A GIS-Based Analysis for Transportation Accessibility, Disaster Preparedness, and Rural Libraries' Roles in Community Resilience

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ABSTRACT

Outreach to rural communities is always challenging, but in disasters, connecting with vulnerable communities becomes nearly impossible considering widespread destruction and lack of resources to travel obstructed distances. We used a geographic information system (GIS) framework to gather, analyze, and compare two rural county public library systems' accessibility during Hurricane Michael's devastating strike on the Florida Panhandle in 2018. This approach helped us explore the connections among public libraries, their communities, and the built environment (e.g., population densities, transportation infrastructure). Our findings identified access issues for libraries in each county which can inform disaster preparedness, response, and recovery efforts and improve delivery of valuable resources to all community members. Implications for library directors, librarians, county emergency management officers, and affected communities using travel times between population block groups are provided.

ALISE RESEARCH TAXONOMY TOPICS

Public libraries; Specific populations; Data visualization; Information use.

AUTHOR KEYWORDS

Rural libraries, GIS, natural disasters, vulnerable populations.

INTRODUCTION

To support resilience, community leaders must develop and maintain vital disaster preparedness, response, and recovery plans. Critical facilities, including hospitals, fire stations, police stations, and public libraries, support communities all in phases of disasters (Federal

Emergency Management Agency [FEMA], 2010), and effective disaster plans detail how these facilities' staff and first responders can best serve residents. In Florida, however, public libraries are also critical facilities and public librarians are contractually obligated to serve as essential personnel (Stricker, 2019); therefore, thorough disaster plans reflect public librarians' capabilities and libraries' facilities' accessibility to vulnerable populations.

Purpose of this study.

The purpose of this study was to explore the ways in which geographic information systems (GIS) can inform the ways in which public libraries can function in crisis management. We reviewed public librarian and public library emergency service roles and concluded that, in emergencies, public librarians function with few community disaster management resources and public libraries receive little recognition as critical support facilities. As a result, public librarians are often excluded from disaster planning, though communities rely on access to libraries in adverse events. Armed with this clear oversight and opportunity, we applied a geographic information system (GIS)-based framework to assess the spatial distribution of vulnerable populations (e.g., senior citizens or highly rural populations) relative to public library branches, in conjunction with available transportation networks and regional traffic characteristics. The research focused on two rural counties, one inland and one coastal, devastated by Category 5 Hurricane Michael. The question of how GIS data analyses can inform critical facilities planning by improving public library access for vulnerable populations in natural disasters guided our work.

LITERATURE REVIEW

Public libraries as critical disaster response facilities.

Public libraries are a critical community facility before and after a hurricane event (Brobst et al., 2012; Stricker, 2019). During disasters, public libraries function as aid distribution points, community information hubs, and meeting places; public librarians extend normal hours, aid evacuees, provide improvised on-demand services, and ensure library service continuity and restoration. Through these activities in and beyond library buildings, public librarians exercise disaster preparedness and response service roles ranging from institutional, community, and government supporters to collection managers to information disseminators to educators/trainers to community builders (Brobst et al., 2012; McClure et al., 2009). In the aftermath of disasters, public librarians, particularly in rural areas, improvise services and collaborate with local community initiatives to fulfill crucial emergency functions (Celedón et al., 2012).

Public librarian roles in disaster planning and response.

Library disaster planning studies have primarily focused on larger libraries located in more urban settings, resulting in less guidance on the specifics of disaster planning for smaller

public libraries, particularly in rural areas (Green & Teper, 2006). Despite lacking robust emergency preparedness resources, public libraries with public librarians working at the forefront of disasters have served a pivotal role in community disaster response by meeting critical community needs (Young, 2018), although small and rural libraries have tended to be "less likely to be prepared for emergencies and disasters than their large and medium counterparts" (Institute of Museum and Library Services, 2019, p.3).

Public librarians produce trust and social capital through information services; equitable distribution of community goods; and spaces that support knowledge-building, community-building, and social investment (Caidi, 2006; Hertel & Sprague, 2007; Vårheim, 2014). Public libraries utilized social media platforms, such as Twitter, to spread important information to their population before, during, and after the disaster event (Han, 2019; Yang & Ju, 2021). Public libraries also offer shelter and physical aid, while public librarians provide emergency information, care for community members in need, collaborate with partner government and relief organizations, and provide continuity of traditional library and other services to restore normalcy (Bishop & Veil, 2013). Unfortunately, these critical contributions are not always well recognized by emergency responders (Bayraktar & Yilmaz, 2018).

Library services for older populations in rural areas.

