Library & Information Science Research 37 (2015) 100–108

Contents lists available at ScienceDirect

Library & Information Science Research

Visual traffic sweeps (VTS): A research method for mapping user activities in the library space ☆

Lisa M. Given [a,*], Heather Archibald [b]

[a] School of Information Studies & RIPPLE, Charles Sturt University, Locked Bag 588, Boorooma St., Wagga Wagga, NSW 2650, Australia
[b] Information Management Branch, Government of Alberta, Commerce Place, 10155 102nd Street, Edmonton, AB T5J 4G8, Canada

ARTICLE INFO

Available online 26 May 2015

ABSTRACT

The visual traffic sweeps (VTS) approach combines traditional observational methods for assessing library space with geographic information system (GIS) visualization techniques. This unique approach to spatial analysis can be used across library and information settings (or in other spaces with large amounts of human traffic) to map patterns in user behavior. Results of the visual analyses can be triangulated with other methods (e.g., questionnaires or interviews) to better inform library policy and space planning decisions. Findings from a study that used VTS in the business library of a large, urban university illustrate the potential application of this technique across library settings. Specific findings (e.g., patrons' preferences for certain spaces for laptop use, despite the library reserving other space for laptops) demonstrate the power of visualization techniques for analyzing results in ways that are not possible with standard statistical analysis approaches. In addition, the visual maps that result from the analysis process are useful for the presentation of visual data in conference presentations and/or to library stakeholders. Overall, this approach provides evidence for space planning decisions that are grounded in users' real activities within the library space.

1. Introduction

In the last two decades, librarians, scholars, and the public have debated the library's future, particularly given changes in technology and in users' information needs (Bennett, 2007; Engel & Antell, 2004; Hufford, 2013; Montgomery, 2014; Raju, 2014; Shill & Tonner, 2003). As access to digital resources and services increased, some writers questioned the need for the physical library, while others believed that modern upgrades could augment the traditional library as "place" (e.g., Buschman & Leckie, 2007; Campbell, 2006; Council on Library and Information Resources, 2005; Cunningham & Tabur, 2012; Donkai, Toshimori, & Mizoue, 2011). In balancing the ongoing need for new and different resources and technologies, libraries must make structural changes to suit patron activities (e.g., rewiring for laptop use; providing rooms for group work) in spaces designed, originally, for physical, book-oriented collections. Libraries need valid data to inform thoughtful and well-planned manipulation of space.

Understanding patrons' use of spaces is vital for appropriate planning, as users of libraries will "seek spaces that balance the need to find, to reflect and to absorb" (McKinstry, 2004, p. 128) while in the library. Unfortunately, renovations are often based primarily on design guidelines (e.g., Bazillion & Braun, 2001; Leighton & Weber, 1999; McDonald, 2006; Staines, 2011), rather than on local research results. Where patrons' needs inform space planning, this may be based only on informal observations of the patrons' behaviors or only using one formal measure of user preferences (e.g., a quantitative survey); rarely do studies involve multiple techniques to gain a holistic picture of user behavior.

The demands of new technologies and evolving styles of information engagement make re-configuring library spaces quite complex. Students may study, read, and search for materials, but they also use libraries for social gatherings and for group learning (see Haddow, 2013; Powell, 2002; Shill & Tonner, 2003; Soria, 2013; Soria, Fransen, & Nackerud, 2014). In assessing spaces, librarians and scholars have not made adequate use of visual research methods, which are often used by architects, urban planners and other designers. The exploration of patrons' use of space is vital for (re)designing modern libraries to suit users' ways of working. This paper presents one method (visual traffic sweeps) that integrates visualization with traditional observational

☆ An earlier version of this article won the Association for Library and Information Science Education's Best Methodology Paper Award

* Corresponding author.
E-mail address: lgiven@csu.edu.au (L.M. Given).

http://dx.doi.org/10.1016/j.lisr.2015.02.005
0740-8188/

methods used to assess users' needs within the library. The focus of the paper is on the presentation and application of the method; however, selected results of a large study that used this approach (Simpson, 2007) are presented to illustrate the potential value of this method.

1.1. Visual traffic sweeps: a brief overview

Visualization techniques allow researchers and librarians to better understand the ecology of the modern library. Interviews, questionnaires, and other user-focused methods can provide data on users' information needs, and observational methods document patrons' activities. However, visualization techniques also allow scholars and practitioners to gain a complete picture of patrons' activities by tracking how people move in the space and use furnishings, and how they interact with one another while engaged in information seeking.

The visual traffic sweeps (VTS) approach is one viable tool for assessing and designing library space to suit modern needs. To enable visualization of occupied spaces, spatial data (gathered through systematic 'seating sweeps' observations) are combined with geographic information system (GIS) technology to analyze data visually for a clear understanding of library usage at the local level. The results can be used in conjunction with other user-based methods (e.g., interviews or questionnaires) and alongside published space design guidelines, so that librarians can make decisions informed by evidence gathered from local users.

2. Space planning in the library context

Understanding users' preferences for library facilities (and redesigning to suit these needs) is key to effective space planning. In the last decade, libraries have altered some policies to suit patrons' needs (e.g., allowing food and drink) and have introduced comfortable furniture, multimedia instruction rooms, gaming spaces, group study areas, and so on. The goal is often to design areas for reading, browsing, reference and other activities that cater to diverse user needs; published guidelines address this type of multi-purpose design. In the UK, for example, Jisc (2014) has produced an information kit on the design of learning spaces that are "open, inviting and stimulating spaces" that address users' needs. Covert-Vail and Collard (2012) highlight the need for redesigned academic library spaces given the "growing need for collaboration — particularly across disciplines" (p. 5) in graduate students' research activities. These guides are consistent with earlier studies in the field, which called for varied designs to support learners' diverse information activities. Leighton and Weber (1999), for example, discussed the need to plan for a mix of stacks, seating, floor areas, and computer terminals; among these, they noted that seating for readers and related services (e.g., reference) was the largest area in most libraries. In academic libraries, they noted the maximum allowable space for tables of four or more patrons (up to 20%) and for lounge chairs (up to 15%), while noting that individual seating could comprise up to 85% of available space (Leighton & Weber, 1999, p. 723). These types of guidelines should not be used in isolation; rather, decisions should always be grounded in user-focused data gathered at the local level.

2.1. Understanding and responding to patrons' needs for varied space use

Recent studies of patron behavior in public libraries demonstrate the continuing need for traditional uses of space (e.g., reading or writing) alongside new technology. Mandel's (2013) research notes, for example, "despite the increasing shift toward digital services, the [physical] facility remains crucial to the daily operation of the public library" (p. 270). Similarly, Aabø and Audunson (2012) found that public library users' activities were "complex," with the library serving as "an extension of the school or work place" (p. 148). Research by May and Black (2010) and Most (2009) also point to the complexity of users' behaviors in the public library environment. These research findings are consistent with earlier studies that found patrons engaging in reading, writing, and other traditional information behaviors in the public library, alongside the use of digital resources. Leckie and Hopkins (2002), for example, observed that 50–60% of patrons were involved in reading activities while located at worktables or study carrels (p. 21). McKechnie et al. (2004) found that worktables were heavily (and almost exclusively) used for reading and writing activities.

