Measuring public library accessibility: A case study using GIS

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ABSTRACT

Physical accessibility is considered a fundamental measure of freedom to attend activities. Although several accessibility analyses have been conducted of public libraries, these studies tend to measure the distance from the users' homes to the library using straight lines. This generally serves as a poor measurement of actual travel distances. In order to provide more realistic analysis, and measure patterns of library access more accurately, this study employed geographic information systems (GIS), including descriptive and statistical analyses, and a road network-based distance measure. One finding from the GIS analyses was that distance was a determining factor for library use. Specifically, the evidence shows that distance affected a considerable number of registered users who lived within the areas that were defined through Thiessen polygons. Another finding was that there was a difference in the travel distance between ethnic groups: Caucasians went further to access public libraries than other ethnic groups. Finally, in terms of the relationship between distance and demographic data, household characteristics relative to children and education level were significantly related to the travel distance of users. To improve the accessibility of public libraries, this study recommends librarians define service areas for libraries, develop library programs and services for susceptible user groups, and evaluate user groups' needs.

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1. Introduction

Accessibility has been conceptualized in many different ways, as well as in many different academic fields. Researchers in transport geography focus on spatial relationships; Kwan and Weber (2003, p. 341) refer to it as "the proximity of one location to other specified locations". Web developers generally consider web accessibility in the context of web access by individuals with disabilities (Slatin & Rush, 2003). Recently, such issues as "social norms and the attitudes of a particular social world" (Burnett, Jaeger, & Thompson, 2008, p. 53) have also been examined in the context of information access. Additionally, accessibility has been analyzed from cognitive, economic, intellectual, and political perspectives.

Several factors deriving from these various perspectives are found to either facilitate or constrain access to activities. Physical accessibility, in particular, is a fundamental measure of the equal chance to take part in activities (Weibull, 1980). Therefore, research on the physical accessibility of public libraries as providers of diverse information sources is related to measuring the fundamental ability of people to access information. The investigation of physical issues is also related to analyzing patterns of library use and planning new facilities. Resultant information from such investigation can indicate to facility planners or policymakers the optimal areas for locating facilities (Miller, 1999). Knowing the home locations and characteristics of library

users and their reasons for visiting libraries helps planners and policymakers determine not only where to locate a new library, but also what materials to select, what programs to offer, and what hours the library should be open (Kinikin, 2004).

Researchers in library and information science (LIS) have long been interested in the physical issues of library accessibility, including the factors which affect library use (Cole & Gatrell, 1986; Hayes & Palmer, 1983; Obokoh & Arokoyu, 1991; Osiobe, 1981; Palmer, 1981; Sannwald, 2001), library facility location (Dunstan, 1977; Freestone, 1976; Koontz, 1997; Park, 2005), and the social and economic dimensions of library use (Mladenka & Hill, 1977). Accessibility analysis studies (Hawkins, 1994; Hertel & Sprague, 2007; Kinikin, 2004; Ottensmann, 1997) in LIS have focused on analyzing accessibility through measuring the distance between users' homes and the local public library which they must often use. More recently, researchers have used geographic information systems (GIS) to analyze geographical accessibility of public libraries. This research examined the physical accessibility of public libraries through use of GIS, with a particular focus on the distances library users traveled to access public libraries, in relationship to the users' socio-economic characteristics.

2. Problem statement

Several studies have been conducted to measure the physical accessibility of public libraries, and previous researchers often applied estimated distance measurements, represented by radius of distance. For example, Kinikin (2004) measured accessibility by counting the

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number of registrants living within radii of one, two, three, and five miles, found that the majority of users lived within a two-miles radius, and concluded that distance is a determining factor in the physical accessibility of public libraries.

While this method has the advantage of computational convenience, there are disadvantages in using it (Nicholls, 2001). Straight lines do not provide a realistic representation of the actual travel of library users. For instance, travel distance can be greater than the straight-line distance if the person moves along a curved road. Also, people's movements can be limited by physical barriers such as rivers, lakes, and highways. If there is a lake between the departure and destination points and no bridge to connect the two points, the actual route may not be a straight line. Therefore, to measure library accessibility more realistically, distance measurements using transportation or road networks need to be applied.

Additionally, integrating geographical data with socio-economic or human-related data allows the researcher to better understand the patterns of library use in terms of physical access. Individual characteristics of library users are associated with library use. Several studies suggest the use of socio-economic data such as censuses for library planning and service development (Adkins & Sturges, 2004; Kinikin, 2004). Despite this suggestion, there is little research available to explain how individual characteristics influence users traveling to their libraries, or the degree to which these characteristics are related to library utilization.

