ANALYSIS OF TRANSPORTATION ACCESSIBILITY TO HOSPITALS IN JACKSONVILLE, FLORIDA

APPLIED RESEARCH PAPER

IN FULFILLMENT OF THE MASTER OF CITY AND REGIONAL PLANNING

SCHOOL OF CITY AND REGIONAL PLANNING

COLLEGE OF ARCHITECTURE

GEORGIA INSTITUTE OF TECHNOLOGY

ROBERT JACOB GUTHART

MOTIVATION AND BACKGROUND

The Fifth Assessment Report of the intergovernmental Panel on Climate Change reports that human activity is responsible for observed climate change, including the increase in global temperatures (Field et al., 2014). Climate change is expected to cause several effects on the current ecological state of the planet. According to the Transportation Research Board, five climate changes that are particularly impactful to transportation are increases in very hot days and heat waves, increases in Arctic temperatures, rising sea levels, increases in intense precipitation events, and increases in hurricane intensity. Historical climate patterns used by transportation planners to guide future plans are no longer reliable. Because current transportation infrastructure is designed for typical weather patterns of a local climate, planners must take into consideration new weather patterns and climate extremes in order to plan for livable communities in the future (Transportation Research Board, 2008).

In addressing climate change throughout the planning process, the consideration of possible future scenarios, a longer term perspective, and the ability to process uncertain and changing information is necessary (Transportation Research Board, 2008). Transportation infrastructure in use today was constructed to withstand expected weather patterns of yesterday. An increased frequency of weather extremes resulting as a result of climate change was not usually considered for aging transportation infrastructure assets. Current transportation infrastructure was designed to operate under normal, expected weather patterns. As a result, the performance of transportation systems under adverse and extreme weather conditions is much worse than under normal clear weather conditions. Performance under adverse weather conditions and

extreme weather is exacerbated in dense urban environments. Within dense urban environments, a single event can create a chain reason severely impacting the entire transportation system (Koetse & Rietveld, 2009).

Interdisciplinary climate research, data gathering, modelling and forecasting, mapping, and structuring of the comprehensive planning process is necessary to ensure that resilience of the US multimodal transportation system and the communities and businesses they support (Cambridge Systematics, Inc., 2009). As transportation infrastructure is constructed to last over decades, climate factors must be incorporated into the siting, investment, and design decision making process (Cambridge Systematics, Inc., 2009). Many infrastructure elements are designed to withstand the 100 year storm but projections indicate that the 100 year precipitation event is likely to occur every 50 or 20 years by the end of this century (Transportation Research Board, 2008).

Planners must take into consideration the recommendations suggested by climate research, data, and forecasting when planning for future development in urban areas. Localized planning efforts for climate change impacts, such as extreme weather, are important to ensure the resiliency of cities. Urban areas are currently unprepared for extreme weather and other climate change effects. Planners must assess the current state of local transportation and analyze potential vulnerabilities in order to prepare and adapt to climate change.

Current climate change models indicate increases in global temperatures, changes in precipitation patterns, and sea level rise (Koetse & Rietveld, 2009). The

historical climate patterns used by transportation planners to guide future plans are no longer reliable. Planners must take into consideration new weather patterns and climate extremes (Transportation Research Board, 2008).

Healthcare has become an increasingly important issue as population grows and the median age of the population increases. In general, healthcare costs have increased while the quality and quantity of services had decreased. (Loh, Cobb & Johnson, 2009). Reasonable access to healthcare is a valuable issue to consider. The ability to access healthcare can impact the public health of a population. It is important for cities to provide sound transportation infrastructure for residents to have the capacity to access healthcare. Hospitals represent a general point of access to healthcare by the general public.

The research and analysis presented in this paper seeks to answer the following research questions: What is the current state of accessibility to hospitals by the street network in Jacksonville, Florida? To what extent is accessibility impacted under the disruption of the 100 year storm event?

PREVIOUS RESEARCH ON ACCESSIBILITY

There is great importance in conducting accessibility analyses on local urban areas. The Transportation Research Board (TRB) recommends that federal, state, and local governments in collaboration with owners and operators of infrastructure should inventory critical transportation infrastructure with consideration towards the projected impacts of climate change. Additionally, agencies should consider when and where projected climate changes within their regions might occur (Transportation Research

Board, 2008). Accessibility measures can help to inform which links in a transportation network are most vulnerable to climate changes.

Several techniques exist to assess vulnerability of transportation infrastructure. Some techniques used previously are similar to the California Seismic Retrofit Program which analyzes vulnerabilities to earthquakes and determines priorities of retrofit and replacement; however, a need exists for geographic information system (GIS) analyses that map locations of critical infrastructure overlaid with information on climate change effects (Transportation Research Board, 2008). An accessibility analysis is one such method using GIS data layers to assess infrastructure vulnerabilities.

Geurs and Van Wee define accessibility as "the extent to which land use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport modes(s)." This definition of accessibility is adopted for this study. Geurs and Van Wee identify four types of components of accessibility. These components include land use, transportation, temporal, and individual. The components of land use and transportation are relevant to this study. The land use component represents the supply of opportunities at each origin, such as employment, health care, and amenities, and the associated demand for these opportunities at each origin, such as households. The transportation component reflects the disutility for an individual to travel between an origin and destination using a specific mode of transportation. This transportation component of accessibility takes into consideration the amount of time, the costs, and the effort required to travel. Essentially the land use component is the distribution of opportunities, while the transport component is the travel demand (Geurs & Van Wee, 2004).

According to Geurs and Van Wee there are four perspectives for measuring accessibility: infrastructure-based, location-based, person-based, and utility-based. This study takes both a location-based approach. A location-based measure describes the degree of accessibility to spatially distributed activities (Geurs & Van Wee, 2004).

There are several types of location-based measure that have been developed for accessibility studies. These types include distance, potential, and balancing measures. For this study, a potential accessibility measure was adopted. Potential, or gravity-based, accessibility measures estimate the accessibility of opportunities in origin zone, i, to all other zones, n. Opportunities in distant zones have a diminishing influence on the origin zone. The general form of the measure is: $A_i = \sum_{j=1}^{n} Dje^{-\beta c_{ij}}$. A is the measure of accessibility in zone i to all opportunities, D, in zone j, c_{ij} is the costs of travel from i to j, and β is the cost sensitivity parameter. This general form is a negative exponential cost function, however, several other impedance functions can also be used including power, Gaussian, or logistic functions. Gravity-based accessibility measures are useful because they are easily calculated with existing land use and transportation data. This type of measure is appropriate as an indicator for access to social and economic opportunities from different social, economic, and demographic groups (Geurs & Van Wee, 2004).

Berdica introduces the concept of considering accessibility as an indicator of vulnerability. Accessibility provides a framework for conceptualizing the idea of vulnerability in the transportation system (Berdica, 2002). Vulnerability is defined as a problem of reduced accessibility that results from various causes. Berdica (2002) defines accessibility as the ease of reaching various opportunities from a given location

provided by the transportation system. Accessibility can be increased by either increasing the number of routes to a certain service or by increasing the amount of services reachable on a certain route.

Liu and Zhu describe a general method for use of GIS tools to measure accessibility. An accessibility analysis is spatial in nature and is well suited for a GIS environment. In order to conduct an accessibility analysis, transportation and socioeconomic data is required. GIS tools are utilized to provide data management, data integration, analysis, and visualization for transportation planning. An accessibility analysis is not a fully integrated and standard GIS function. Instead, underlying network analysis functions that are part of the Network Analyst extension are manipulated to create a measurement of accessibility (Liu & Zhu, 2004).