The "rural" locale designation specifies that all population, housing, and territory is not included in urbanized areas of 50,000 or more people (U. S. Census Bureau, 2020). Approximately 15.6% of public libraries in Florida are defined as rural (Swan et al., 2013), and many of those libraries were in Hurricane Michael's path. Public libraries and librarians have incorporated multiple services, programming, and outreach initiatives to better serve their rural populations. Even when faced with challenges to community engagement, librarians have optimistically and effectively served their communities with limited resources (Reid & Howard, 2016).

Vulnerable populations face unique access barriers to accessing public libraries during normal times, especially senior populations in rural areas in our own analysis. Senior citizens are one of several vulnerable populations directly impacted by natural disasters. While preparing for hurricanes directly impacts elderly individuals, they also experience psychological trauma as a result of the adverse event (Bayraktar & Yilmaz, 2018). Information assistance following a hurricane often includes instruction and completion of relief forms, yet elderly individuals often seek support from familiar individuals versus public assistance. In order to combat this, public librarians are actively working to support elderly individuals by increasing the geographic footprint (Alajmi, 2016; Horton, 2019). Compared to urban libraries, rural librarians have higher demand for support services for elderly individuals over programming services (Lenstra et al., 2020).

GIS

GIS has been incorporated into successful disaster recovery planning (Craner, 2019; Grottenberg & Nja, 2017; Imran et al., 2018; Ledraa & Al-Ghamdi, 2020; Miller et al., 2006; Nur et al., 2018). GIS makes use of geodatabases, which allows the integration of diverse information sources for spatial data (Nur et al., 2018). This technology provides a means for identifying important planning information, such as residents' locations. GIS also helps to facilitate communication, which increases the chances of a successful contact with responders (Miller et al., 2006; Nur et al., 2018). GIS has also been used as a decision-making system (Feizizadeh et al., 2021; Ledraa & Al-Ghamdi, 2020), particularly in spatial planning (Nur et al., 2018) and in emergency management (Grottenberg & Nja, 2017). Research on GIS and its effectiveness has been improving over the years (Grottenberg & Nja, 2017; Nur et al., 2018). However, some areas of improvements are needed (Ledraa & Al-Ghamdi, 2020) and experts have proposed models to improve GIS planning in emergency situations (Rahman et al., 2021) and a system to bridge the gap between urban sustainability assessment and spatial analysis (Pedro et al., 2019).

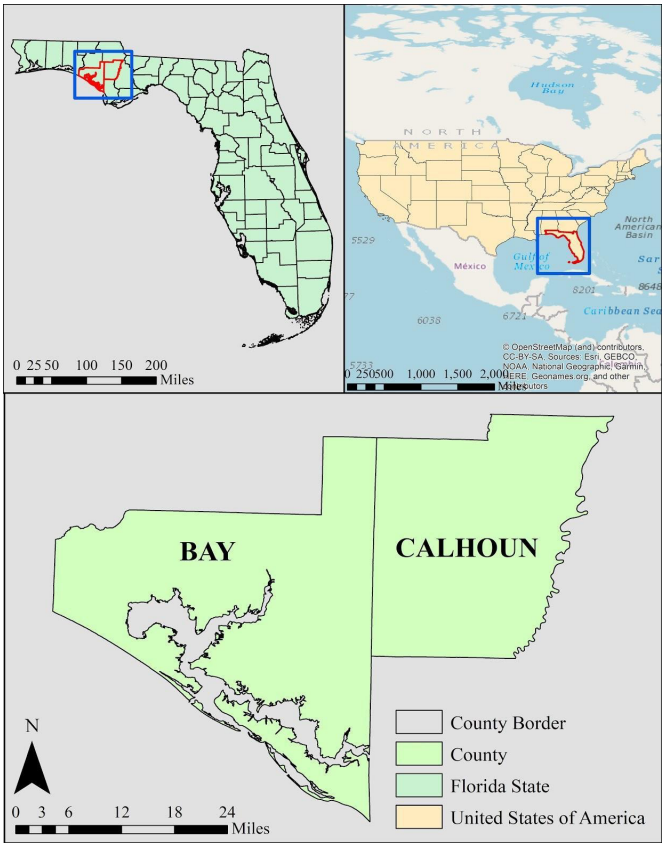
Library siting and GIS.

GIS mapping is an invaluable tool in all phases of an emergency (Craner, 2019). Several studies showed that GIS use in libraries could prove beneficial if used for disaster planning (Kong et al., 2017; Lim & Park, 2015; Veil & Bishop, 2014). Ideally, public library facility placement maximizes all citizens' access to and interaction with information (Gibson & Kaplan, 2017; Koontz, 2007). Public librarians have utilized GIS to not only manage their collections and facilities, but also to analyze the population served (Bishop & Mandel, 2010). Considering the needs of the immediate community when planning services and programs is of utmost importance for librarians, as it has been shown that distance plays a large part in decisions to attend these services (Park, 2012). Alternatively, GIS gives public libraries information on population and neighborhood data phenomena (Bishop et al., 2011).