3. Literature review

The term *accessibility* has been defined and put into operation in many different ways since the late 1950s, when Hansen (1959) modeled accessibility. He defined it as "the 'potential for interaction,' taking into account the distance between an origin and a destination, as well as the value, or number of, opportunities available at a destination" (Envall, 2007, p. 5). To clarify the meaning of accessibility, Ingram (1970) distinguished between *relative* and *integral accessibility*. Relative accessibility refers to "the degree to which two places (or points) on the same surface are connected," while integral accessibility means "the degree of interconnection" of a point with all other points (p. 101). Penchansky and Thomas (1981) defined access as a concept representing the degree of "fit" between clients and services, and identified such dimensions of access as availability, accessibility, accommodation, affordability, and acceptability to be "more specific areas of fit" (p.128). Regarding these dimensions, accessibility is differentiated from other dimensions by being defined as the "relationship between the location of supply and the location of clients, taking account of client transportation resources and travel time, distance and cost" (p. 128).

These definitions of accessibility are composed of three major components: origin, destination, and the relationship between the two. As an indicator of the relationship, the distance between origin and destination influences or hinders the accessibility of a destination for people. If the destination is close to the origin, people may easily access it, and the degree of accessibility of the destination will be high. Also, the transportation mode used by a target group to get to the destination is another important factor associated with accessibility. No matter how far the destination is from the point of origin, if people have their own vehicles or can easily use public transportation, the destination may be accessible for them, and the degree of accessibility will be high.

Joseph and Phillips (1984) explained accessibility using not only geographical terms, but also nongeographical dimensions such as culture and function. They suggested *locational* accessibility and *effective* accessibility as ways to describe various dimensions of accessibility. These researchers used these terms to aid in the analysis of health service delivery patterns. The former term has come to refer to the generally used geographical dimensions of accessibility

such as travel time or distance. The latter term, however, refers to nongeographical dimensions, such as the characteristics of services and the socio-economic status of users. *Locational* accessibility is readily measured by various technological tools and therefore is easily used to measure accessibility. On the other hand, *effective* accessibility involves more intricacies, and therefore lacks efficiency in measuring accessibility.

Liu and Zhu (2004) placed accessibility measurements into four categories: *opportunity-based* measures, *gravity-type* measures, *utility-based* measures, and *space–time* measures. These methods attempt to answer questions regarding physical access, such as, "How many people can have access to a certain service in a specific location or area?" or "How accessible is it for them?" While the first three measurements analyze accessibility relative to the facility itself, the space–time measure analyzes access from the perspective of individuals.

Opportunity-based measures count the number of opportunities that can be reached within a given distance or travel time, and offer an indication of the range of choices available to residents. Gravity-based measures are derived from the denominator of the gravity model used to predict trip distribution; these measures weigh the amount of activity at different destinations by the cost, time, or distance to get there. The third type of measure is based on random utility theory, in which the probability of an individual making a particular choice depends on the utility of that choice relative to the utility of all choices; the accessibility measure comes from the denominator of the model, and reflects the total utility of all choices. Recently, space–time measures have been frequently used for accessibility measurements. The space–time framework is a detailed approach allowing many different types of people to be considered, and requiring that the complexity of real world transportation networks be taken into account. The common element shared by these measurements is distance. Based on the concept of distance, each of them incorporates other concepts relative to accessibility, such as time and opportunity, and then measures the accessibility of facilities.

Some research related to accessibility has been conducted in library settings. The physical accessibility issue is related to library utilization; a high degree of accessibility elicits an increase of library use, and vice versa. In terms of distance, Palmer (1981) reviewed the literature on the effects of distance on library usage and found that library users tend to live within 10 miles of a library. The distance a user is willing to travel is also affected by the available means of transportation. To select optimal locations for public libraries, a previous study surveyed the relative importance of various selection criteria, such as accessibility and security (Park, 2005). Survey participants rated several factors important for their use of libraries, including the convenience of public transportation, distance from schools, and security.

GIS helps researchers utilize spatial data. While issues relative to GIS used to be vigorously discussed only in the field of geography, GIS has now been broadly adopted in other sciences, for example, in the social sciences, to analyze social phenomena from a spatial perspective. In the social sciences, GIS has been applied to a wide range of studies, such as political conflicts (Buhaug & Rod, 2006; Raleigh & Urdal, 2007), elections (Gimple, 2008; Perepechko, Kolossov, & ZumBrunnen, 2007), hazard management (Guinau, Pallas, & Vilaplana, 2005; Liu, Huang, & Chandramouli, 2006), health services (Hare & Barcus, 2007; Stellman et al., 2003), and information access (Prieger & Hu, 2008; Xia, 2004).