A general accessibility analysis is a four step process: concept formulation, measure selection and specification, accessibility measurement, and interpretation and evaluation (Liu & Zhu, 2004). The measure of accessibility assumes that accessibility between origins and destinations is proportional to the demand and attraction, and inversely proportional to the distance, time, or cost for traveling between them. The specification of an accessibility measure includes the definition of a spatial unit for analysis, definition of socioeconomic groups, types of opportunities, mode of travel, definition of origins and destinations, and the measurement of attractiveness and travel impedance (Liu & Zhu, 2004).

Socioeconomic characteristics such as income, vehicle ownership, gender and occupation are utilized to analyze the accessibility of socioeconomic groups.

Opportunities for these socioeconomic groups include employment opportunities, retail outlets, parks, schools, medical centers, etc. Travel mode can be private vehicles, buses, trains, walking, or cycling. An accessibility analysis indicates the number of opportunities that can be reached by socioeconomic groups. Definition of origins and destinations specifies from where to where accessibility is measured. The attractiveness of a given opportunity could be measured by the number of opportunities established in a given spatial unit of analysis (Liu & Zhu, 2004).

The measure of accessibility is generally calculated from data organized into origin-destination matrices (OD matrices). OD matrices store values representing travel impedance between each origin and every destination. These travel impedance values can be straight line or network distances, travel time, or costs. An accessibility measurement function is used to calculate a value for the accessibility measure. The functions of potential models have been used in GIS for a number of past research applications (Liu & Zhu, 2004). The accessibility function for a potential model is:

$$A_i = \sum_i M_i f(c_{ij})$$

$$A_i = \sum_i M_i c_{ij}^{-\alpha} - \text{power function}$$

$$A_i = \sum_i M_i \exp(-\alpha c_{ij}) - \text{exponential function}$$

Where:

A_i = accessibility of a location i,

M_j = attractiveness of location j for a given activity,

f = impedance function,

α = distance decay parameter,

c_{ij} = travel distance, time or cost form location I to location j.

Sohn (2006) used an accessibility measure to analyze flood vulnerability of the highway network in Maryland. GIS was used to calculate an individual measure of accessibility for each county in the state. The 100 year floodplain was overlaid the highway network system. All network links that were located within the 100 year floodplain were assumed to be disrupted when flooding occurs (Sohn, 2006).

The accessibility measures were used to evaluate the significance of individual network links. The hypothetical disruption of a highway link due to flood damage was assessed in terms of the loss in accessibility to the state transportation network system. For example, if link one induces a greater accessibility loss than link two, then link one is thought to be more significant. The significance of individual links were assessed by both distance only and distance-traffic volume criteria. The results provided very different accessibility measures by the two different criteria which indicate different priority transportation investments for each individual county (Sohn, 2006).

Access to healthcare involves geographic accessibility, meaning the travel impedance between patients and providers. Adequate and equitable access to healthcare has become increasingly important to policy makers, public health reformers, and medical practitioners. Spatial barriers between consumers and providers result in

low health care utilization and use of preventative services. Poor public health can result. Neutens carries out an extensive literature review of previous studies analyzing accessibility to hospital by transportation. Neutens asserts that current indicators and studies in geographical access to health care fall short in measuring accessibility to determine social disparities in geographical access to healthcare. The study of access to healthcare experiences two geographical problems: the modifiable areal unit problem (MAUP) and the uncertain geographical context problem (UGCoP). MAUP is a statistical bias that occurs when the results of a spatial analysis are different when different data schemes and scales are used, while UGCoP is related to the uncertainty of the area and timing in which individuals are exposed to influences affecting health behavior and outcomes (Neutens, 2015).

Loh, Cobb, and Johnson conduct a GIS based analysis of access to healthcare in the Jacksonville, Florida metropolitan statistical area. The study examines both the potential accessibilities to healthcare services and the actual utilization of healthcare services. Potential accessibilities were determined using GIS to generate service areas which describe the drive times associated with reaching given hospitals. Then, using Huff's Probability Model, the role of hospital size and the effect of distance of a hospital to a user's choice of travelling to a hospital was explored; considering that the closest hospital to a user is not always the hospital that a user travels to. The findings of this study suggest that higher income communities are usually closer to a hospital than lower income communities. Lower income communities are in very close proximity to a hospital, within the urban core of Jacksonville, or very far from any hospital, further than a 30 minute drive time. The Business Analyst extension of ArcGIS was then used to

9

generate hospital service areas based on actual patient data using Huff's Probability Model. The results suggest that distance to the nearest hospital in not a representative measure of access to healthcare because this measure does not consider hospital capacity. Hospital utilization rate was higher for lower income communities than higher income communities.

This review of previous studies on different measures of accessibility inform the process used in the case study for Jacksonville presented in the next section.

CASE STUDY: ACCESSIBILITY TO HOSPITALS IN JACKSONVILLE, FL

An analysis of hospital accessibility was conducted for Jacksonville, Florida (Figure 1). Accessibility measures were calculated from hospitals for both the current state and a disrupted state of the street transportation network. The disrupted state created for this analysis was an artificial 100 year flood event affecting the entirety of Duval County; the result of a truly extreme weather event if this occurrence ever happened in reality. The purpose of this analysis is to evaluate the differences in accessibility measures from the current state and the disrupted state. The results of the analysis may help inform urban planning within Northeast Florida.

By land area, Jacksonville is the largest city in the continental United States of America. The government of Duval County and the government of the City of Jacksonville consolidated in 1968. In this study, Jacksonville and Duval County may be used interchangeably; both refer to the same study area shown in Figure 1. Population and economic forecasts indicate the Jacksonville metropolitan area will experience steady growth for both population and business development (Loh, Cobb & Johnson,