Space preferences are affected by many factors including quality of sound and light, density of occupancy, degree of familiarity between users, cultural practices, variance of personalities, and nature of the reading material (Leighton & Weber, 1999, p. 221). Research shows that some readers prefer noisy environments, while others want quiet, private areas (Given, 2007; Powell, 2002). Leckie and Hopkins (2002) discovered that 12% of public library patrons complained others were "too noisy" (p. 346) and thus disruptive. These types of studies are vital for ensuring that space planning is informed by user-driven evidence of patron needs.

2.2. The academic library: one example of the evolving nature of physical space

To meet the demands of today's users, academic libraries are developing new models for providing access to electronic resources and assisting individuals with their information needs. In academic libraries one model of integrated physical space is the information (or knowledge) commons, which combines technology and reference services in a central library location (Dale, Beard, & Holland, 2011; MacWhinnie, 2003; Matthews & Walton, 2013; Xia, 2005). Often, the information commons includes hi-tech classrooms and group study spaces designed for collaborative learning. Education research explores the design of these spaces and implications for student learning, with results applicable to library design. Long and Ehrmann (2005), for example, discuss the inadequacies of traditional classroom spaces in the face of new technologies. Johnson and Lomas (2005) highlight links between learning theories and the design of university campus spaces. Indeed, Forrest and Hinchcliffe (2005) state that librarians must "get off the grid" by eliminating typical rectilinear configurations shaped by rows of bookshelves in favor of flexible, moveable furnishings (p. 297). Similarly, Given (2007) describes a shift in the perceived culture of the library, from a place where students are "shushed" to a place flexible enough to suit students' diverse needs (p. 184). Her research notes the importance of spaces for group work and discussion, requiring comfortable spaces "filled with bright, natural light" (p. 180) and other factors conducive to on-campus study. These findings are also echoed in May and Swabey's (2012) study of students' use of academic library spaces.

For more than a decade, librarians have also noted a continuing rise in the use of laptops and other portable devices, making it increasingly important for libraries to provide wireless access in general seating areas (Bazillion & Braun, 2001; Shill & Tonner, 2003). The shift to personal computing has also increased calls to change lighting and provide more power outlets. However, there is controversy over how best to accommodate laptop users while providing spaces for traditional activities (Xia, 2005). Thomas (2000) notes that planners must provide as much flexibility as possible for readers and technology users in order to accommodate a variety of space types and interactions; the ideal design should allow for the coexistence of the physical and virtual library, with spaces that reflect "what really happens in the library" (p. 415).

3. Planning library space: traditional approaches and guidelines

Space planning often involves counting seating capacity or calculating average personal occupancy during peak periods. Library associations also publish guidelines for quantifying space use. For example, the Association of College & Research Libraries (ACRL), 1995 "Standards for College Libraries" includes formulas for space requirements based on

student enrolment. Although ACRL's (2011) "Standards for Libraries in Higher Education" provides a number of performance indicators to measure the importance of library space, there is little guidance provided for data collection strategies related to these indicators. Further, guidelines for small or specialized libraries are typically not found in the published literature, leaving librarians to modify general guidelines to suit local needs. Ramsay (2002) argues that the formulas used by academic libraries are deficient in several respects, as they do not provide sufficient reading space when equipment is used to access information (e.g., computers, laptops, or microfiche readers). These technologies have always raised issues related to noise and lighting, which can be distracting to some users. In other cases, spaces designed for fixed computing may not meet users' personal equipment needs (e.g., cellphones); for example, library lighting guidelines often do not specify guidelines for laptop users or provide only minor suggestions for buffering new noises (see Leighton & Weber, 1999; Malman, 2005). It is important to use a range of methods to assess patrons' use of (and satisfaction with) spaces, alongside the use of design guidelines.

Technological change has altered patrons' expectations of library spaces and services, while flexibility of spaces was often omitted in the original designs. Jones (2003), a library building consultant, noted more than a decade ago that libraries must plan for flexibility to support new configurations and technologies in the future; this concern remains valid today, particularly given the rise in portable devices such as tablets and smartphones. To that end, new methods for assessing physical space use are also required so librarians, architects and interior designers can create effective spaces that best suit users' needs. This study presents one new research method designed to provide evidence for effective space planning; by understanding how individuals use the library, designers can make short and long-term changes to library spaces to best meet patrons' needs.

4. Using spatial analysis methods for assessing and designing library space

Spatial analysis is used in many disciplines to assess human behavior, through locational inventories and mapping, cognitive or perceptual mapping, and activity tracking or spatial observations (Cromley, 1999; Given & Leckie, 2003; Mandel, 2010). Given and Leckie (2003) describe how individuals use social activity spaces that are both private and public, and which can be confined (e.g., in private, such as a house) or quite open (e.g., in public, such as a city neighborhood). Observational methods are used to develop maps of people's movements within a space. One approach used by psychologists, sociologists, and architects is "room geography" (Jakle, Brunn, & Roseman, 1976), where mapping examines how individuals distribute themselves across a space. This technique has been used to study personal boundaries. For example, individuals searching for a place to sit in a library will first try to find an empty table, sitting as far away as possible from other occupants, which creates a certain amount of personal space and privacy (McKechnie et al., 2004). This phenomenon has also been observed in people sitting on public benches, or in public transportation such as busses or trains (Given & Leckie, 2003). Another technique is wayfinding, (Passini, 1981), which examines the ways that patrons orient to, and navigate around, built public spaces. Mandel (2010, 2013) has used wayfinding to explore how individuals move within the public library space, with a particular focus on signage and other key physical markers.

To properly and efficiently manage library space, librarians need tools that allow for detailed understanding of various options for arranging stacks, reading areas, and workstations. For decades, changes in library spaces have often involved trial and error or sketching out floor plans and using small cut-to-scale paper models fitted on blueprints (Fuller & Post, 1991; Xia, 2004a,b). By reassembling library elements on sketches, a space plan can be made; however, such techniques are tedious, clumsy and cannot easily integrate evidence on patrons' space use.

When evidence-based planning is implemented, librarians often investigate users' needs through interviews and questionnaires or employ observation to analyze the use of facilities. These data, which are usually summarized by statistical or textual analysis, form the basis for many librarians' decisions about space considerations. For example, Potthoff, Weis, Montanelli, and Murbach (2000) followed a role repertory grid procedure to collect data on patrons' perceptions of library space. Given and Leckie (2003) discuss the time–space mapping method, where individuals are followed through library spaces and their activities mapped over the course of a day or week. This latter approach can provide librarians with data on which areas of the library are heavily used, which pieces of furniture obstruct people's movements through space, where to place information technologies, why certain areas are preferred by patrons for reading and studying, and which areas the library should designate for "quiet" work. However, although potentially very useful, this method is labor-intensive and possible only with small samples (Given & Leckie, 2003, p. 383). Although some computer-based techniques (such as GIS visualization) can also take time, particularly on first use, the benefits—particularly for data comparisons over time—can outweigh the initial time investment in the long term.