In a library setting, in particular, research designed to map users' addresses can be used to visualize locations on a map. This can be valuable for planning to improve library utilization (Kinikin, 2004; Koontz & Jue, 2003; Lee, 2007; Ottensmann, 1997). Ottensmann (1997) provided some possible applications of GIS in library settings, and applied GIS to the analysis of library user data. Through this, he showed several possible GIS utilities, such as mapping the distance

effect, identifying service areas, planning a new facility, and integrating demographic information. Kinikin (2004), Koontz and Jue (2003), and Lee (2007) have used GIS and library user data to find new library locations and to identify library service areas, respectively. Similarly, this research uses GIS to analyze library user data collected from a public library management system.

4. Research design

4.1. Data collection

Lake County in north-central Florida, with 245,061 people, according to the U.S. Census Bureau in 2000, was purposely selected as a study area. This county is served by the Lake County Library System (LCLS) and is comprised of 13 public libraries, including six branch libraries and seven member libraries. Data on these libraries – such as the size of the library collection, user registration, and circulation information – are managed by SirsiDynix, an integrated library management system (Lake County Library System, 2008). Each registered user's information, including address, registration date, last check-out date, along with demographic information including age, gender, and ethnicity, was retrieved from the system.

Geographic data such as addresses, lake locations, and road networks were used to investigate how far users travel, and how their demographic characteristics relate to their travel to one of the county's libraries. Table 1 shows the data set collected, including registration, road network, census, and county boundaries. The road network data set used in this research was provided by ESRI Software. The road network data set in the ESRI CD-ROM includes information about the status of roads across the United States. The boundary map of Florida counties including Lake County was collected from the Florida Geographic Data Library, which is a warehouse that distributes geographic information concerning the state of Florida (Florida Geographic Data Library, 2002). After reviewing previous research (Adkins & Sturges, 2004; Kinikin, 2004; Ottensmann, 1997), four variables – percentage of households with children under 18 years, education level, median household income, and poverty level – were identified as significant factors related to library use. Those four characteristics for Lake County residents were extracted from the 2000 census data.

4.2. Data preprocessing

After acquiring registration data from LCLS, the data were preprocessed for analysis as follows: First, any address that only had a post office box was deleted, since the box is located in the post office and does not show the user's actual address. Also, tools for geocoding cannot generate an XY location for an address with only a post office box. Second, any data with an incorrect address or zip code type was

Table 1
The characteristics of collected data.

Data	Data type	Feature type	Data source	Contents
Register location	Vector	Point	Lake County Library System	Birth data, registered date, last-checkout date, age, gender, ethnic group
Road network	Vector	Line	ESRI CD-Rom	Road type, length, and width
Census	Vector	Polygon	Census Bureau	Socio-economic data such as education level, median household income, and poverty level
Florida County Boundary	Vector	Polygon	FGDL	Boundary, county identification information

also eliminated. Third, any address without a zip code was deleted. Using these screening criteria, a total of 8613 users were eliminated. In addition, library registrants who did not check out any materials from the libraries during one year (from March 2007 to February 2008) were excluded. Even though these library users had registered in LCLS, it was assumed that they did not use the libraries because of other alternatives, or moves to other areas. Therefore, for a more accurate analysis of library access, only the 41,639 registrants who had a check-out record within the previous year were extracted from the whole data set. The remaining preprocessed data were geocoded onto the map using the Batchgeocode website (http://www.batchgeocode.com). Through this website, any address with a ZIP code can be converted into a latitude/longitude matrix.

4.3. Data analysis

The preprocessed data were mapped and analyzed using ArcGIS 9.2, one of the most popular GIS software packages. Using a network analyst, a function in AcrGIS, travel distances from users' homes to public libraries based on road networks were measured. In order to investigate the effect of distance, the map is presented in a Thiessen polygon. Thiessen polygons, also called Voronoi polygons, indicate the influential area for each set of points. This polygon is based on the assumption that the area is closest to a certain point, relative to all other points. Therefore, if a library user location is within the Thiessen polygon for 'A,' the nearest library to that user is 'A.'

Spatial autocorrelation, which reveals "the fact that the value of a variable at one point in space is related to the value of that same variable in a nearby location" (Rogerson, 2010, p. 18) was used to measure the relationship between travel distance and social-economic characteristics. Spatial autocorrelation statistics were measured using Multivariate Moran's I, which is useful for describing the correlation between two variables. Here, the multivariate Moran's I presents the average correlation between neighbors' social-economic characteristics and individual travel time. GeoDa, a GIS software package for statistical analysis, was employed to measure the spatial autocorrelation.