2009). Considering that Jacksonville will experience a steady increase in population growth, access to healthcare is an important issue for the city and region.
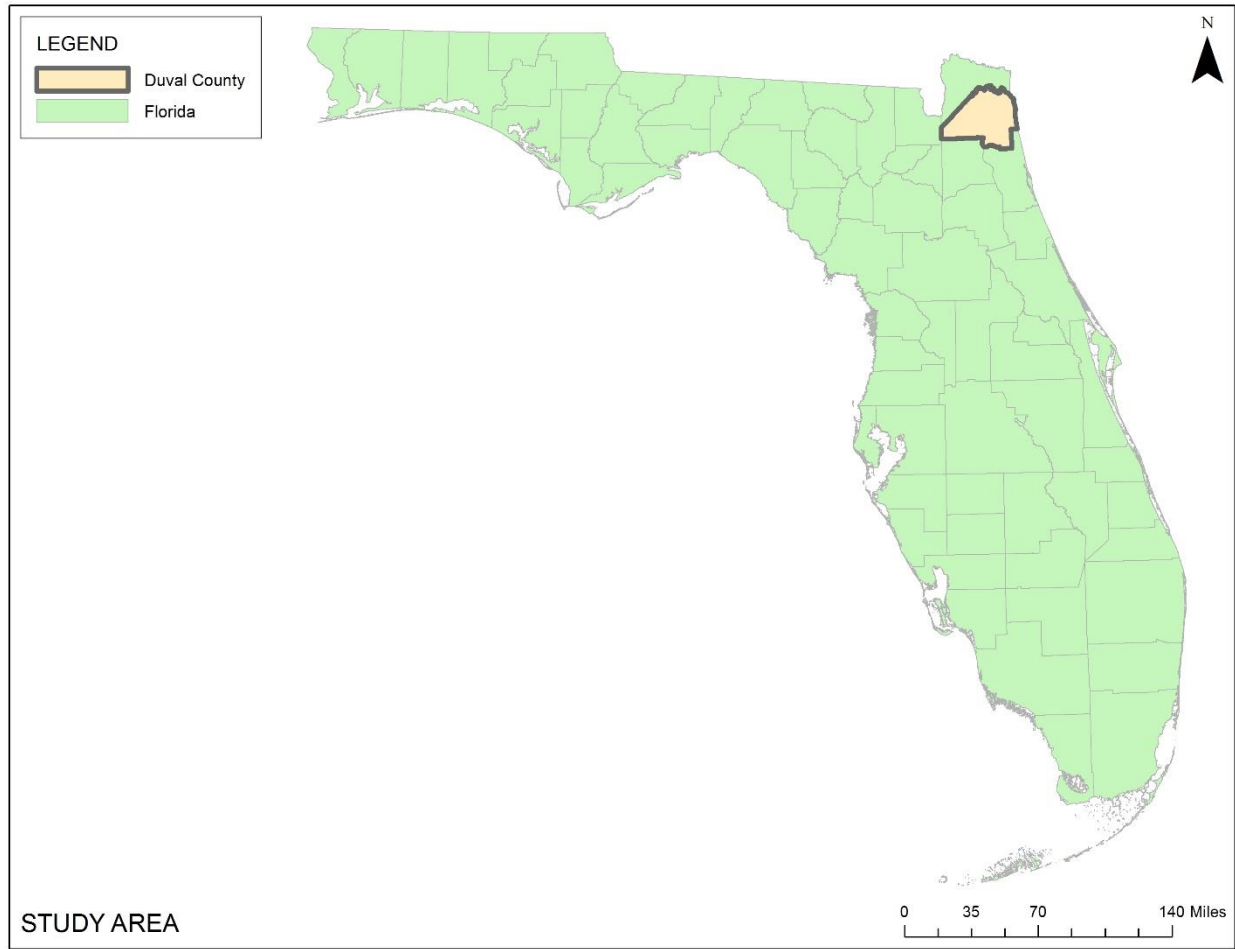

FIGURE 1

The accessibility analysis was conducted using the capabilities of the Spatial Analyst extension of ArcGIS 10.2 (ESRI, 2013). Census block groups were used as the spatial unit of analysis (www.census.gov). The census block group data used in this analysis is a GIS shapefile obtained from the Florida Geographic Data Library (www.fgdl.org). The dataset includes 2010 census block groups with additional fields from the 2009-2013 American Community Survey (ACS). ACS data provides survey

estimates distributed for one, three, and 5 year time periods. The five year estimate provides data at the block group level.

The street network was obtained from FSUTMS Online which is maintained by the Systems Planning Office of the Florida Department of Transportation (www.fsutmsonline.net). The Northeast Regional Planning Model (NERPM) was converted from the node-based binary format into an ArcGIS shapefile. This street network dataset includes free flow travel times along street links which were used in this study to determine accessibility to hospitals.

Initially, socioeconomic variables were analyzed in Jacksonville, FL. Using the 2009-2013 ACS data at the census block level, visualizations of socioeconomic data were created. Figures 2 – 6 display the spatial arrangement of population, income, poverty, age, and nonwhite races.
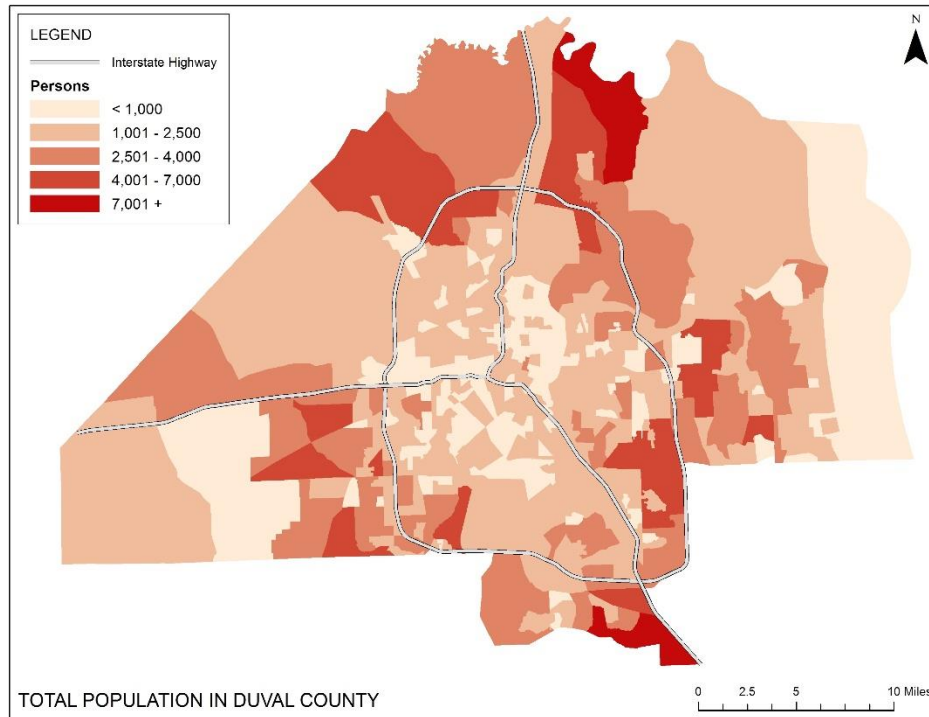
FIGURE 2

Figure 2 shows the spatial distribution of total population by Census block group in Jacksonville. Census block groups within the central urban core of the city have lower total population counts than surrounding census block groups. The census block groups with the largest total population counts are located outside the Beltway (Interstate 295) which encircles the central city. Census block groups located farther from the city center tend to have larger total population counts, indicating a decentralized spatial organization of the city of Jacksonville.
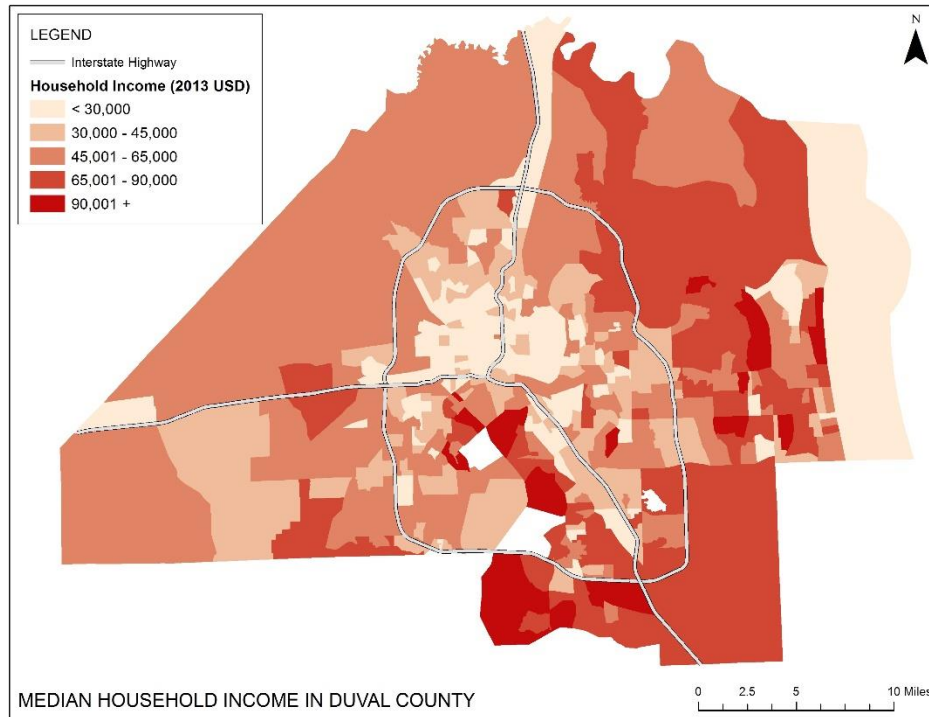
FIGURE 3

