a data warehouse (Inmon 2005), the resulting system architecture of a library's data warehouse, as shown in figure 1, is composed of three layers: (1) data source; (2) data extraction, cleansing, and storage; and (3) data presentation.

Data Source Layer

The data source layer is composed of the information extracted from different data sources. In our structure, data sources selected are based on the holistic matrix, which includes the analysis of processes, resources, and costs of library services; the point of view of the users regarding the quality of services; the usefulness of the library collection; and the users' behaviors in the library system.

Data Extraction, Cleansing, and Storage Layer

The resulting data are processed by the data extraction, cleansing, and storage layer through extract, transform, load (ETL) processes, allowing a clean, homogeneous, and anonymous

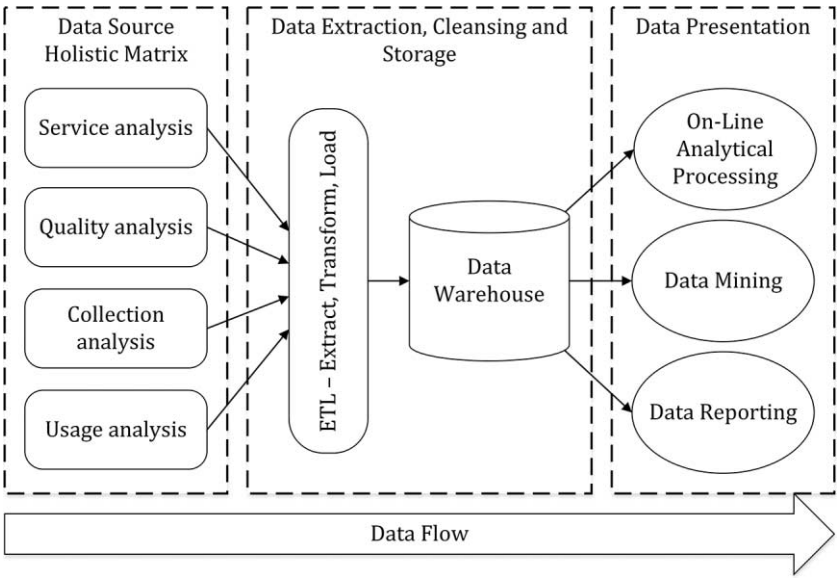


Figure 1. Data warehouse architecture for library holistic evaluation

version of the library data. ETL is a group of processes whereby the information collected from the operative systems is converted into a uniform format required by the data warehouse (Laitinen and Saarti 2012). ETL also includes tools for loading the data into the data warehouse and for periodically refreshing it. This is a challenging and time-consuming task because the process must combine all the different data sources and convert them into a uniform format, excluding possible inconsistencies, redundancies, and incompatibilities (Nicholson 2003). At the same time, ETL processes play a key part in protecting patron privacy during data warehousing (Laitinen and Saarti 2012).

Once the data have been processed, the next step is to build the data warehouse. Because this process is the most tedious and time-consuming part, Scott Nicholson (2003) suggests starting with a narrowly specific query, working through the entire process, and then iteratively continuing to develop the data warehouse. This is done in order to minimize the initial time required and to improve the collection and cleansing algorithms as early as possible.

Data Presentation Layer

Eventually the stored data are analyzed through reporting techniques located in the data presentation layer, such as data reporting, online analytical processing (OLAP), and bibliomining tools. The tools utilized in this area depend on the decision-making needs of the library manager. For instance, *data reporting tools* are traditional reports that allow library

managers to ask basic information about the data (Hwang, Keezer, and O'Neill 2003). *OLAP tools* are the methods used to produce reports without the need to know a database query language (Nicholson 2006b). Emil Hudomalj and Gaj Vidmar (2003) describe them as a multidimensional system that allows browsing the data by dimensions and measures. The authors show how OLAP tools can be used to prepare regular and unplanned reports, ensure quality, check data integrity, monitor the development of science, and evaluate or benchmark disciplines, fields, or research groups.

Bibliomining is defined by Scott Nicholson and Jeffrey M. Stanton (2003) as the combination of data mining, bibliometrics, advanced statistical, and reporting tools used to track patterns of behavior-based artifacts from library systems. Bibliomining is an important tool for discovering unknown and useful information in historical data in order to support budget allocation decisions (Kao et al. 2003). Once the information has been collected into a data warehouse, bibliomining explores the content with data-mining tools and then analyzes, validates, and generates the results (Hwang et al. 2003). The resulting information makes it possible to perform scenario analysis of the system, meaning the evaluation of different situations, such as types of users, services, resources, and budgets, that need to be taken into account during a decision-making process (Nicholson 2006b). At the same time, the matching of bibliomining with demographic information allows researchers to discover patterns of use in order to, for example, offer and personalize services to meet the needs of specific groups of users (Nicholson and Stanton 2003). In addition, Scott Nicholson (2006b) suggests the use of bibliomining to standardize structures and reports in order to share data warehouses among groups of libraries, allowing a library to benchmark its information with data collected by other libraries.

Since bibliomining is a powerful tool that combines different techniques for analysis and reporting and may also be used for different purposes, in our study its use is promoted as an important part of implementing a strong decision-support system that allows, for instance, justification of difficult decisions about budget or clarification of funding requests that library managers must make.