Although computerized space management is used by some public libraries, most academic libraries do not use this in daily operations (Xia, 2004b). The benefits of computerized models are outlined by Bazillion and Braun (2001), who note that floor plans can be modified to account for changes, which is beneficial for long-term planning. The use of computerized models of facilities makes instant simulation of space change possible, resulting in a less time-consuming and more precise planning process (Fuller & Post, 1991).

Computer-aided design (CAD) is also used in some libraries. CAD can create three-dimensional views of objects, enabling people to experience the space in which they will work (Bazillion & Braun, 2001; Xia, 2004b). Michigan State University, for example, has implemented a CAD system to aid in library space management (Haka & Hensley, 2003); this allows librarians to measure facilities use so that space allocation decisions can be assessed. Unfortunately, these systems do not allow for integration of data gathered on users' activities. A method that combines computer modeling with evidence-based approaches for library planning is a useful innovation for facilities planning. The VTS approach allows for such integration by combining observational methods with GIS visualization techniques.

4.1. Geographic information systems and data visualization: a brief overview

Geographic information system (GIS) approaches provide for the input, storage, retrieval, manipulation, analysis, and output of geographic data (Ottensmann, 1997, p. 26). Knigge and Cope (2006) note that GIS facilitates an iterative analysis process to identify themes, raise questions, and build theories. Overall, visualization techniques allow users to explore, interpret, and integrate data to provide rich and flexible media for data exploration. Geographic data refer not only to the physical features found on a map (e.g., a city boundary), but also to non-spatial attributes of those features (e.g., the population of that city). A powerful capability of GIS is to produce a variety of maps for different purposes; however, GIS also allows researchers to manipulate and analyze spatial and attribute data to produce new information. GIS can be used, for example, to identify the best location within a city (given neighborhood demographics) for a new public library.

In urban planning, Kong and Nakagoshi (2006) used GIS to view changes in green space usage patterns in China's urban centers. In library and information studies, MacDonald and Black (2000) used GIS to analyze the history of the book. In a study linking environmental studies, geography, and justice, Pain, MacFarlane, and Turner (2006) used GIS to identify locations in need of street lighting by using hotspot

maps and lighting coverage maps to analyze areas where crime and lighting were linked.

In general, visualization methods have generated ways for exploring data that were never before possible. According to Kwan (2000), GIS and visualization techniques can facilitate the exploratory analysis of spatial data, so researchers can overcome traditional limitations of studies of human spatial behavior. Granados (2003) used GIS visualization to map out the enrollment of students at universities, making "many spatial patterns…easier to identify and understand" (p. 25); previously, researchers relied heavily on only tables and graphs to analyze data.

Overall, few studies in library and information studies have made use of GIS techniques. Studies have been conducted, for example, to examine library service areas (e.g., placement in cities) and for collection management decisions. Bishop and Mandel (2010) and Michalec and Welsh (2007) present comprehensive overviews of published research in the field. Examples of previously published studies include Koontz's (2005) project where GIS was used to identify characteristics of library branch market areas, enabling branches to plan services and facilities. Preiser and Wang (2006) used GIS to create a master plan for the Public Library of Cincinnati and Hamilton County using visual rankings of library performance. GIS software (e.g., Library Decision) can associate library statistical data with community geographic data to display user patterns visually; this type of analysis is useful for service planning or to identify where a library is needed; it can also provide a more complete understanding of the user population (Dorman, 2002).

Johnston and Bishop (2011) make the call for school librarians to consider the use of GIS in considering the school library as "place". Similarly, Xia's (2005) paper proposed GIS as a tool for analyzing potential changes to the interiors of libraries. To date, Xia's work, the research conducted by Mandel (2010, 2013), and the findings of the study reported in this paper (from Simpson, 2007) are the only projects to make use of GIS techniques inside the library space. Mandel's (2013) results present interesting findings related to the ways that individuals use signage, as well as the pathways users take when navigating the library space. Xia (2004a) used GIS to monitor books pulled off the shelves and discarded in the library space by users, and then re-shelved. The findings showed that collection adjustments could be made, especially where books were seldom pulled by users. Xia (2004c) also used GIS to draw objects (such as chairs, and tables) on maps and look for changes in usage patterns. Xia (2005) also conducted an experiment using GIS, which mapped the observed occupancy of study areas to evaluate the efficiency of library resource use. According to Xia (2004b), the advantages of GIS technology are that:

- GIS can perform spatial analysis, allowing for easy measurement of library space use;
- A GIS database can store data related to each object (e.g., a carrel) and link those data to the visual presentation of the object;
- GIS allows for management at a detailed level (e.g., a room, or a chair in that room);
- Floor plans and design sketches can be navigated easily, printed and used for presentations to stakeholders; and,
- System development costs are low, especially in academic contexts which often have licenses for GIS software (p. 378).

As information on library space (including occupancy) is geospatial in nature (i.e., dealing with physical locations and the place of people in those locations), library design is ideally suited to these methods. GIS maps can provide visual evidence of high and low use, which is highly beneficial for space planning. By creating visual maps to better design areas in libraries, GIS is an ideal tool for providing the evidence needed to influence decision makers on required changes.

Unfortunately, Xia's method was quite time-consuming, as information was collected at three levels: the floor level (the total study area), the segment level (the number and type of study facilities), and the facility level (such as carrels, and chairs). Xia's study only included a small portion of the total library area and this technique was not triangulated with other methods. Mandel's (2013) project combined interviews, content analysis, unobtrusive observation, expert reviews, and other techniques, to present a very rich approach to the use of GIS to examine library space. By combining GIS with another, established method for gathering observational data in library settings (i.e., Given & Leckie's, 2003 seating sweeps approach), the VTS technique outlined here provides librarians and researchers with a method for visually analyzing larger amounts of observed data, gathered in a more efficient manner.

5. Visual traffic sweeps: a new approach for unobtrusive observation

Many researchers have used unobtrusive observational methods to explore how people use library spaces (e.g., Leckie & Hopkins, 2002; Mandel, 2013; McKechnie et al., 2004). Although individuals may describe particular activities or express concerns on a written questionnaire (e.g., saying that the library is "always busy"), observing behaviors provides concrete evidence of real patron activities. The seating sweeps method, developed by Given and Leckie (2003), is one unobtrusive technique for assessing library spaces; this tool allows researchers and librarians to gather data on what patrons are actually doing within a library space. It has been used by a number of scholars, worldwide, since its inception (e.g., Hoivik, 2008; May & Black, 2010; Silver, 2007). Seating sweeps can show the diversity of patron behaviors and activities in libraries, which may accord or conflict with the library's established policies; this evidence can be used to support changes in design or policy decisions (Given & Leckie, 2003). One limitation of this technique is that the data are typically analyzed in table form, making it difficult for library planners to see various hot spots of activity within the library space. Although Given and Leckie (2003) do note that spatial analysis is useful "for mapping the physical layout of libraries, to examine ways that people make use of that space" (p. 366), neither they nor other scholars make use of this in their analysis.