5. Findings

Public library locations and registrants' home addresses were geocoded and mapped. Fig. 1 shows the home locations of 41,639 registrants color-coded according to the library they visited. The majority of registered users of LCLS are Lake County residents. Residents of other counties also use the libraries in Lake County, including residents of the neighboring counties of Marion, Sumter, Polk, Osceola, Orange, Seminole, and Volusia, even though these counties also provide public library services to their residents. This map shows that policies for collaboration between counties and for non-resident services are critical; however, such issues are not within the scope of this study. Thus, to analyze the impact of travel distance on library use, data for the 35,921 registrants who live in Lake County, FL were extracted from the whole user data set.

Thiessen polygon analysis results indicate that about 65.24% of all library registrants live in the area presented by each Thiessen polygon. The analysis also shows that, overall, 34.76% of registrants live outside of the polygon. In the case of the Citrus Ridge library, in particular, most registrants' homes (74.57%) are located outside of the polygon. Table 2 also shows the mean and median travel distance from users' homes to the libraries. Unlike previous research, this study uses the more realistic distance measure of actual road networks. The mean distance from users' homes to the libraries they use is 5.02 miles. The mean travel distance (2.76 miles) of the Astor library registrants was the shortest, and the mean travel distance (7.93 miles) of the Citrus Ridge library registrants was the longest.
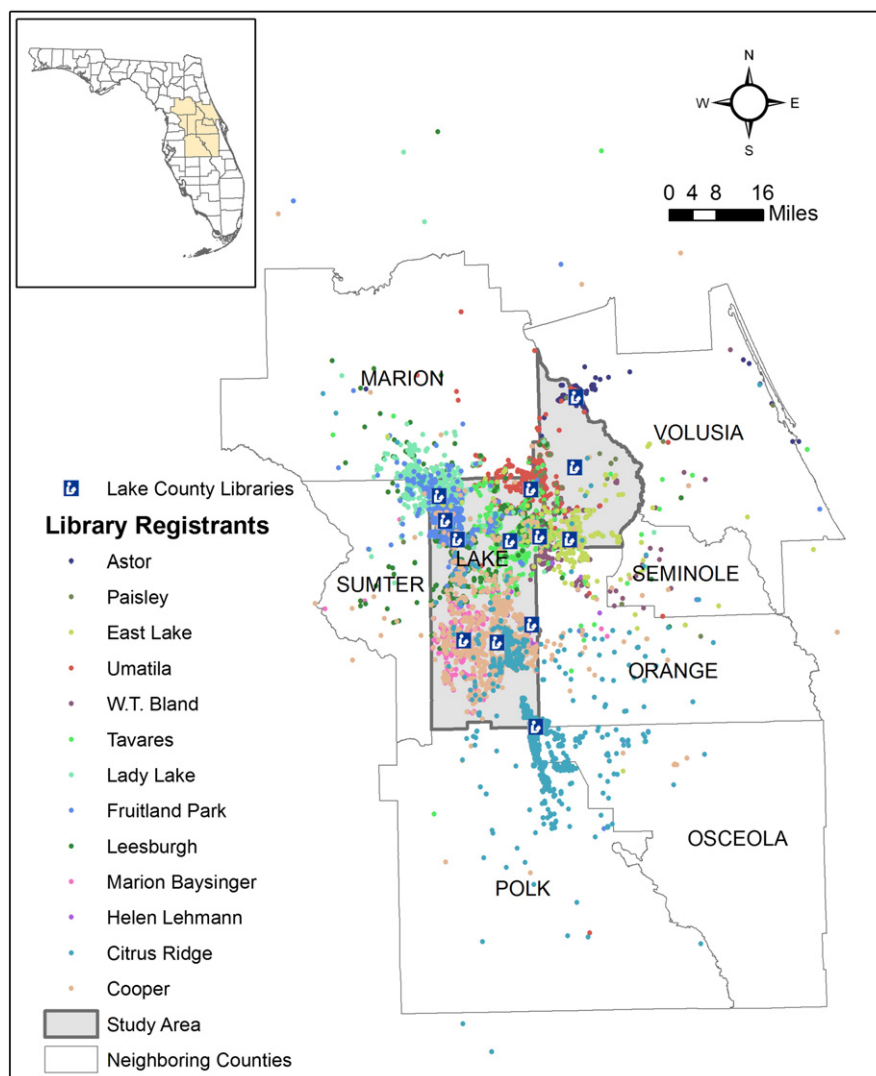
Fig. 1. Locations of LCLS libraries and registers.

Travel distance was also analyzed by ethnic groups. Registration data of LCLS includes information about the ethnicity of registered users, which falls into eight categories: African American, Hispanic, Indian and Pakistani, multi-racial, Native American Indian, Asian, other or unknown, and Caucasian. As Table 3 indicates, the majority (56.8%) of registrants are Caucasian. The mean travel distance for Caucasians to reach their libraries is approximately 5.3 miles, and the mean travel distances for Hispanics and Africans Americans are

Table 2
Library users within Thiessen polygon, their mean and median travel distance, and library characteristics.

