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Assessment of EMS Response and Hospital Arrival Times in Nebraska

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UNMC College of Public Health

Abstract

Timely EMS response and ground transport to the appropriate hospital are essential to patients' survival and health outcomes during emergencies. This study utilizes interactive Geospatial Information System (GIS) mapping to assess emergency medical service (EMS) response and hospital arrival times in rural and urban Nebraska counties. The goal is to determine if there are underserved areas in the State and to propose potential interventions if identified. 2018 Social Vulnerability Index Scores (SVI) collected from Census Data were also reviewed for these areas to see possible correlations. The interactive GIS map revealed the Western and Central regions of Nebraska to be the most underserved. Specifically, the map identified numerous underserved counties, including Gage, Pierce, and Hitchcock. A pattern emerged that showed access to emergency services decreases as the urban percentage decreases since many of the rural counties are primarily served by volunteer responders. Also, no correlations between SVI and underserved areas were identified for Lancaster, Pierce, and Hitchcock counties, but Gage County had a strong, positive correlation. Proposed interventions for the underserved counties may include mobile stroke units, community paramedicine, stroke-ready certifications for rural hospitals, improved access to other forms of transportation for trauma patients in addition to ground transport, and using telemedicine when transportation is not available.

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Introduction and Literature Review

Specific Aims/Problem Statement

EMS is integral in improving the community's health because of its essential role in responding to medical emergency calls and providing onsite medical care to stabilize, treat, and transport patients to the hospital. As a result, it's essential to continually evaluate EMS capabilities and resources and ensure the various agencies operate optimally to provide the best care possible. For example, evaluation of EMS resources and capabilities can provide insight into challenges, such as inequities and potential improvements that can be made to make the system more effective. After all, EMS agencies continually face challenges such as population density and resource (e.g., number of employees, transportation capabilities, etc.) availability based on their location. Rural EMS agencies, for example, typically face challenges with sparsely distributed populations, lower proportions of EMS providers, delayed response with EMS providers serving on a volunteer basis, and increased distance to medical facilities (e.g., trauma centers, hospitals, etc.), resulting in more extended response and transport times (Grossman et al., 1997). Volunteer EMS agencies are a concern because they're unable to respond immediately since they may be working at a job in the community they serve in or commuting to a larger community, and this is a barrier because these individuals not only need employers that support their volunteer work but the delays in their initial response could be the difference between life and death for a time-sensitive medical emergency. Therefore, in a state like Nebraska, where fifty of Nebraska's 93 counties are considered 100% rural and 662,761 people live in these rural areas, it's crucial to consider rural EMS coverage (Schafer, 2020; USDA ERS, 2022)

For this research report, EMS response time (ERT) for ground transport and estimated hospital arrival time zones will be mapped to evaluate EMS service coverage and identify any underserved areas for EMS resources in Nebraska. Furthermore, specific comparisons will be made for EMS and hospital coverage for four Nebraska counties: Lancaster, Gage, Pierce, and Hitchcock. This assessment is vital because "rapid transport to medical facilities is the standard of care for EMS providers" (Rogers et al., 2014), so it's essential to ensure that the EMS resources available in the state can transport patients to appropriate care facilities in all areas of the state. For example, strokes are one of the many major medical emergencies dependent on timely EMS response, triage, and transport to the appropriate medical facility (Wibring et al., 2020). Therefore, an emergency patient's survival depends on the timeliness of EMS transport and hospital arrival times, so addressing any inequities in access to these services is important. In fact, studies have found that "high-income zip codes have on average faster ambulances than low-income zip codes" (Friedson, 2018), which results in poorer health outcomes and further deepens the health disparities prevalent in low SES communities. In conclusion, this research report aims to assess the distribution of EMS resources and ensure that the locations for the EMS facilities are in centralized areas that allow for equitable access to care, regardless of external factors such as income, and provide intervention options for supplemental care and/or future facility placement for EMS agencies in any areas that are identified to be underserved.

Research Question

In urban and rural Nebraska counties, are there areas with less timely access to Emergency Medical Services (EMS) ground transport response and hospitals? If so, are there any correlating factors such as socioeconomic status (SES) that may influence the inequitable distribution of EMS and hospital access?