This study presents a new technique that addresses this gap in the methodological literature, by using GIS technology to map patron data gathered using the sweeps approach. By extending Given and Leckie's (2003) work, and by analyzing the data visually, librarians can more quickly assess areas of concern within a library space. The end result—VTS—is a unique research tool for spatial analysis that can be used across library and information settings (or in other spaces that have large amounts of human traffic) to map patterns in user behavior that can inform future policy and planning decisions. Findings from one study (conducted in the business library of a large, urban university), which used this approach in conjunction with other methods, are provided in the sections that follow, to illustrate the application of this technique (see Simpson, 2007 for the complete findings of this study).

5.1. Observational sweeps: using a handheld device for data collection

Given and Leckie (2003) provide instructions for gathering data using their seating sweeps technique. Data are gathered during timed walks (or sweeps) through the space; a print checklist of areas (e.g., worktable or circulation desk) documents users' activities, as well as possessions, and demographics. Data are presented in table form and analyzed for patterns. Given (2007) has used this same technique to study student use of campus spaces; she used a personal digital assistant (PDA) to gather checklist data, which allowed for more efficient analysis by using the PDA's spreadsheet.

In the present study, a handheld device was also used for collecting data using the VTS technique. This technique can also be adapted for use on tablets, smartphones, or other devices that allow for data collection using spreadsheets that can be exported to Excel. The first step of this method involves the creation of Excel spreadsheets representing different times and dates for data collection; Given and Leckie's

(2003) coding worksheet served as a model (e.g., WT denotes a worktable), modified only slightly for the local library environment. A unique filename is assigned to each day/time session. A small map of the library was uploaded for easy reference to codes and locations named on the checklist. Different locations in a library were coded in advance (e.g., area A = circulation desk, or area G = work tables on first floor). Each spreadsheet row represents one individual occupying an area; the presence of possessions or the activities for each person are coded numerically (i.e., 1 = yes) in the spreadsheet, where columns denote specific activities or possessions. The number of data collection sessions will vary depending on the research questions. Here, data were gathered a few times a week for 3 months to account for changes in the academic term. Data were exported to Excel on a computer and then analyzed using GIS software.

5.2. Observational sweeps: pre-testing and techniques

Pre-testing is an important next step in the process. The data collection spreadsheets are created prior to formal data collection to run a pilot of the sweeps and ensure that all categories of activities, possessions, and locations are appropriate. In the full study (Simpson, 2007), pretesting was done during the initial data collection phases, including a thorough review of all categories defined for each location; this ensured a comprehensive approach across all data categories, prior to full data collection. One tip for capturing this type of data is to work from the same cardinal direction in each session (i.e., starting north and moving clockwise). This is key to ensuring that occupancy is documented reliably, so that it is clear during the GIS analysis which area a patron occupied during a particular observational session.

5.3. Manipulation of spreadsheet data

After the sweeps are complete, the Excel spreadsheets are cleaned up to be easily imported into the GIS. First, these Excel files must be saved as database files (i.e., in CSV format). Manipulation may include adding 0 (i.e., 0 = no) to any cells where occupancy was not observed (e.g., to denote that no one was standing at the photocopier). This is important, as understanding places of heavy or light usage can help library planners in design. Other changes to the spreadsheet might include adding an "occupied" column to record the rate of occupancy of each area (or each carrel/table/chair) at designated intervals. Identification numbers for locations corresponding to those on library map can be made to match the images that are later created in GIS. These processes enable the sweeps information to be linked to the visual areas on the map.

After being manipulated, Excel sweeps files must be imported into the GIS software to run queries and visualize the data, producing results that could not be achieved through a spreadsheet or statistical program alone. Spaces are presented in map form to show the floor plans and furniture layouts. An initial map can be created from paper versions, however a to-scale representation is important to use for accurate visualization. Paper plans can be scanned and then touched up using a drawing program; in some cases, floor plans may need to be manipulated to reflect the current state of the space (e.g., if new furnishings have been added recently). The new map is imported as a bitmap file (bmp) into the GIS software.

For this project ArcGIS was used, as it provides software products that create, edit, import, map, query, analyze, display and publish geographic information (Environmental Systems Research Institute (ESRI) (ESRI), 2009). ArcGIS software is used in earth and atmospheric sciences, agriculture, forestry, biology, and other fields. Some training in ArcGIS or other GIS software is important for successful visualization of observational data as described in this article.

After importing the bit map into ArcGIS, the software is used to create overlay polygon shape files, which imitate the library areas corresponding to the data collected in the sweeps. Polygons are areas that are fully encompassed by a series of connected lines, and are linked to the observational data (e.g., the polygon of one chair is linked to its occupancy). Segments must be drawn as polygons to imitate their actual shape (e.g., the polygon of a worktable is created in a rectangular form to match the scale of the library). Additional polygons can be created to imitate seating, circulation desks, computer terminals, stacks and other locations users may inhabit. The floor map provides an overall look of the space, while the data can be linked to the shapes of the areas to provide activity information in those spaces. In the sections that follow, examples of these maps are provided using real data from the study.

Queries can be run to produce maps of different activities. These queries can be any number of combinations involving the activities or possessions data gathered in the sweeps. Querying can correspond to specific, user-related research questions (e.g., "How many people used laptops at open worktables compared to carrels specifically reserved for laptop use?"). The visual presentation of objects can be distinguished by the use of colors to show higher values (e.g., high occupancy of people over the semester using a laptop in a particular seat is shown in a dark color); similarly, clustering of shapes on the map can be done (e.g., large numbers of patrons talking in a particular area throughout the semester can be shown by large circles). ArcGIS provides tools for color coding and options such as legends, scale measurements, and other visuals to help the researcher view and understand the meaning of the data being displayed. Completed maps resulting from the analysis

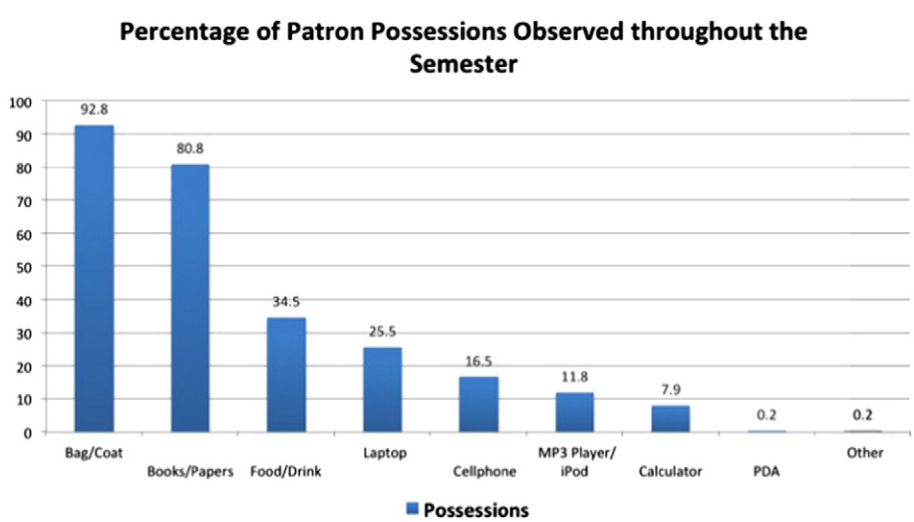

Fig. 1. Total possessions of library patrons observed throughout the semester.