Lake County libraries	Thiessen polygon		Distance			Library characteristics		
	% of registrants in Thiessen polygon	% of registrants out of Thiessen polygon	Mean	Median	% of total circulators	Total square feet	# of materials	Total annual programs
Astor	79.88%	20.12%	2.76	1.73	1.50%	4200	18,816	125
Paisley	68.39%	31.61%	5.33	4.45	2.00%	4200	24,467	181
East Lake	61.37%	38.63%	5.51	2.89	3.40%	5000	31,009	211
Umatilla	55.41%	44.59%	5.65	3.96	6.20%	8620	32,121	504
W.T. Bland	69.48%	30.52%	5.86	2.78	8.10%	15,000	66,731	467
Tavares	74.47%	25.53%	5.05	3.99	10.80%	9100	46,050	336
Lady Lake	71.27%	28.73%	2.93	2.23	7.20%	8700	45,636	1093
Fruitland Park	70.45%	29.55%	3.42	2.22	4.60%	6800	34,039	405
Leesburg	65.39%	34.61%	5.25	3.61	12.00%	41,971	128,024	291
Marion Baysinger	77.83%	22.17%	3.79	2.32	7.20%	5000	25,444	165
Helen Lehmann	84.09%	15.91%	2.37	0.96	1.00%	3500	14,485	59
Citrus Ridge	25.43%	74.57%	7.93	4.59	7.80%	6000	36,709	372
Cooper	76.50%	23.50%	4.96	4.40	28.20%	7000	61,826	197
Total	65.24%	34.76%	5.02	3.52	100%	125,091	565,357	4406

Table 3
Travel distance per ethnic groups.

ETHNIC	Mean	Median	N	Std. deviation	% of total N
African American	4.4643	2.9516	1858	4.62368	5.2%
Hispanic	4.7726	2.9680	2483	4.76186	6.9%
Indian, Pakistani, etc.	4.9754	3.6529	227	3.67304	0.6%
Multi-racial	4.3981	3.6484	27	3.44184	0.1%
Native American	4.3991	3.0146	23	5.05488	0.1%
Asian	5.0835	4.0142	136	4.15465	0.4%
Other, unknown	4.7061	3.2947	10,779	4.83772	30.0%
Caucasian	5.2630	3.7819	20,388	4.92703	56.8%
Total	5.0170	3.5160	35,921	4.87137	100.0%

Table 5
Results of multivariate Moran's I.

Variables	Multivariate Moran's I
Mean travel distance	
% of household with own children under 18 years	0.0648*
Education	
% of people without high school diploma	−0.0807*
% of people with high school diploma	0.0727*
% of people with bachelor's degree	0.055
% of people with master's degree	−0.0889*
% of people with Ph.D.	−0.1135
Median household income	0.0468
Below poverty	0.0592

Note: Values with * mean Moran's I index is significant at the 95% Confidence Level.

about 4.5 and 4.8 miles, respectively; the travel distance of the two minority groups is lower than that of Caucasians. However, this result may not indicate that travel distance between groups is significantly different. To test whether or not the difference is significant, the researcher conducted an ANOVA (Analysis of Variance) test, which is used to prove the difference among two or more independent groups. As Table 4 indicates, there is a significant difference between the travel distances of these three groups.

To analyze the relationship between travel distances and registrant's social-economic characteristics, spatial autocorrelation analysis was conducted after integrating travel distance and census data including demographic data. Table 5 shows multivariate Moran's I statistics. The value of each variable is a correlation coefficient between mean travel distance and other variables. From the table, four variables – the percentage of households with children under 18 years, the percentage of people without high school diplomas, the percentage of people with high school diplomas, and the percentage of people with master's degrees – are significantly at the 95% confidence level, but others are not. Among the four variables, while mean travel distance to libraries is positively correlated with the percentage of households with children under 18 years and the percentage of people with high school diplomas, the percentage of people without high school diplomas and the percentage of people with master's degrees are negatively correlated with the mean travel distance.

6. Discussion

6.1. Travel distance

Distance is an important factor for library use and is frequently cited in library location research. Tobler (1970) argued that the first law of geography means that "everything is related to everything else, but near things are more related than distant things" (p. 236). In this research, Thiessen polygon results employed to identify the impact of distance on travel to public libraries show that the registrants use the library nearest to their home, and that travel distance is an important factor for their choice of library. Even though many factors affect library users' travel, distance is one of the critical factors of access to libraries. This finding also suggests that defining service areas of public libraries based on distance is meaningful, and could be a first concern with regard to development of library services

and programs. Based on the service area, librarians can create customer profiles, which help them to make better plans for their customers. Fig. 2a shows the service areas of public libraries in Lake County identified using the Thiessen Polygon analysis. This appears similar to what is seen in Fig. 2b, which is a traffic analysis zones-based map obtained from the library. Fig. 2a can be easily created using GIS, however, and a more accurate service area map could be developed in consultation with library staff. In addition, by incorporating the service areas and social-economic data such as census data, librarians can get a better understanding of people who live in the area they serve.