Significance

The significance of this research project stems from the potential to improve the health outcomes of medical emergency patients by identifying challenges in EMS resources and capabilities in Nebraska that limit timely response and transportation, and to provide interventions that can solve these challenges. For example, in the case of stroke patients, "2 million brain cells die each minute the brain is denied oxygen, and restoration of blood flow is the most critical determiner of functional brain survival…so transportation to the closest hospital, only to be referred to a more qualified stroke center wastes precious time and results in poorer patient outcomes" (Holley, 2019, p. 4). In fact, "permanent brain damage begins after only 4 minutes without oxygen and death can occur as soon as 4 to 6 minutes later" (NIH, 2022, p. 4). In addition to strokes, there is an abundance of other time-critical medical conditions where the time it takes for EMS to respond, stabilize, and transport patients can be the difference between their survival and negative health outcomes, such as severe trauma, sepsis, myocardial infarction, and respiratory failure (Wibring et al., 2020). Further, a study done in Sweden found that "survival to 30 days after a witnessed out-of-hospital cardiac arrest decreases as ambulance response times increase...so shortening EMS response times is an effective way to increase these patients' survival" (Holmen et al., 2020). Additionally, a study done in Utah found that "on average, a minute increase in response times increases mortality by between 8% (measured one day after the initial incident and 17% (measured 90 days after the initial incident)" (Wilde, 2012, p.5). As a result, response time and hospital arrival times can contribute to disparities in patient survival and outcome, so evaluating the access to various hospitals and EMS is important to identify systemic inequities.

Systemic inequities in EMS response have previously been assessed in a national U.S. cross-sectional study on patients with out-of-hospital cardiac arrest, which found that “EMS times remained 10% longer in the poorest areas and compared to high-income areas, they were less likely to meet national benchmarks of 8-minute and 15-minute ERTs” (Hsia et al., 2018). Therefore, this research report is significant because timely ERTs are critical to patients’ survival and their resulting health outcomes. In fact, this study seeks to fill a critical gap in knowledge by examining the EMS resources and capabilities in Nebraska and if the distribution of these resources correlates with SVI data using an interactive Geospatial Information System (GIS) map. Previous research sought to examine stroke and cardiac arrest patients and the impact of ERT, hospital arrival times, and/or SES on these patients' health outcomes and survival. Studies have also been done to evaluate the challenges of rural EMS agencies compared to urban EMS, but no studies have been conducted that explore correlations between underserved areas and SES, and the overall inequitable distribution of EMS resources using estimated ERT and hospital arrival times. This study utilizes EMS survey data on facility locations, capabilities, and resources to create an interactive GIS map. The GIS map will be used to evaluate EMS coverage based on estimated ERT zones created around the EMS facilities and hospital arrival time zones around the hospitals. As a result, the GIS map will create a visual and current map of all the EMS resources and their capabilities in Nebraska. In addition, this study can assess correlations between health disparities from the Census data since it is a readily available dataset in the Nebraska ArcGIS program. Further, future research could be done using this map to see if there are poorer health outcomes in any of the underserved areas identified to have longer EMS times along with areas with limited access to the various levels (e.g., different trauma levels) and designations of hospitals (e.g., hospitals with stroke and/or burn units).

The GIS map has a multitude of public health applications. For example, the GIS map can be utilized for emergency preparedness plans as a reference for critical infrastructure and other resources when developing and conducting training and exercises for various disasters/emergencies because it highlights all the EMS resources and capabilities for emergency management operations for different local, city, or county agencies (FEMA, n.d.). The GIS map can also be used for emergency management plans, such as mapping shelter sites in a disaster or mass dispensing sites for emergencies in Nebraska (FEMA, n.d.).