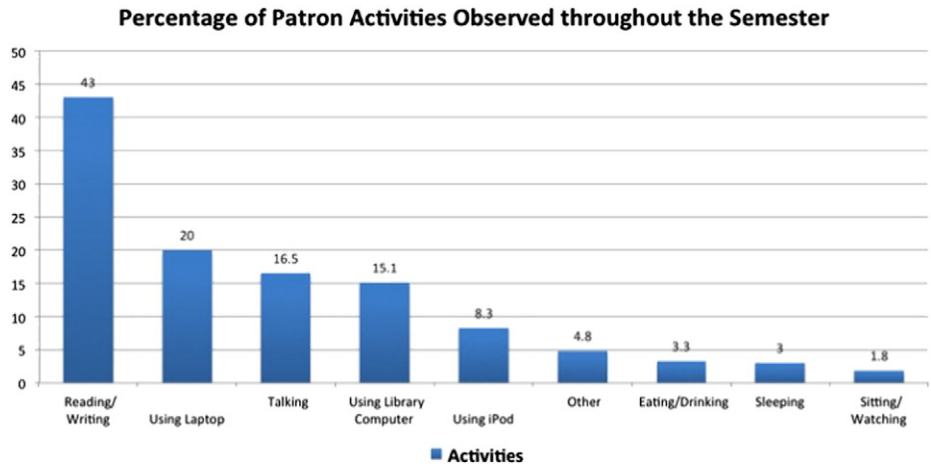

Fig. 2. Total activities of library patrons observed throughout the semester.

can be exported as PDFs or JPEGs, which can be used in publications. The usefulness of visualization of observational data (including spatial analysis and presentation), and the low cost, makes this technology desirable for library projects.

6. Results of GIS visualization: a brief discussion of select examples

In this study, data were collected and analyzed to produce results relating to demographics, patron possessions, and activities. Possessions were objects or other things that patrons had with them (e.g., books, paper, coats, bags, laptops, and food/drink). For example, the data showed that 25% of patrons were seen with a laptop during the study period (see Fig. 1).

Some library patrons were engaged in reading and writing activities; however, a large number of patrons also engaged in use of digital resources. Indeed, the high use of electronic resources (e.g., computers and laptops) was in stark contrast to the number of patrons physically searching for paper resources in the library (Fig. 2). The lack of use of the physical collection is a key point, given that the print collection comprised a large amount of space.

In addition to high computer and laptop use, a large number of library patrons were observed to be talking. This is in line with findings of other scholars who have recognized the need to provide areas for quiet reading and studying, as well as discussion (Given, 2007; Shill & Tonner, 2003).

6.1. GIS visualization of observational sweeps

The GIS analysis visualized where activities took place and showed how they were affecting library design. Through VTS, a better understanding of some of the major issues and activities occurring in a library can be demonstrated (e.g., the existence of quiet versus noisy spaces, places where people are eating, and areas where people are using laptops). These findings may also guide other libraries to design efficient and useful areas for patron use.

6.2. Visualizing areas of use of library spaces: reading and writing

In many areas, patrons engaged in reading and writing activities (Fig. 3). The carrels were most heavily used for these activities, as were areas near the worktables on the first floor. Areas of low use

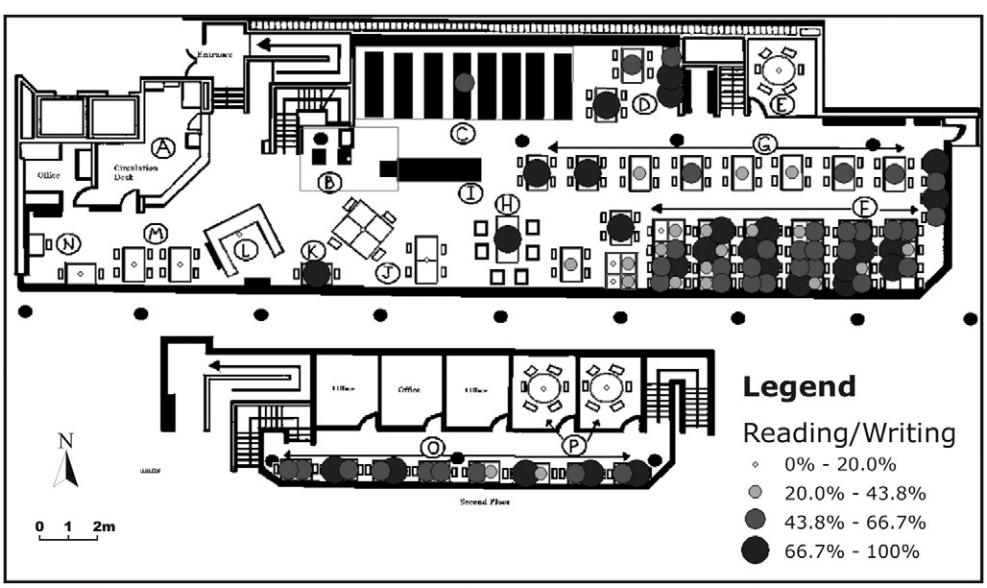

Fig. 3. Map of areas in the library where patrons were observed reading and writing. The darker areas with the largest circles are where the heaviest areas of total reading and writing were occurring throughout the semester. The areas are shown in densities (out of the total number of occupants that were in that area).