The finding also shows that not all registrants use the nearest library to their home. Some registrants use a more distant library instead of the nearest library, suggesting that their library use might be affected by factors other than simple distance. As previous research has found (Koontz, 1997; Ottensmann, 1997), people tend to choose library branches that are more attractive for some reason, and thus might prefer new branches, branches with larger collections, or more comfortable atmospheres. In Lake County, as Table 2 indicates, the Astor County Library and the Helen Lehmann Memorial Library have relatively small collections and facility sizes, and their users, compared to users of other libraries, travel shorter distances. On the other hand, users of libraries with large collections and varied library programs, such as the Umatilla Public Library and the W.T. Bland Public Library, travel further, suggesting that library attractiveness is associated with library usage and willingness to travel further.

Results from Table 2, however, do not show the full picture of public library access, and reasons for such users' behaviors. The behavior patterns identified from the GIS results can be more fully explained when combined with other results from surveys and questionnaires, interviews, and focus groups. Additionally, through these methods perceived accessibility, which is a critical element in the accessibility analysis (Brabyn & Skelly, 2002), can be examined. Although the distance between the library and users' homes may be considerable, if users have a lot of time and are willing to spend it by visiting the library, the perceived distance may be shorter than the actual distance. Therefore, the combination of actual and perceived accessibility can explain some aspects of library use. However, the complexity of accessibility modeling and computations makes this difficult.

6.2. Travel distance per ethnic group

The results indicate that Hispanic and African American groups are more sensitive than other groups to travel distance, which means travel distance could be a barrier to library access for these groups. Through a review of library literature, Koontz and Jue (2008) identified major barriers that decrease library use, including reading/library habits, transportation, literacy skills, discretionary time, and knowledge of services. Even though transportation issues related to

Table 4
ANOVA results.

		Sum of squares	df	Mean square	F	Sig.
Between groups	(Combined)	3011.385	7	430.198	18.189	.000
	Within groups	849,380.007	35,913	23.651		
	Total	852,391.391	35,920			

accessibility were not recognized by the researchers as a major barrier, respondents – particularly Hispanics and Asians – still perceived it as such. To better support those groups, therefore, library staff need to pay more attention to eliminating these barriers, and developing community partnerships with local government agencies, such as public transportation departments, in order to enhance the accessibility of their facilities. Also, mapping where those groups live might help library staff develop plans to reduce the time needed to access library services and programs.

6.3. The relationship between distance and social-economic characteristics

The results of multivariate Moran's I analysis indicate several issues in library access. Mean travel distance to libraries produces positive and significant results against the percentage of household with children under 18 years, which means they are willing to travel farther to access public libraries. As previous research (McClure & Bertot, 1998) has pointed out, library services for children have a critical impact on a community and are strongly connected with library use. The frequency of library use for households with children is higher than that of households without children, regardless of distance.

The next issue is related to information literacy. Mean travel distance to libraries is negatively, but significantly, associated with the percentage of households in which parents have no high school diploma. This result suggests that if the public library is located near their home, they may use it. If the library is not near their home, however, they may not consider using it. As the level of educational attainment is generally associated with literacy levels (Broucker & Lavallee, 1998), some people without high school diplomas may have poorer literacy skills, and distance could be a barrier to library access for them. Furthermore, the finding that households including people with high school diplomas appear to be positively and significantly associated with mean travel distance supports the relationship between literacy education and library utilization.