Figure 3 illustrates the spatial distribution of median household income in Jacksonville by Census block groups. Median household income tends to be higher also the southeast bank of the Saint Johns River and along and near the Atlantic coast. Median household income tends to be lower within Census block groups within the central urban core of the city.
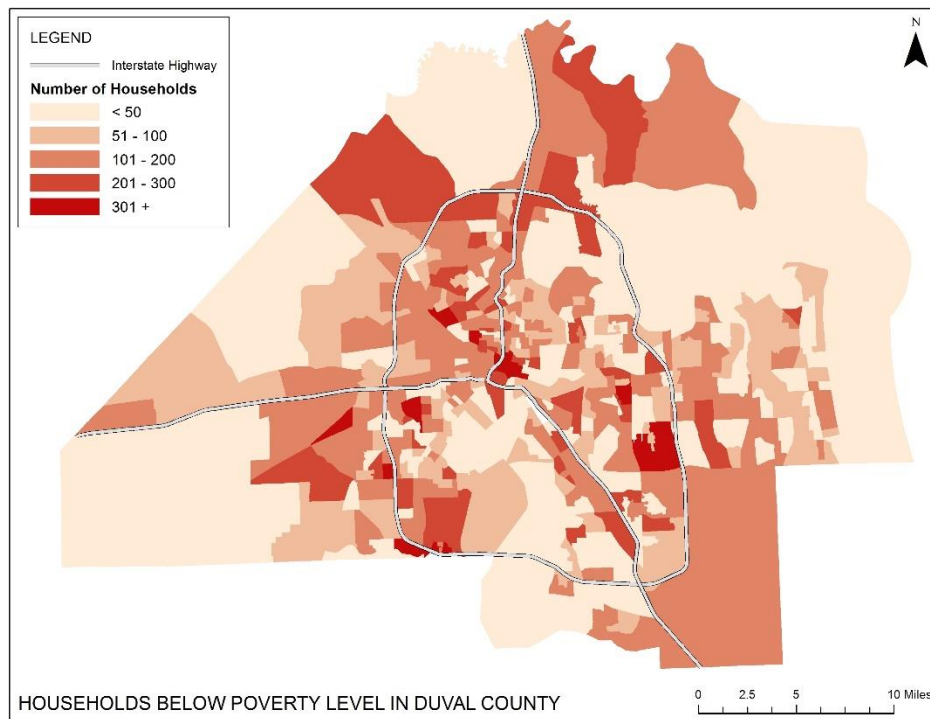
FIGURE 4

Households below the poverty level by Census block group in Jacksonville are shown in Figure 4. The greatest numbers of households below the poverty level tend to be located within the central urban core of the city. Census block groups with greater amounts of households living below the poverty level appear to be located in close proximity to major highways.
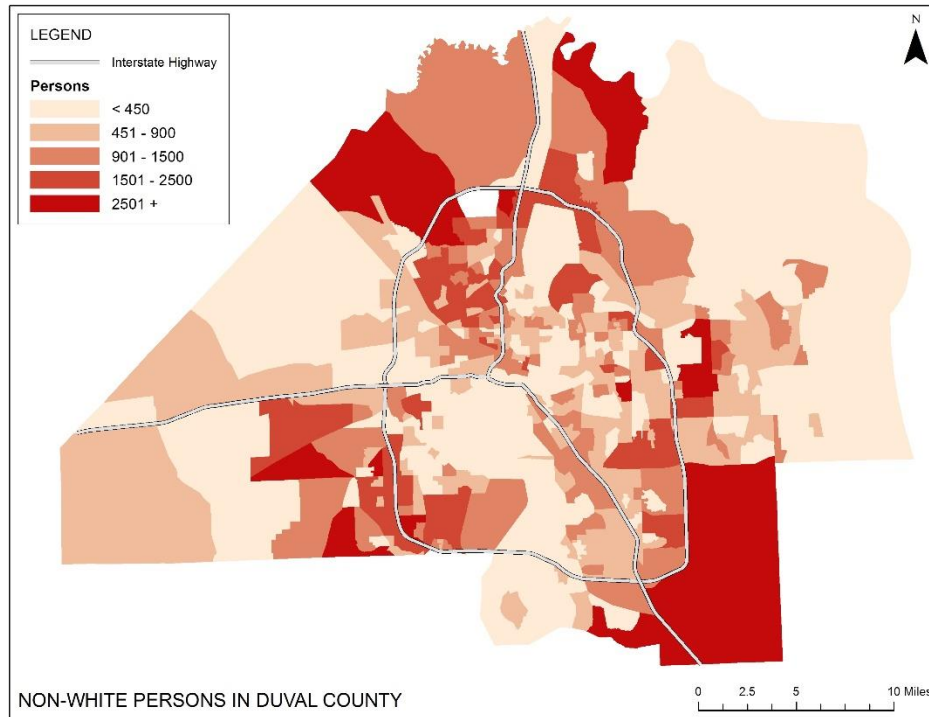
FIGURE 5

The spatial distribution of nonwhite persons is shown in Figure 5. As shown by the map, the city of Jacksonville appears to be relatively diverse demographically. Along the banks of the Saint Johns River and the Atlantic coast, however, show lower representation of nonwhite population.

Below, Figure 6 indicates the spatial distribution of the median age by census block groups in Jacksonville. Census block groups along the Saint Johns River and the Atlantic coast tend to have an older median age of the population.
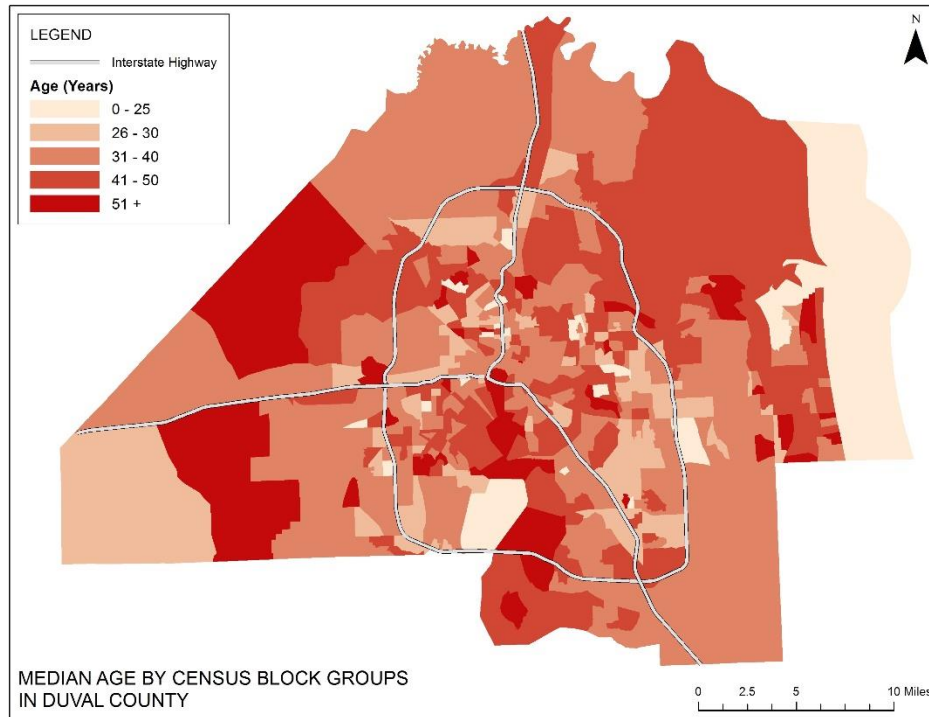
FIGURE 6