The final results of this architecture are (1) an ETL that collects, links, and cleans the information gathered through different data sources generated by the library system and its users; (2) a data warehouse database that stores the collected information; and (3) a group of presentation tools that report more accurate library information on how the resources and services are being accessed by users.

Conclusion

Libraries are accustomed to constant evaluation; consequently, they have a long history of data collection statistics (Laitinen and Saarti 2012). Unfortunately, these statistics are only partially used for decision-making processes because of the wide variety of formats and the lack of

efficient methods for grouping information. In this article, a complete framework and set of tools to holistically analyze libraries for financial decisions have been proposed. The approach for implementing the structure is to start extracting and collecting the information generated based on the two-dimensional holistic matrix. The theoretical matrix is used to analyze the library collection and services from internal and external perspectives. Furthermore, several methods and appropriate measurement tools have been evaluated and proposed for an integrated decision-making process. Library managers can select one or more instruments in every quadrant based on their current availability or decide to include other measurements and detailed issues in the model. An example of organizing and collecting the information based on this holistic approach is presented by Siguenza-Guzman, Holans, et al. (2013). The authors document the preliminary experiences of the implementation, concluding that the holistic model is a simple and powerful structure for grouping library information. Although the authors support the practical validity of the proposed approach, they also describe important considerations that need to be borne in mind, for example, the time required to implement the complete approach, as well as the need for dedicated systems to automate the different quadrants.

In addition, this article proposes the architecture of a data warehouse to store the collected data. This resource will allow the use of information, not only in traditional measures or for generating reports but also to enhance decision making. For example, information on the following four issues is accessible: (1) redistributing and prioritizing the allocation of resources assigned to a specific service; (2) gaining knowledge about users coming into the library and also users who are served by digital services; (3) awareness of the gaps and strengths in services and collections; and (4) the building of collections based on a library's holdings, user priorities, and technological tendencies. Ultimately, this article attempts to integrate this structure with an optimization tool to determine optimal resource allocation decision making in specific scenarios such as budget decreases, journal subscriptions and cancellations, and the creation of new services.

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Lorena Siguenza-Guzman: aggregate professor, Department of Computer Science, University of Cuenca, and doctoral candidate at the Centre for Industrial Management Traffic and Infrastructure, Katholieke Universiteit Leuven (KU Leuven). Siguenza-Guzman holds an engineering degree in computer science and a master's degree in telematics. Her doctoral research, under the supervision of Dirk Cattrysse, centers on resource allocation and budgeting in libraries at the KU Leuven. For this project, she has worked since 2009 with libraries at the KU Leuven, the biomedical library of the University of Ghent, and several academic libraries in Ecuador. Her research interests are library management and automation. E-mail: Lorena.SiguenzaGuzman@kuleuven.be, Lorena.Siguenza@ucuenca.edu.ec.

Alexandra Van den Abbeele: professor and head of the Department of Accounting, KU Leuven. Her teaching and research interests focus on management control systems in interfirm relationships. Other work explores how management control systems and incentive compensation can stimulate creativity and knowledge transfer. She also studies cost accounting systems in nonprofit settings (e.g., municipalities and libraries). Her work has been published in leading journals, such as *Organization Science, Accounting Review*, and *Accounting, Organizations and Society*. She serves as an editorial board member for the journals *European Accounting Review, Management Accounting Research*, and *Behavioral Research in Accounting*. E-mail: Alexandra.Vandenabbeele@kuleuven.be.

Joos Vandewalle: emeritus professor and former head of the SCD division at the Department of Electrical Engineering (ESAT), KU Leuven. He has been chairman of ESAT, vice dean of the Faculty of Engineering, and member of the Group of Science and Technology and is currently responsible for the Library of Science and Technology. Vandewalle has authored or coauthored more than 200 international journal articles. He is a member of the editorial board of several international journals and is a fellow of IEEE, IET, and EURASIP. He is a member of the Academia Europaea and of the

Belgian Academy of Sciences and is currently its head of the Class of Technology. E-mail: Joos .Vandewalle@kuleuven.be.

Henri Verhaaren: emeritus professor at the Faculty of Medicine and Health Sciences, Department of Pediatrics and Medical Genetics, Ghent University. He is former director of the Biomedical Library of Ghent University and Ghent University Hospital and continues to teach information sciences as emeritus. He is a fellow of the European Association of Health Institution Libraries, Medical Library Association, Association for European Pediatric Cardiology, and American College of Cardiology. E-mail: Henri.Verhaaren@ugent.be.

Dirk Cattrysse: professor, Centre for Industrial Management, KU Leuven. Cattrysse's research focuses on the applications of operations research models on logistic problems such as distribution logistics (vehicle routing, location, reversed logistics) and (integrated) production planning and scheduling. He researched applied operations as a visiting fellow at the MIT Sloan School of Management (1987–88) and served part-time at the University of Stellenbosch (Zuid-Afrika), Department of Industrial Engineering (1998–2004). He is a member of the board of the VLW (Traffic and Logistics Working Group) and is one of the founders of the new engineering master program Traffic, Logistics, and Intelligent Transportation Systems. E-mail: Dirk.Cattrysse@kuleuven.be.