METHOD

To understand how transportation-based data can inform key community stakeholders' hurricane disaster plans and disaster recovery efforts (Patterson et al., 2010), we used GIS to analyze two rural counties in rural Northwest Florida. Both counties were seriously impacted by Hurricane Michael in 2018. Bay County is 758 square miles and with a population of about 180,000, of whom 16% were 65 years and older (U. S. Census Bureau, 2016). Bay County's public librarians staff five public library branches, located in rural and non-rural areas of the county; highly rural Calhoun County is 567 square miles with a population of 14,500, of whom 17.7% were 65 years and older. Calhoun County includes six public library branches. The illustration of the study's geographical case area is shown in Figure 1.

Figure 1
Bay County and Calhoun County locations in Florida



As Figure 1 suggests, Bay and Calhoun counties provided an insightful case area to study and make comparisons using GIS-informed accessibility data in terms of rurality, total population, and vulnerable rural and elder populations; Calhoun County is more rural and less populated and Bay County is slightly more urban and populated.

To assess the accessibility of population block groups to public libraries in Bay and Calhoun counties, we obtained the congested travel times for each roadway from the Florida Standard Urban Transportation Model Structure model (2014). We used these data to conduct two GIS assessments: 1) unique qualities that shaped transportation accessibility-based community disaster planning and responses; and 2) accessibility of population block groups to each public library site located in each of the two counties.

We used the Network Analyst module in the ArcGIS mapping software to find the optimal path between origins and destinations. Here, origins are the centers of the census population block groups and destinations are the facilities. Based on the obtained congested travel times between each origin-destination pair, using GIS-based maps, we visualized the

accessibility of each census block group to public libraries. In this analysis, we identified the population block groups with the highest and lowest accessibility to libraries. To document the extent to which rurally located and senior populations could access libraries, we calculated the county weighted average total congested travel time for population groups in each county for each public library. This calculation was used to rank counties in terms of accessibility to libraries for population groups. In the context of this study, congestion not only reflected likely traffic density, but also likelihood for roadways to have been blocked by storm-caused debris and flooding.

FINDINGS

Library facilities and roadways.

The location of these public library facilities, as well as the roadway network in the case area, are shown in Figure 2. In the case area, there are 11 public libraries (FGDL, 2015). Librarians staff six library facilities within the Calhoun County Public Library System and five in Bay County. These facilities constitute the destinations for the trips.

Figure 2
Public library branches in Bay and Calhoun counties

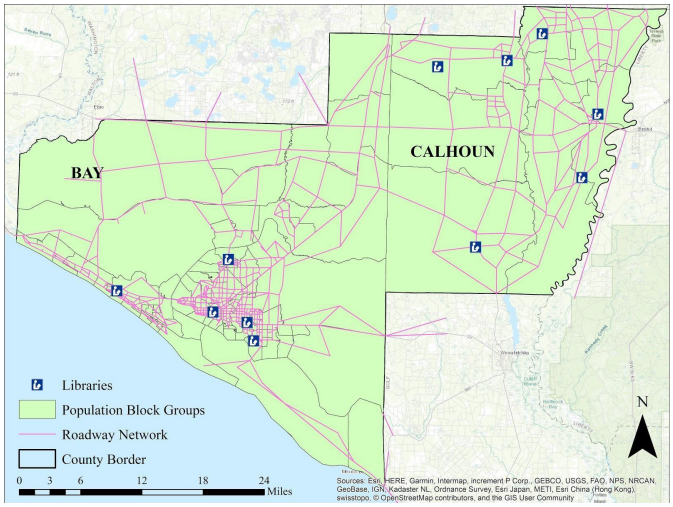


Figure 2 also illustrates roadways that connect the origins and destinations, based on the FSUTMS model provided for the Northwest Florida region (FSUTMS, 2014). The data depicted in Figure 2 can assist in determine important and alternate routes to library sites.

Population blocks.

As Figure 2 showed, Bay County's public library facilities are primarily centrally located within the county, with the exception of one coastally sited public library. In Figure 3, geometric

centers of population block groups are considered as travel origins, and the population block groups along with their geometric centers.