Following a review of the spatial distribution of social, demographic, and economic factors, access to healthcare is examined. Using the functionality of the Spatial Analyst extension of ArcGIS, service area polygons were generated for all hospitals in Jacksonville, FL. Hospital spatial data was obtained from a 2013 shapefile from the Florida Geographic Data Library. The service area polygons measure the distance of travel possible along the street network in increments of 3 minutes, 5 minutes, and 10 minutes. Service areas for hospitals by the current street network are provided in Figure 7.

The road network was then disrupted using floodplain data. Any portion of the street network located within the 100-year floodplain was removed from the road network data. This flood-disrupted network represents a hypothetical occurrence of the

17

100-year flood across the entirety of Duval County. Service area polygons were once again generated based on the reduced network. Service area polygons indicate the maximum distance that can be traveled within 3 minutes, 5 minutes, and 10 minutes over the street network that is disrupted by the 100 year flood. Service areas for hospitals by the disrupted street network can be viewed in Figure 8.

The hospital with the largest service area was identified to be Shands Hospital Jacksonville. Figures 9 and 10 show the service areas with travel times possible to Shands Hospital both at the current state of the street network and at the 100 year flood disrupted state of the street network.
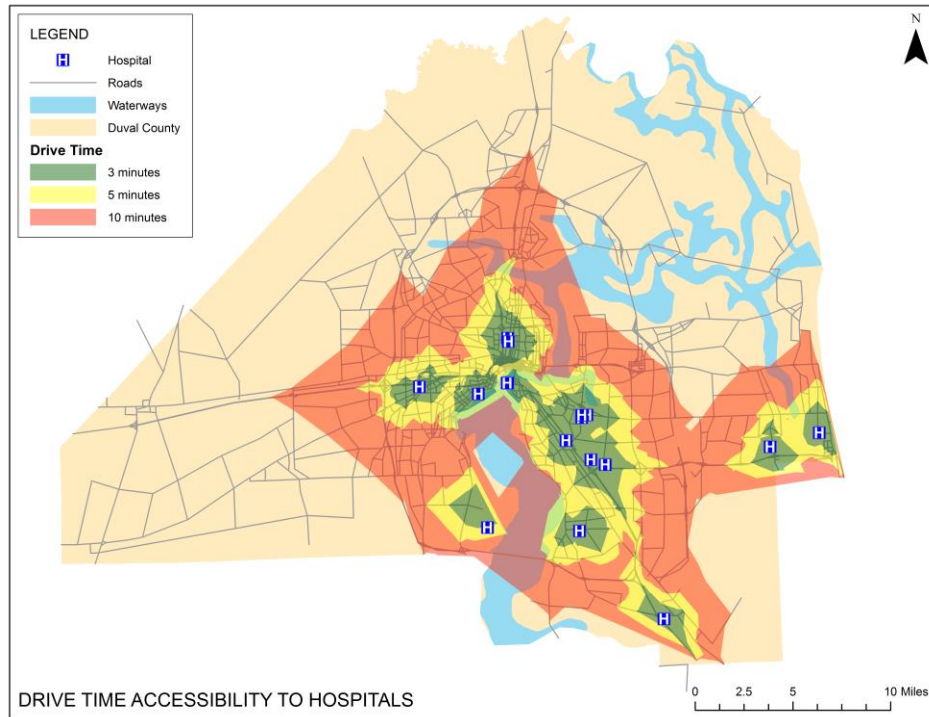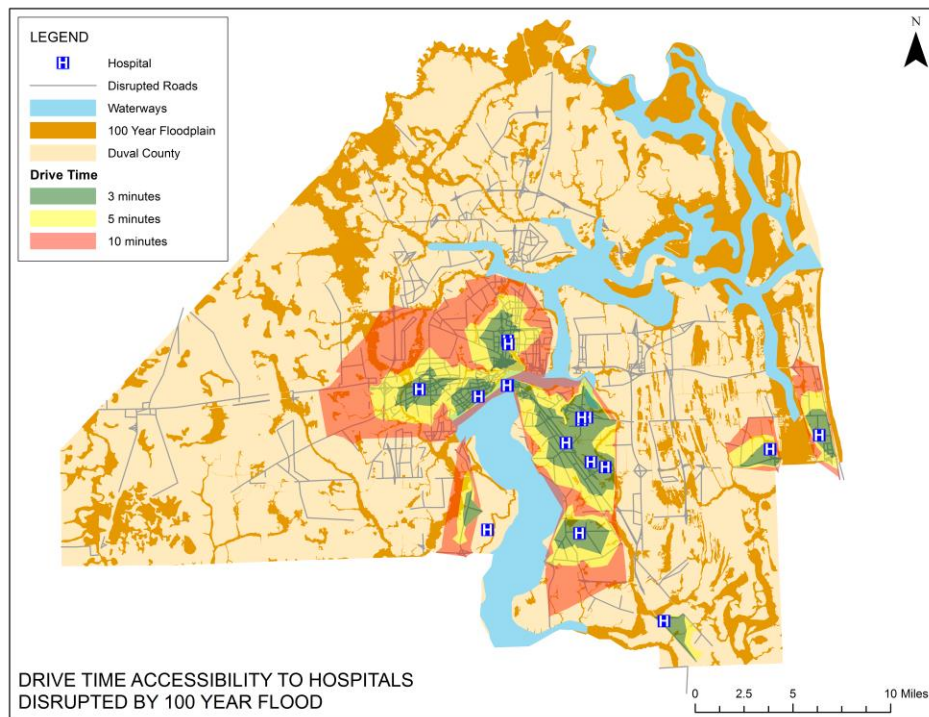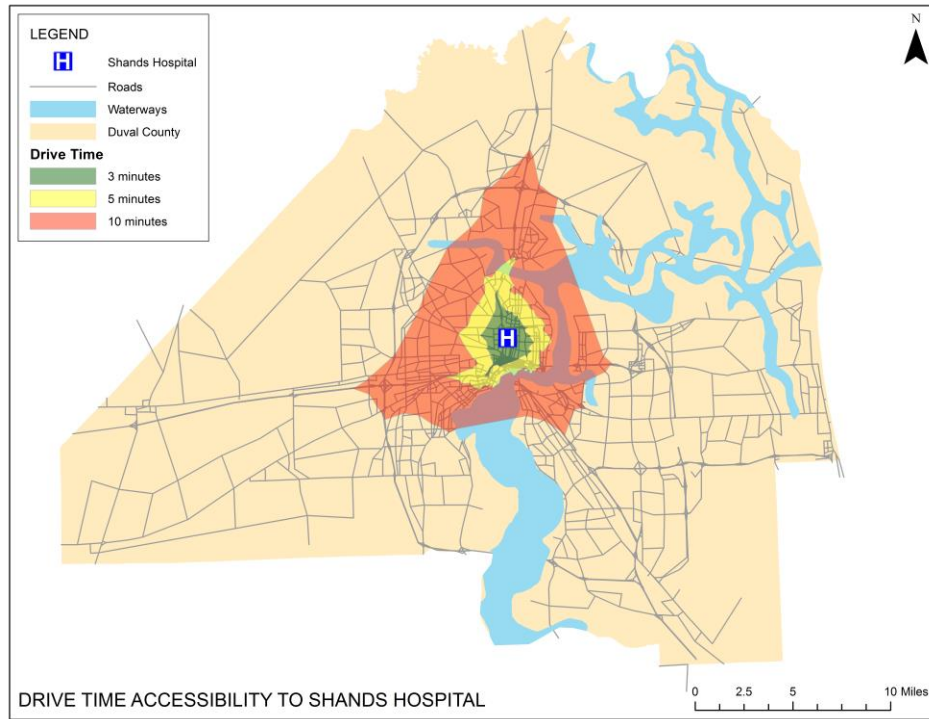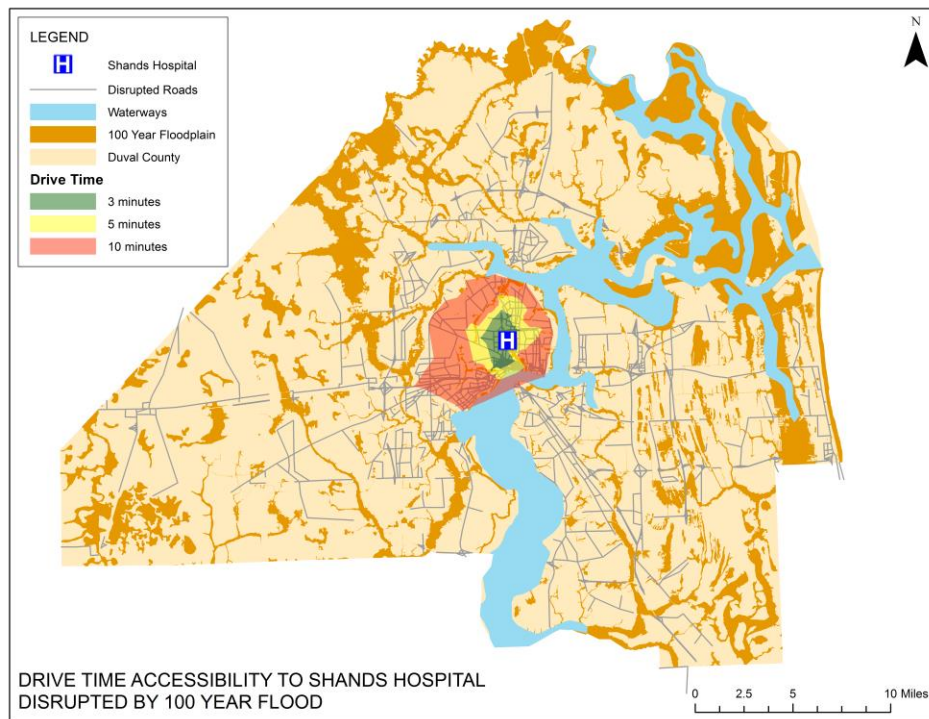
FIGURE 7