Finally, the results show negative and significant relationships between mean travel distance and the percentage of people with master's degrees. The negative relationship means the usage of people with master's degrees decreases as travel distance increases. The finding suggests
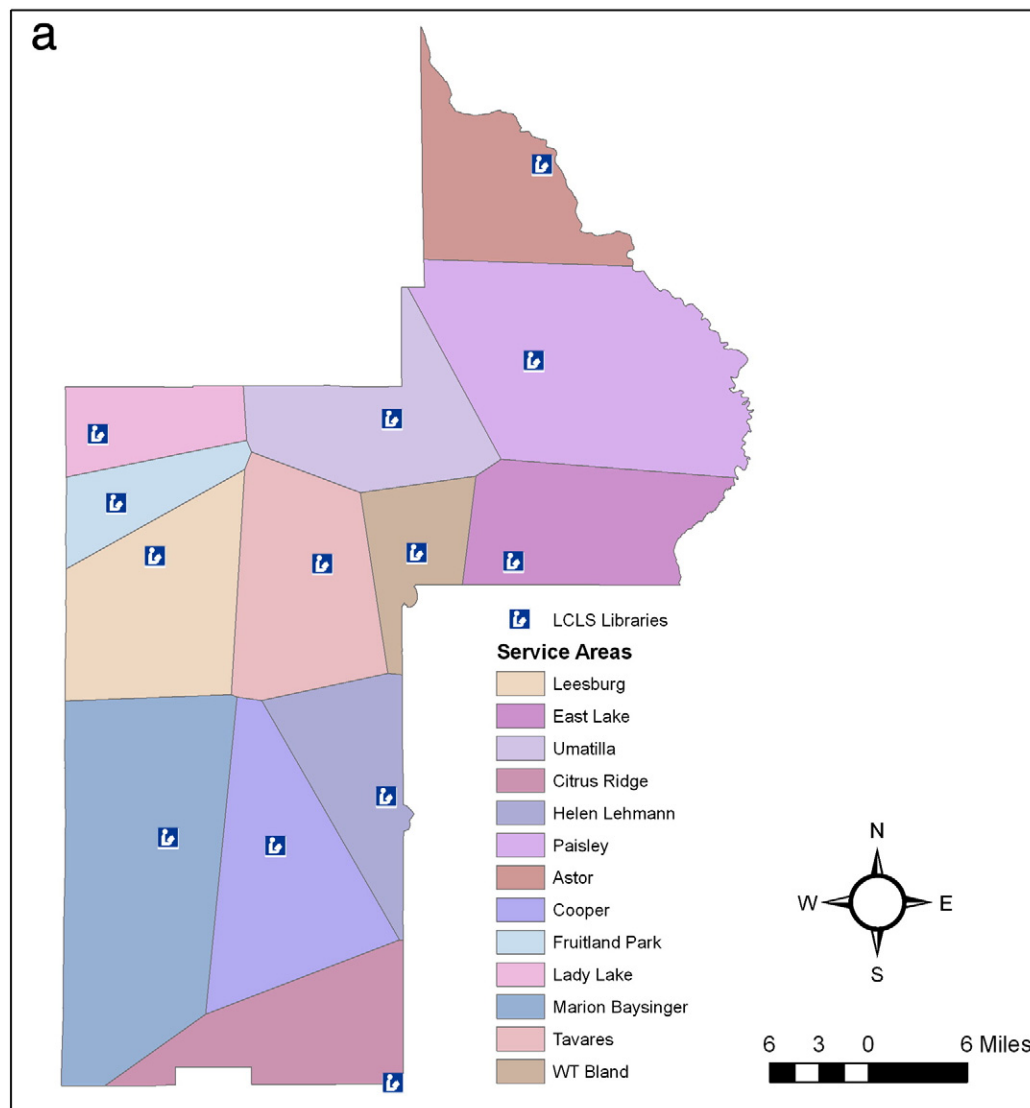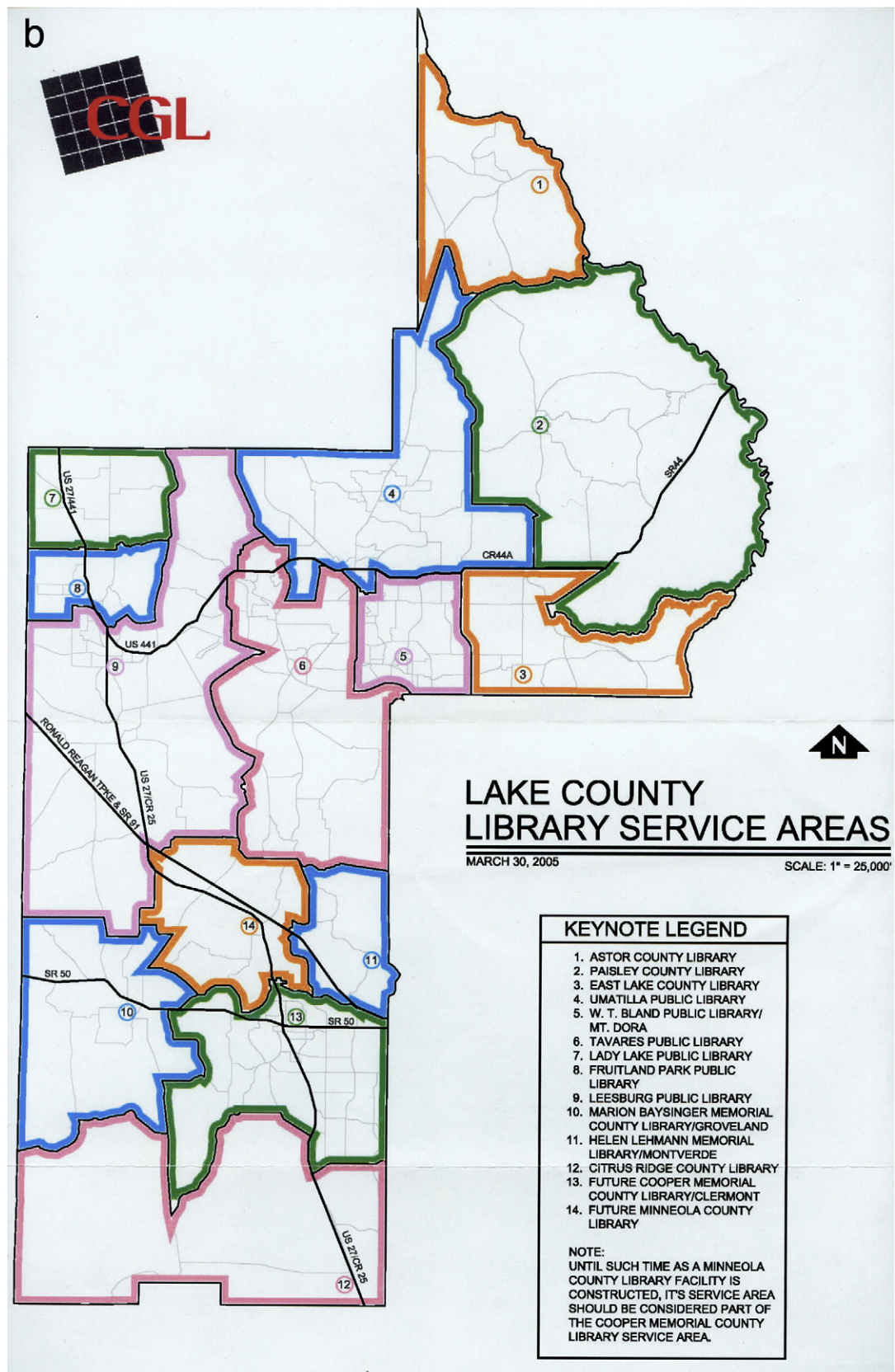