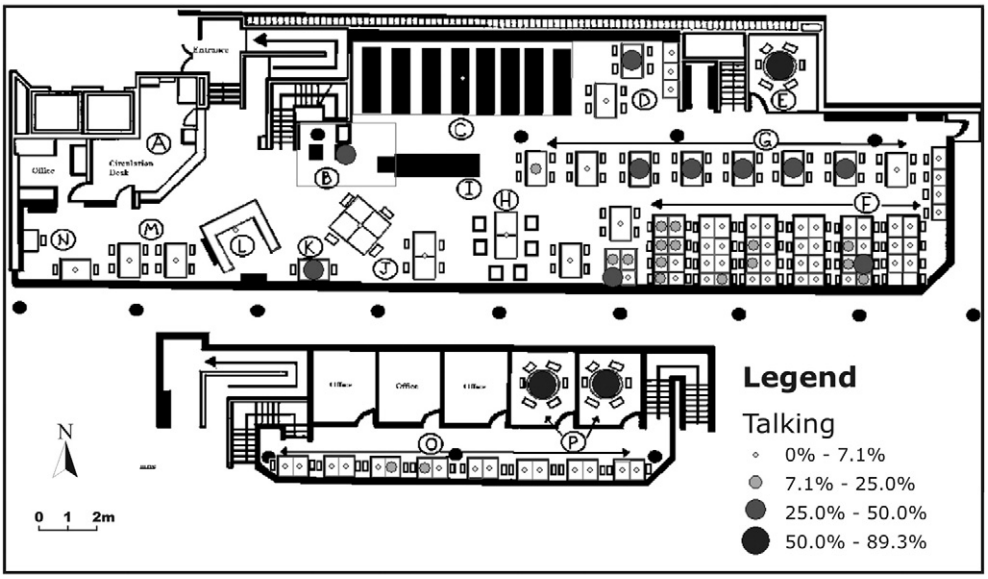

Fig. 4. Map of areas in library where patrons were observed talking. The darker areas are where the heaviest areas of total reading and writing were occurring throughout the semester. The areas are shown in densities (out of the total number of occupants that were in that area).

were found in the group study rooms, at computers, by photocopiers, and in carrels prioritized for laptop use. Few patrons read in active areas (e.g., near the circulation desk).

The VTS also showed hotspots of non-traditional use (e.g., eating, or sleeping). Often, libraries have not allowed eating and drinking due to possible damage or because of noise and smells. In this particular library, patrons were observed with food and drink in many areas; the maps created through the VTS showed areas where this practice was occurring regularly. Patrons were also observed sleeping in many seats (particularly in carrels).

6.3. Visualizing areas of use of library spaces: patrons talking

Although the main floor was intended for quiet study, there was much talking observed during the sweeps. The balance between quiet and noisy areas in library planning has been highlighted in the literature (Given, 2007). As shown in Fig. 4, talking patrons can be found in areas throughout the library. However, when compared to Fig. 3, some areas where the highest amount of talking took place are right next to areas with people working quietly (e.g., Zone F, study carrels next to worktables). In fact, areas with a high number of patrons reading and writing were only found outside of the areas where talking was occurring, showing that those areas (e.g., the worktables) were areas avoided by those wishing to engage in reading and writing activities.

6.4. Areas of talking/discussion: group study rooms, photocopiers and printers, worktables

Talking also occurred in areas where this might be expected, such as group rooms; these are used mainly for group study and meetings and were occupied frequently during the observational period. Another heavy zone (as outlined on the GIS maps) was near the photocopiers and printers, where library patrons would talk while waiting for their documents to copy or print. Indeed, librarians and patrons alike noted that one of the problems in this library was the number of people talking on the first floor, which is intended as a quiet area. The highest levels of

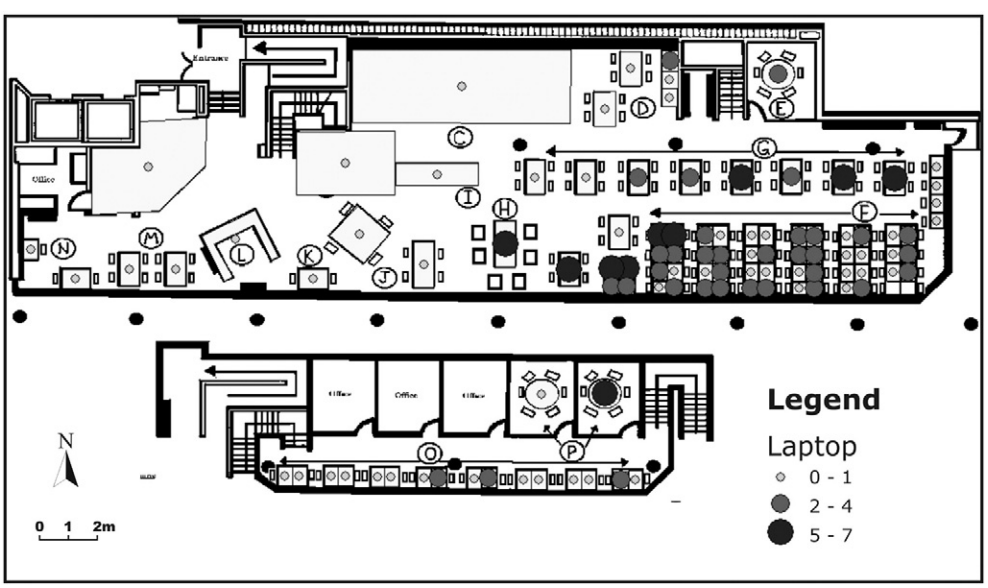

Fig. 5. Map of areas of laptop use throughout the semester. Total numbers of patrons using laptops during the semester studied are included.

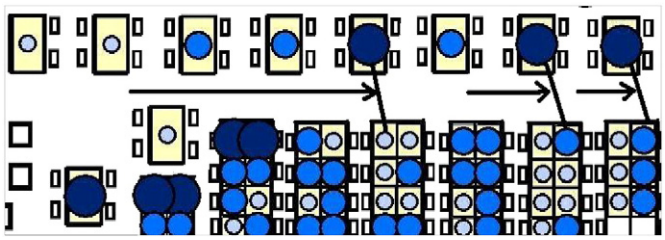

Fig. 6. Map of areas where students were observed running cables across walkway.

talking in this area were almost entirely at the worktables in the middle of the first floor (see Fig. 4, area G). Unfortunately, the small size of this library meant that talking patrons were near those who were reading in carrels. The librarians were trying to solve this problem to enable efficient and useful work areas while providing a quiet/conversation balance in the spaces to suit all the needs of the patrons. Through the maps produced using the VTS method, areas were able to be clearly identified where problems such as talking may be causing issues for library patrons.

6.5. Visualizing the areas of laptop use

Laptop users require power outlets, wireless networks, and additional lighting. This library tried to satisfy these needs by offering wireless access and providing dedicated carrels (with power and small lights) for laptop use. However, laptop users flocked to other areas of the library, including those where their special needs could not be met. Fig. 5 shows a number of areas with high numbers of laptop users. One of these areas is the group study room on the second floor (see area P), where students would often use their laptops while doing group work.

Where laptop users did use laptop priority areas (i.e., the first two rows of study carrels; see area F), they only did so on the end of the rows of carrels. It is possible that users felt more comfortable in the end carrels where they had more room to stretch out. Overall, some of busiest areas of laptop use were at worktables. Patrons were observed using laptops at worktables, with books, cellphones, and bags spread out around them. Although power outlets were in all study carrels on the first floor, patrons often chose tables where they had more space and ran power cables across the aisle (Fig. 6). One of the researchers even witnessed one individual who tripped and fell on the wires during data collection at noon hour. In this case, the practice of patrons running wires across the walkway could prove to be quite dangerous to other library patrons.