FIGURE 8

FIGURE 9

FIGURE 10

Further, potential accessibility measures were calculated from the origin block group in which Shands Hospital was located to all destination block groups in Duval County. With the use of the Origin-Destination (OD) Cost Matrix within ArcGIS, travel time from the origin to all destinations was determined and then joined to the ACS shapefile. The following paragraphs describe the process of developing the hospital accessibility analysis within ArcGIS.

First, a Network Dataset was created from the Jacksonville street network shapefile. Distance and free flow time were set as specified attributes for the network with usage set to cost and units set to miles and minutes respectively.

The ACS block group shapefile which includes socioeconomic data on population is a polygon shapefile. This file was converted to a point shapefile by calculating the x and y geometry of the polygon centroid. From this new point shapefile of block groups, destinations and origins were defined. The block group associated with Shands Hospital was defined as the origin. All block groups were defined as destinations.

Using ArcGIS's Model Builder, two model were developed to create two OD Cost Matrix Layer. One model was for the current network and the other was for the disrupted network. The model adds input origins and destination to calculate drive times between all origin and destination pairs in the network dataset. The attribute table of the Lines feature, and output of the OD Cost Matrix, was joined to the block group shapefile. The attribute for congested time was manipulated to free flow drive time from the origin.

The equation used to calculate accessibility was determined from the review of previous academic literature. The equation used to calculate the measures of accessibility has been applied to several previous studies using GIS (Liu & Zhu, 2004). Accessibility to population and accessibility to employment were calculated using the following formula (Welch, 2014):

$$A_{ij} = \sum_j O_j^{(\theta T_{ij})}$$

Where:

A_{ij} = the accessibility between origin zone i and destination zone j

O_j = the number of opportunities at the destination zone j

θ = the value -0.1

T_{ij} = travel time between zone i and zone j

After drive time accessibility and accessibility to population were calculated for the current state of the Jacksonville street network from the origins, the accessibility values were calculated for the disrupted Jacksonville street network. The disrupted street network was created by overlaying the shapefile of the 100 year floodplain over the Atlanta street network shapefile. The artificial extreme weather event scenario is a precipitation event resulting in flood levels of the 100 year storm.

All 100 year floodplains in Duval County were considered to be flooded. All network links that intersect with the 100 year floodplain were deleted from the network as they were considered obstructed network links. A new network dataset was created for the disrupted network. The geoprocessing steps described above were conducted in

a second round in which accessibility values were calculated under the street network

disrupted by the 100 year flood.

FINDINGS

The following figures (Figures 11 – 14) display the results of the accessibility

analysis for Shands Hospital. These figures were generated using ArcGIS 10.2. The

figures show drive time accessibility and accessibility to populations at the current state

and under the disruption of the 100 year flood. Comparing drive time accessibility from

Shands Hospital at the current state and under the disruption of the 100 year flood

indicates areas of Jacksonville where infrastructure is either vulnerable or resilient to an

extreme weather event. Comparing accessibility to populations from Shands Hospital at

the current state and under the disruption of the 100 year flood provides an indication

for the ease with which people residing within each Census block group can travel to

access healthcare from Shands Hospital.

Comparing the mapping displays in Figures 11 through 14 indicate that the

Jacksonville street network is certainly impacted by the 100 year flood event to a large

extent. Under the current condition of the street network, the vast majority of Duval

County can be traveled by personal vehicle within 25 minutes (shown in Figure 11).

Under the disruption of the 100 year flood event across the entire county, however,

accessibility is drive time accessibility is severely constrained to the western bank of the

river. A drive time under 25 minutes covers a small amount of Census block groups.