Fig. 2. Distance-based service areas for each library in Lake County, FL.

Fig. 2. Lake County library service areas based on TAZs. Reprinted from *Lake County Library System* facilities plan 2005–2020, unpublished manuscript, Lake County Library System, FL. Adapted with permission. (*continued*).

that if they live far from libraries, such users are inclined to find alternatives to library services. Use of the Internet may be such an alternative. The U.S. Department of Commerce (2004) reported that usage of the Internet increases as education level rises. People with higher educational levels might go online to find the information they need, and develop online communities. In addition, higher education is associated with buying books; households with higher education tend to buy more books (Danziger, 2002).

Distance negatively influences library access both for people without high school diplomas, and for people with master's degrees who have alternatives to library services. This means that distance may be a factor of nonuse for at least some of these people. A library's literacy services will likely be irrelevant for people with graduate degrees, and such users may also have more options available to them when it comes to accessing and using information resources. Since distance also seems to be an impediment for users without high school diplomas, however, libraries may be able to better meet the needs of such users by enhancing their literacy services and other services. Needs assessment of these people can enable library staff to design library services for them, making libraries useful and attractive places to meet their needs. To further shrink the distance barrier, partnerships with local government agencies are also recommended.

6.4. Limitations

This research is subject to several limitations. Regarding methodology, the registration and circulation data do not represent all types of library use; the users considered are only individuals who checked out materials such as books, CDs, and DVDs, while other types of users, including in-house users and library program attendees were not considered. In addition, the reality is that people's daily outdoor activities are not simply home-based single-destination trips, but include various types of trips, including multi-destination trips. This research, however, focused only on patterns of users making single destination trips. For a better understanding on how library users reach their library, and what the relationships between travel distance and library use are, research analyzing all types of library users, including those making multi-destination trips, needs to be conducted.

7. Conclusion

A geographic analysis of access may permit a better understanding of library users' travel to libraries. GIS results reveal that distance is a critical factor of library access and may be used as a starting point for further study. Also, findings from this study, using a measure of distance based on road networks, have important implications for improving library access and usages. To increase the use of their libraries, it is recommended that public librarians identify distance-based service areas of libraries as a first step, in order to better understand the socio-economic characteristics of a particular library's users, and thus, bring enhancement to all library services. Also, librarians should pay more attention to the attractiveness of their libraries, in particular for user groups susceptible to distance related barriers. Additionally, both designing literacy education and assessing the needs of library users can help to alleviate the barriers caused by distance.

Acknowledgments

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