7. Conclusion

Patron uses of space for eating, reading, talking and laptop use in this library reflect major issues in space planning in today's libraries. By using the VTS approach it is possible to better understand the habits of users in libraries. These visualizations can help library planners to improve spaces and better understand problem areas (e.g., areas of congestion or tripping hazards). VTS extends traditional observational methods by using GIS visualization techniques. This unique approach can be used across library and information settings (or in other spaces with large amounts of human traffic) to map patterns in user behavior. Results can be triangulated with other methods (e.g., questionnaires or interviews) to inform library policy and design decisions. Specific findings presented here (such as patrons' preferences for particular spaces for laptop use, despite the library reserving other dedicated space for laptops) demonstrate the power of visualization for analyzing results in ways not possible with standard statistical analysis. By applying a visualization technique, evidence-based design decisions, such as changing the layout of furniture or renovating spaces to provide in-desk power for portable devices, can inform librarians and administrators' decisions to implement change. The visual maps that result from the type of investigation can be useful for the presentation of visual data in conference presentations and to stakeholders, including those in decision-making roles around the design of library space. Overall, this approach provides evidence for planning decisions grounded in users' real activities within the library.

References

Aabø, S., & Audunson, R. (2012). Use of library space and the library as place. *Library and Information Science Research*, *34*, 138–149.

Association of College & Research Libraries (1995). Standards for college libraries. *College & Research Libraries News*, *56*(4), 245–257.

Association of College & Research Libraries (2011). *Standards for libraries in higher education.* Chicago, IL: Association of College & Research Libraries.

Bazillion, R. J., & Braun, C. L. (2001). *Academic libraries as high-tech gateways: A guide to design and space* (2nd ed.). Chicago, IL: American Library Association.

Bennett, S. (2007). Designing for uncertainty: Three approaches. *The Journal of Academic Librarianship*, *33*, 165–179.

Bishop, B. W., & Mandel, L. H. (2010). Utilizing geographic information systems (GIS) in library research. *Library Hi Tech*, *28*, 536–547.

Buschman, J. E., & Leckie, G. J. (Eds.). (2007). *The library as place: History, community and culture*. Westport CT: Libraries Unlimited.

Campbell, J. D. (2006). Changing a cultural icon: The academic library as a virtual destination. *Educause Review*, *41*(1), 16–30.

Council on Library and Information Resources (2005). *Library as place: Rethinking roles, rethinking space*. Washington, DC: Council on Library and Information Resources. Retrieved from: http://www.clir.org/pubs/reports/pub129/contents.html

Covert-Vail, L., & Collard, S. (2012). *New roles for new times: Research library services for graduate students.* New York, NY: Association of Research Libraries.

Cromley, E. K. (1999). Mapping spatial data. In J. J. Schensul, M. D. LeCompte, R. T. Trotter, M. Singer, & E. K. Cromley (Eds.), *Mapping social networks, spatial data, and hidden populations* (pp. 51–123). Walnut Creek, CA: Altimira Press.

Cunningham, H. V., & Tabur, S. (2012). Learning space attributes: Reflections on academic library design and its use. *Journal of Learning Spaces*, *1*(2). Retrieved from https://libjournal.uncg.edu/index.php/jls/article/download/392/287

Dale, P., Beard, J., & Holland, M. (Eds.). (2011). *University libraries and digital learning environments*. Farnham, UK: Ashgate.

Donkai, S., Toshimori, A., & Mizoue, C. (2011). Academic libraries as learning spaces in Japan: Toward the development of learning commons. *International Information and Library Review*, *43*, 215–220.

Dorman, D. (2002). GIS provides a new way of seeing service areas. *American Libraries*, *33*(2), 62.

Engel, D., & Antell, K. (2004). The life of the mind: A study of faculty spaces in academic libraries. *College & Research Libraries*, *65*, 8–26.

Environmental Systems Research Institute (ESRI) (2009). *Desktop GIS*. Retrieved from http://www.esri.com/software/arcgis/about/desktop.html

Forrest, C., & Hinchcliffe, L. J. (2005). Beyond classroom construction and design: Formulating a vision for learning spaces in libraries. *Reference & User Services Quarterly*, *44*(4), 296–300.

Fuller, F. J., & Post, W. E. (1991). Library space management by computer. *Library Software Review*, *10*, 170,172–170,173.

Given, L. M. (2007). Setting the stage for undergraduates' information behaviors: Faculty and librarians' perspectives on academic space. In J. E. Buschman, & G. J. Leckie (Eds.), *The library as place: History, community, and culture* (pp. 177–189). Westport, CT: Libraries Unlimited.

Given, L. M., & Leckie, G. J. (2003). "Sweeping" the library: Mapping the social activity space of the public library. *Library and Information Science Research*, *25*, 365–385.

Granados, M. (2003). Mapping data on enrolled students. *New Directions for Institutional Research*, *120*, 23–35.

Haddow, G. (2013). Academic library use and student retention: A quantitative analysis. *Library and Information Science Research*, *35*, 127–136.

Haka, C., & Hensley, J. (2003). Evaluating the utilization of facilities in ARL libraries. *ARL*, *230/231*, *704*, 24–25.

Hoivik, T. (2008, August). *Count the traffic*. Paper presented at the 74th IFLA General Conference and Council, 10–14 August 2008, Québec, Canada.

Hufford, J. R. (2013). Can the library contribute value to the campus culture for learning? *The Journal of Academic Librarianship*, *39*, 288–296.

Jakle, B., Brunn, S. D., & Roseman, C. C. (1976). *Human spatial behavior: A social geography*. North Scituate, MA: Duxbury Press.

Jisc (2014). *Learning spaces [InfoKit]*. UK: Jisc. Retrieved from http://www.jiscinfonet.ac.uk/infokits/learning-spaces/

Johnson, C., & Lomas, C. (2005). Design of the learning space: Learning to design principles. *Educause Review*, *40*, 16–28.

Johnston, M. P., & Bishop, B. W. (2011). The potential and possibilities for utilizing geographic information systems to inform school library as place. *School Libraries Worldwide*, *17*(1), 1–10.

Jones, D. J. (2003). Is your building 'future-proof'? *INCITE*, *24* Retrieved from http://www.alia.org.au/publishing/incite/2003/10/future-proof.html

Knigge, L., & Cope, M. (2006). Grounded visualization: Integrating the analysis of qualitative and quantitative data through grounded theory and visualization. *Environment and Planning*, *38*, 2021–2037.