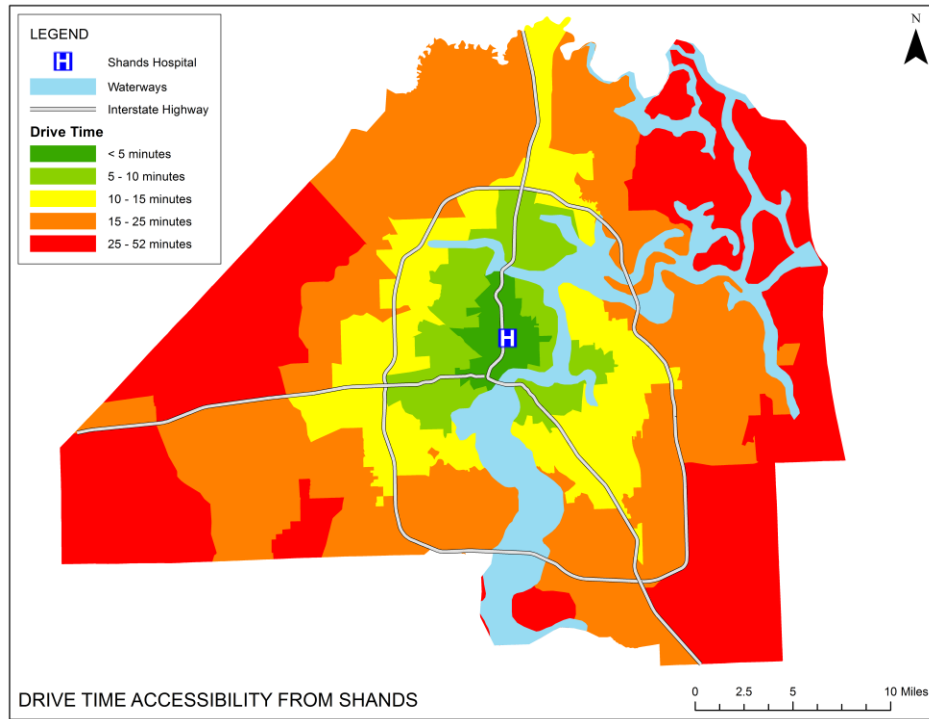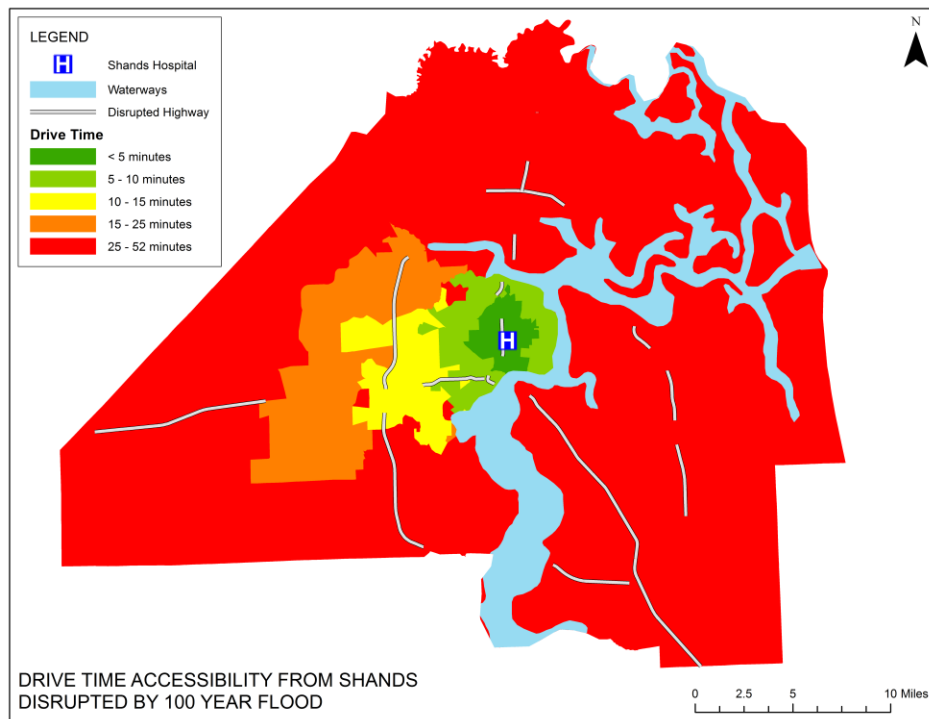Drive time accessibility is clearly impacted by the 100 year flood event.

FIGURE 11

FIGURE 12

24

Figure 13 shows distribution of accessibility to population at the current state of the street network. The map shows Shands Hospital is highly accessible to populations across most of the entire county. Census block groups in closest proximity to Shands Hospital of course have the highest measures for accessibility to population. Census block groups along major street corridors also appear to have higher measures of accessibility to population. Under the disruption of the 100 year flood, the measures of accessibility to population decrease significantly for most Census block groups. Accessibility values diminish sharply within close proximity to Shands Hospital.
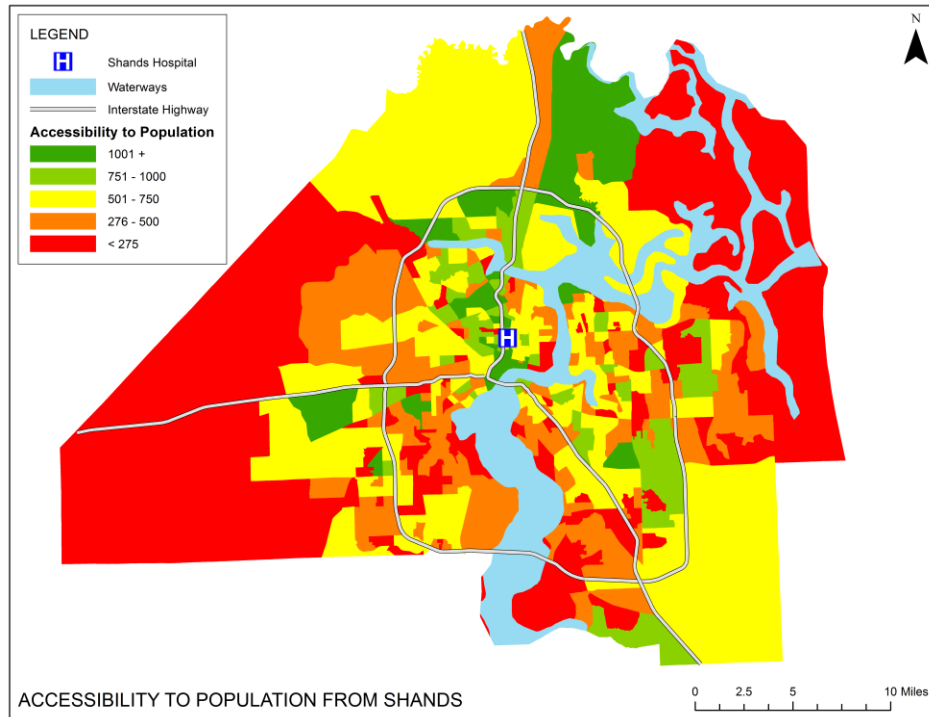
LEGEND