Figure 3
Population Blocks in Bay and Calhoun Counties

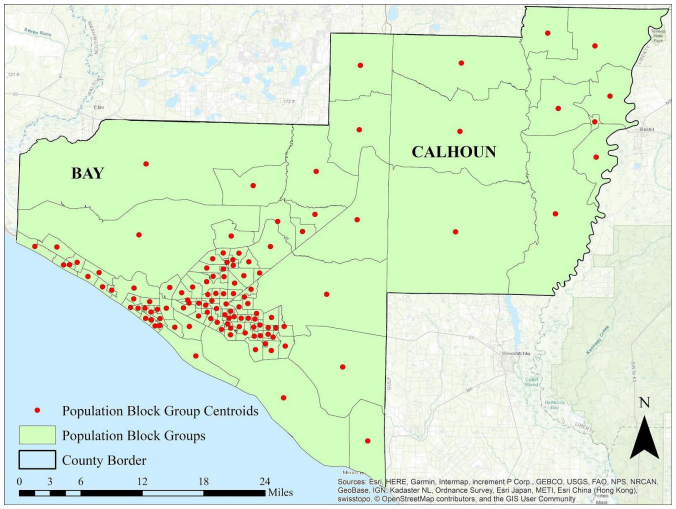
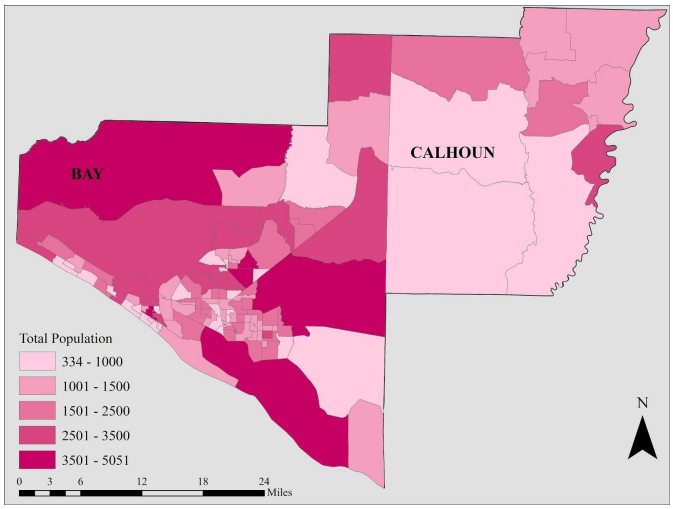


Figure 3 demonstrates Bay County's centrally located population blocks, whereas Calhoun County hosts public library facilities that sited throughout the county. Calhoun County also demonstrates un-clustered population blocks throughout the county.

Total population.

Figure 4 shows that the largest populations were found in the northwestern areas of Bay County, but not necessarily where the library branches were located, as Figure 2 depicted.

Figure 4
Total Population of Bay and Calhoun Counties



As Figure 4 also showed, Calhoun County has three major pockets of population, predominantly spread across the north and northeast of the county, where four of the six public library facilities in the county are located, according to Figure 2.

Aging Population.

Senior populations are not always in populous areas. Although most of Bay County's seniors are located in the urban areas of the county, as Figure 5 shows, senior populations are also in the highly rural northeast and southeast areas of the county, far away from Bay County branches, but close to Calhoun County library branches. Therefore, Bay County has to take into account seniors living in a variety of settings, and cooperative relationships with the adjacent counties' disaster planning strategies.

Figure 5
Senior Citizen Population in Bay and Calhoun Counties

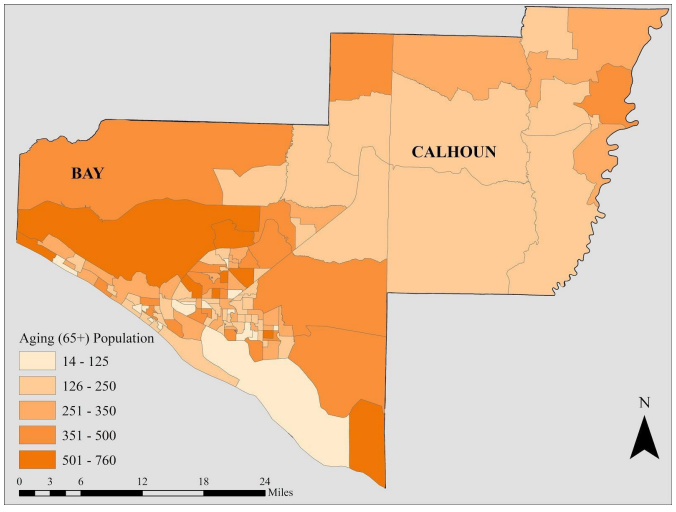
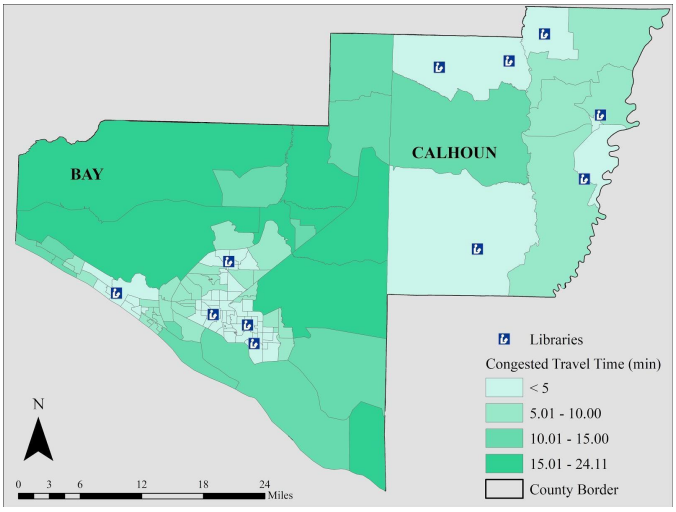