Kong, F., & Nakagoshi, N. (2006). Spatial–temporal gradient analysis of urban green spaces in Jinan, China. *Landscape and Urban Planning*, *78*, 147–164.
Koontz, C. M. (2005). Serving maps of public library customer data over the Internet. *Library Hi Tech News*, *22*, 23–26.
Kwan, M. (2000). Analysis of human spatial behavior in a GIS environment: Recent developments and future prospects. *Journal of Geographical Systems*, *2*, 85–91.
Leckie, G., & Hopkins, J. (2002). The public place of central libraries: Findings from Toronto and Vancouver. *Library Quarterly*, *72*, 326–372.
Leighton, P. D., & Weber, D. A. (1999). *Planning academic and research library buildings* (3rd ed.). Chicago, IL: American Library Association.
Long, P. D., & Ehrmann, S. C. (2005). Future of the learning space: Breaking out of the box. *Educause Review*, *40*, 42–56.
MacDonald, B. H., & Black, F. A. (2000). Using GIS for spatial and temporal analyses in print culture studies. *Social Science History*, *24*, 505–536.
MacWhinnie, L. A. (2003). The information commons: The academic library of the future. *Libraries and the Academy*, *3*, 241–257.
Malman, D. (2005). *Lighting for libraries*. Retrieved from http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/diversos/Lighting%20for%20Libraries.pdf
Mandel, L. H. (2010). Toward an understanding of library patron wayfinding: Observing patrons' entry routes and in a public library. *Library and Information Science Research*, *32*, 116–130.
Mandel, L. H. (2013). Finding their way: How public library users wayfind. *Library and Information Science Research*, *35*, 264–271.
Matthews, G., & Walton, G. (Eds.). (2013). *University libraries and space in the digital world*. Farnham, UK: Ashgate.
May, F., & Black, F. (2010). The life of the space: Evidence from Nova Scotia public libraries. *Evidence Based Library and Information Practice*, *5*(2), 5–34. Retrieved from http://ejournals.library.ualberta.ca/index.php/EBLIP/article/view/6497
May, F., & Swabey, A. (2012). Libraries as learning spaces: Exploring how students make use of the physical space in academic libraries. In I. Hall, S. Thornton, & S. Town (Eds.), *Proving value in challenging times. Proceedings of the 9th Northumbria International Conference on Performance Measurement in Libraries and Information Services* (pp. 263–270). York, UK: University of York.
McDonald, Andrew (2006). The ten commandments revisited: The qualities of good library space. *LIBER Quarterly*, *16*. Retrieved from http://liber.library.uu.nl/index.php/lq/article/view/7840
McKechnie, L., French, P. K., Goodall, G. R., Kipp, M., Paquette, D. L., & Pecoskie, J. L. (2004). Covered beverages now allowed: Public libraries and book superstores. *Canadian Journal of Information and Library Sciences*, *28*, 39–51.
McKinstry, J. (2004). Collaborating to create the right space for the right time. *Resource Sharing & Information Networks*, *17*, 137–146.
Michalec, M., & Welsh, T. S. (2007). Quantity and authorship of GIS articles in library and information science literature, 1990–2005. *Science & Technology Libraries*, *27*(3), 65–77.
Montgomery, S. E. (2014). Library space assessment: User learning behaviors in the library. *Journal of Academic Librarianship*, *40*, 70–75.
Most, L. R. (2009). *The rural public library as place in North Florida*: *A case study* (Unpublished doctoral dissertation). Florida State University, Tallahassee.
Ottensmann, J. R. (1997). Using geographic information systems to analyze library utilization. *Library Quarterly*, *67*(1), 24–29.
Pain, R., MacFarlane, R., & Turner, K. (2006). 'When, where, if, and but': Qualifying GIS and the effect of streetlighting on crime and fear. *Environment and Planning*, *38*, 2055–2074.
Passini, R. (1981). Wayfinding: A conceptual framework. *Urban Ecology*, *5*, 17–31.
Potthoff, J. K., Weis, D. L., Montanelli, D. S., & Murbach, M. M. (2000). An evaluation of patron perceptions of library space using the role repertory grid procedure. *College & Research Libraries*, *61*, 191–203.
Powell, M. (2002). Designing library space to facilitate learning: A review of the UK higher education sector. *Libri*, *52*, 110–120.
Preiser, W., & Wang, X. (2006). Assessing library performance with GIS and building evaluation methods. *New Library World*, *107*, 193–217.
Raju, J. (2014). Knowledge and skills for the digital era academic library. *The Journal of Academic Librarianship*, *40*, 163–170.
Ramsay, K. M. (2002). B.D. (before digital)–A.D. (after digital): Rethinking space in a mid-sized academic library. *Technical Services Quarterly*, *19*(4), 31–38.
Shill, H. B., & Tonner, S. (2003). Creating a better place: Physical improvements in academic libraries, 1995–2002. *College & Research Libraries*, *64*, 431–466.
Silver, H. (2007). *Use of collaborative spaces in an academic library* (Unpublished doctoral dissertation). Simmons College, Boston, MA.
Simpson, H. (2007). *Mapping users' activities and space preferences in the academic business library* (Unpublished master's thesis). University of Alberta, Edmonton.
Soria, K. M. (2013). Factors predicting the importance of libraries and research activities for undergraduates. *The Journal of Academic Librarianship*, *39*, 464–470.
Soria, K. M., Fransen, J., & Nackerud, S. (2014). Stacks, serials, search engines, and students' success: First-year undergraduate students' library use, academic achievement, and retention. *The Journal of Academic Librarianship*, *40*, 84–91.
Staines, G. M. (2011). *Universal design: A practical guide to creating and re-creating interiors of academic libraries for teaching, learning, and research*. Oxford, UK: Chandos Publishing.
Thomas, M. A. (2000). Redefining library space: Managing the coexistance of books, computers, and readers. *Journal of Academic Librarianship*, *26*, 408–415.
Xia, J. (2004a). GIS in the management of library pick-up books. *Library Hi Tech*, *22*(2), 209–216.
Xia, J. (2004b). Library space management: A GIS proposal. *Library Hi Tech*, *22*(4), 375–382.
Xia, J. (2004c). Using GIS to measure in-library book-use behavior. *Information Technology and Libraries*, *23*(4), 184–191.
Xia, J. (2005). Visualizing occupancy of library study space with GIS maps. *New Library World*, *106*(5), 219–233.

Heather Archibald is an information management business analyst with the Government of Alberta. With a background in library and information studies and humanities computing, her experience includes the assessment, business analysis, and project management of large-scale information management (IM) and enterprise content management (ECM) systems. Areas of interest include the use of new technology and systems to improve work flows and information management processes, the use of Agile methodologies, and working with multidisciplinary teams to complete large scale IM projects. She has recently completed her designation as Association for Information and Image Management (AIIM) ECM practitioner.

Lisa M. Given is a professor at the School of Information Studies and the Research Institute for Professional Practice, Learning and Education, Charles Sturt University, Australia. A member of the College of the Australian Research Council, she is also an adjunct professor in the Faculty of Arts (Humanities Computing) and the Faculty of Education at the University of Alberta, Canada. A former director of the International Institute for Qualitative Methodology, she has received numerous research grants and awards and has published widely on topics related to individuals' information behaviors and qualitative inquiry. Her research interests include the social construction of knowledge, web usability, spatial analysis, information literacy, research methods, and information issues in the context of higher education. Dr. Given is editor of *The Sage Encyclopedia of Qualitative Research Methods* (2008).