H Shands Hospital
Waterways
Interstate Highway

Accessibility to Population
1001 +
751 - 1000
501 - 750
276 - 500
< 275

ACCESSIBILITY TO POPULATION FROM SHANDS

0   2.5   5   10 Miles

FIGURE 13

LEGEND

H Shands Hospital
Waterways
Disrupted Highway

Accessibility to Population
1001 +
751 - 1000
501 - 750
276 - 500
< 275

ACCESSIBILITY TO POPULATION FROM SHANDS
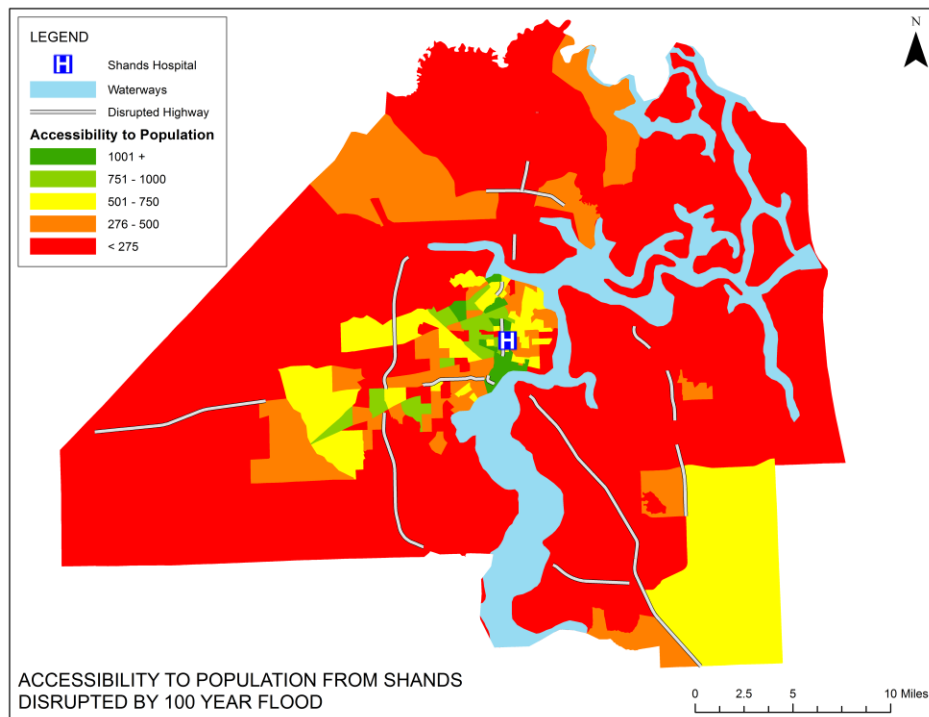DISRUPTED BY 100 YEAR FLOOD

0   2.5   5   10 Miles

FIGURE 14

26

DISCUSSION

An analysis of accessibility to hospitals was conducted for Jacksonville, Florida. The unit of spatial analysis was the Census block groups of Jacksonville, FL/Duval County. Hospital service area polygons were generated using ArcGIS to analyze the travel distance possible in increments of 5, 10, and 15 minutes of drive time. The hospital with the largest service area was identified through this exercise to be Shands Hospital. The accessibility of Shands Hospital as an origin block group was then calculated to each destination block group. This analysis shows accessibility measures from the origin hospital to every destination block group on the current state of the street network in comparison to accessibility values from the origin hospital to every destination block on the street network disrupted by the 100 year flood.

As shown through spatial analysis using ArcGIS, accessibility to hospitals is impacted to a large extent by the disruption of the 100 year flood. The majority of the population of Jacksonville, Florida is vulnerable to the effects of the 100 year flood event. Considering that climate modelling suggests that the 100 year flood event will occur more frequently than every 100 years, this hypothetical scenario constructed in this study could become a reality in the near future.

Planners and policy makers must consider that the 100 year flood will occur more frequently in the near future. This change in climate pattern will disrupt the abilities of the population to travel with ease to their destination. Transportation infrastructure improvements and retrofits should be built to be resilient to the increasingly frequent

27

100 year flood. As population of Jacksonville, Florida continues to grow, accessibility to healthcare is becoming an increasingly important issue to address.

Social justice issues must be taken into consideration when planning transportation improvements and retrofits. This study indicates the need to ensure reasonable access to healthcare to the entire population. Social justice communities might be more vulnerable to climate changes and increased flooding events. This study can help to inform where the need for increased provision of healthcare currently exists in Jacksonville.

CONCLUSION

The effects of climate change will have impacts on transportation in the future. Current planning practices must evolve to plan for this new future and uncertain climate changes. An analysis was conducted to examine the impact of the 100 year flood on accessibility in Jacksonville, FL. Accessibility is the extent to which land use and transportation systems enable people to reach activities or destinations. The Network Analyst extension in ArcGIS 10.2 was used to conduct this accessibility analysis.

The results of the accessibility analysis are an indication of the importance in assessing regional vulnerabilities to the effects of flooding. Drive time accessibility and accessibility to population from Shands Hospital in central Jacksonville significantly decreases under disruption by the 100 year flood event. Service area, drive time, and accessibility to population are significantly impacted when portions of the street are obstructed and mobility is impossible.

The results of this study can inform the priority of transportation investments and retrofits and the provision of health care. There are clearly areas of the Jacksonville street network that are especially vulnerable to flooding as they are within defined floodplains. When the 100 year flood even occurs, transportation infrastructure may be obstructed for some period of time. Identifying these critical areas and having plans for how to react when the event occurs are important to maintaining a resilient transportation network. Additionally planning for an increase in frequency of the 100 year flood is equally important. Transportation infrastructure must be improved and retrofitted to ensure resiliency and accessibility to important amenities such as healthcare.

LIST OF REFERENCES

Berdica, K. (2002). An introduciton to road vulneability: what has been done, is done and should be done. *Transport Policy*, *9*, 117–127.

Cambridge Systematics, Inc. (2009). Transportation Adaptation to Global Climate Change. Bipartisan Policy Center.

ESRI. (2013). ArcGIS 10.2.2

FSUTMS. (2005). Northeast Regional Planning Model. Retrieved March, 31, 2015, from www.fsutms.net.

Geurs, K.T. & Van Wee, B. (2004). Accessibility Evaluation of Land-Use and Transport Strategies: Review and Research Directions. Journal of Transport Geography, 12, 127 - 140.

Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E.,
Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S.,
Levy, A.N., MacCracken, S., Mastrandrea, P.R., & White, L.L. (Eds.).
Intergovernmental Panel on Climate Change. (2014). Climate Change 2014:
Impacts, Adaptation, and Vulnerability. New York, NY: Cambridge University
Press.

Koetse, M., & Rietveld, P. (2009). The Impact of Climate Change and Weather on
Transport: An Overview of Empirical Findings. *Transportation Research Part D:
Transport and Environment*, *14*, 205–221.

Liu, S., & Zhu, X. (2004). An Integrated GIS Approach to Accessibility Analysis.
Transactions in GIS, *8*(1), 45–62.

Loh, C.-P. A., Cobb, S.C., & Johnson, C.K. (2009). Potential and Actual Accessibility to
Hospital and Hospital Services in Northeast Florida. Southeastern Geographer,
49 (2), 171 - 184.

Neutens, T. (2015). Accessibility, Equity, and Health Care: Review and Research
Directions for Transport Geographers. Journal of Transport Geography, 43, 14 -
27.

Sohn, J. (2006). Evaluating the Significance of Highway Network Links Under the Flood
Damage: An Accessibility Approach. *Transportation Research Part A*, *40*, 491–
506.

Transportation Research Board. (2008). Potential Impacts of Climate Change on US
Transportation. *Transporation Research Board Special Report*, *290*, 1 – 298.

U.S. Census Bureau. (2014). 2010 Census Block Groups in Florida (With Selected Fields from

    the 2009-2013 American Community Survey). Florida Geographic Data Library.

    Retrieved April 23, 2015, from www.fgdl.org.

Welch, T. (2014). *Network Analysis: Highway Accessibility in Atlanta*. Presented at the

    Transportation and GIS, Georgia Institute of Technology.