Figure 5 also highlighted the need for services for senior citizens who live closer to another county than their home county. As Figure 5 suggested, Calhoun County's seniors were, in some instances, actually located in very rural areas, some of which were unserved by a public library branch depicted in Figure 2.

Congested Travel Time.

In Figure 6, the highest levels of congested travel time to public library facilities were aligned with the large total populations and elder populations in the northwestern areas of Bay County.

Figure 6
Congested Travel Time



Overall, Calhoun County demonstrated less severe population-induced congested travel time to public library branches when compared with Bay County; low population usually means higher natural environment density.

DISCUSSION

How can GIS findings be used by public librarians to improve critical facilities planning for vulnerable populations in natural disasters? When disaster strikes, public libraries play a significant role in the communities they serve (Ayre, 2019; Ghorbanzadeh et al., 2020; Veil & Bishop, 2014). Thus, the disaster preparedness officials have slowly started to include libraries into the planning phase in emergency situations (Ayre, 2019). Use of GIS methodology with Census, library, transportation, or other pertinent data can provide information about rural counties' vulnerable residents who are challenged to access public library services in a disaster

(Hertel & Sprague, 2007). Because public librarians provide much-needed outreach programs and services in and beyond their library buildings, GIS analyses help them better prepare for all kinds of outreach and directly inform disaster planning activities (Featherstone, 2012).

Public librarians can use GIS mapping and information to update and create disaster plans, if no formal disaster plan exists. As many public librarians are contractually obligated disaster responders, these data can assist library directors in collaboratively creating library emergency response plans to determine which public librarians are to report which public library facilities as well as to increase collaboration between adjacent counties. Public library directors, public librarians, and emergency community planners can use travel accessibility as a part of their decision-making process as to what library facilities to open.

The results of this study indicated that the more populous Bay County faced longer, and potentially more time-consuming, routes between vulnerable populations and public library branches, which Calhoun County's library branches were located closer to high-need users. However, as illustrated in Figure 5, the shorter distances of Calhoun County may not result in shorter travel times when the likelihood of flooding and debris from the denser environment. Regardless of the type of potential complication, this study's results suggested that public library systems need to be attentive to the citizens' needs to access public libraries that may be closer, but not in their home county's library system.

The inclusion of community travel accessibility data during a crisis can assist librarians in preparing for the unique barriers to reaching their most vulnerable users. Travel accessibility data can inform public librarians of the travel challenges faced by community members during a crisis and aid in collaborative disaster planning processes. Data-informed recommendations are especially useful in cases where the closest library facility might not be the most accessible library facility to travel to during a crisis, especially so in considering travel-accessibility barriers faced by vulnerable populations (e.g., the aging populations in Bay County's Northeast boundary are closer to neighboring Calhoun). Accessibility travel time during a disaster might also inform decision makers as to where to site future libraries and/or where to create cooperative agreements, such as the need to increase branch library services in northeast Bay County.

CONCLUSION

In this paper, we explored how GIS might be used to understand how to enhance public librarians' responses to natural disasters. The method we used to conduct this community analysis will enable public librarians to tailor programing and services to serve their communities' needs, especially for vulnerable populations. GIS will also help public librarians to prepare, assess, and revise disaster plans in ways that are consistent with planning processes that may already be underway in county government. Future research might incorporate additional public library facility site data, such as specific resources available at each public library branch to ascertain which services can be delivered directly to citizens in need. Continued collaborative

and interdisciplinary research is critical to address these knowledge gaps and translate this work into the preparation and professional development of library professionals.

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