Methods

I have coordinated with a state GIS specialist, Han Liu, to create an interactive GIS map using the completed EMS and hospital survey data for Nebraska that I updated during my Applied Practice Experience (APEx). Specifically, I converted facility addresses to GPS coordinates to provide up-to-date maps of vital EMS and hospital locations. The surveys for both EMS facilities and hospitals were distributed to the licensed agencies and were similar but had differing data points based on the facility type (EMS or hospital). The similar survey information included agency name, address, county, state ID number, and service primary contact information. For the EMS survey data, the unique data points included whether they are an EMS training agency (if yes, what licenses, modules, and courses they offer), staging location, non-transport/transport (if yes, the type of transportation available: flight service and/or ground transport), license type, advanced life support or basic life support, number of ambulances, service status (volunteer/paid/mixed/etc.), county type (small urban, urban large, non-urban: rural), license subtype, and EMS region. For the hospital survey data, the unique data points included whether the facility is considered a hospital, whether the facility is a non-profit, if they offer Telemed, license type (short-term, critical access, children's, rehabilitation, LTC,

psychiatric, Indian health services, non-participating, etc.), license subtype (general acute, critical access, rehabilitation, LTC, psychiatric, Indian health services, non-participating, etc.), trauma designation level (Level I (comprehensive), Pediatric Level II (advanced), Level II (advanced), Level III (general), Level IV (basic)), stroke designation level (primary stroke center, thrombectomy capable stroke center, comprehensive stroke center, and acute stroke ready center), whether they have a burn center, and whether they have a catheter lab (if yes, is it by appointment or 24/7 access). As a result, the EMS and hospital survey datasets form a comprehensive tool with the potential for numerous analyses based on the various data points available. The focus of this research report, however, will be the evaluation of ground transport EMS facilities and hospitals in Nebraska.

Additionally, the state GIS Specialist utilized the Nebraska ArcGIS program to create this interactive GIS map. The spatial statistical analysis conducted to create the GIS map will derive from using the GIS drive-time analysis tool. The map will create three estimated emergency response time zones around the EMS facilities (8-minute, 15-minute, and 30-minutes) and three estimated hospital arrival time zones around hospitals (15-minute, 30-minute, and 60-minute) to evaluate the EMS coverage in the Nebraska counties of Lancaster, Gage, Pierce, and Hitchcock. These counties were chosen because they have varying population sizes and ratios of urban to rural area percentages, as seen in Table 1. The zones are color-coordinated on the map, and the legend on the map depicts the relationships, as seen in Figure 1. The spatial analysis is based on normal traffic conditions. There are no standards for ERTs and hospital arrival times, so the estimated zones in this study are based on previous studies examining hospital arrival times. The overlap of the estimated 8-minute ERT zone and 15-minute hospital arrival time zone form the ideal service areas to be located within, with the subsequent times being less suitable as the time

zone increases. As a result, the estimated ≥30-minute ERT and ≥60-minute hospital arrival time zones will be identified as the most underserved areas. The underserved areas will be qualitatively identified based on cardinal directions within the counties of Lancaster, Gage, Pierce, and Hitchcock, and visual themes (e.g., magnitude of resource distribution, etc.). The well-served areas will also be qualitatively identified based on cardinal directions within the city/county, the interpretations of the different visual indicators like what darker or lighter shades of the same color mean for the drive time areas, and how the distribution of resources appears. The results will be used as a basis for a short literature review to propose interventions (e.g., supplemental care facilities and resource (EMS/hospital) allocations) that will allow for better access to care for individuals within the areas of concern. Lastly, the Nebraska ArcGIS program has pre-existing Census data with the Social Vulnerability Index (SVI), which has been added as a layer to the map to identify potential correlations between underserved areas and factors such as SES and minority status and can be seen when zooming into the map. “The SVI score is based on Census data, and each census tract is ranked on 15 social factors, including poverty, lack of vehicle access, and crowded housing” (ATSDR, 2021). The SVI data will be based on the 2018 Census data, and correlations to underserved areas will be qualitatively identified based on the visual interpretations of SES areas and underserved EMS communities. Additionally, statistical analyses will be conducted in Excel using Pearson’s coefficient and p-value to determine the strength of the correlation between EMS response times and hospital arrival times, and the SVI score, and the significance of the relationship.

Table 1: Nebraska Counties by Population and Urban to Rural Area Percentage

County	Population	Urban Area %	Rural Area%
Lancaster	315,976	92%	8%
Gage	21,548	56%	44%
Pierce	7,132	0%	100%
Hitchcock	2,788	0%	100%

Sources: **https://www.nebraska-demographics.com/counties_by_population, https://www.city-data.com/county/Lancaster_County-NE.html, and https://www.city-data.com/county/Gage_County-NE.html**

Results

Overall, the results of the interactive GIS map indicate that the underserved areas of Nebraska are located in the central and western regions, which can be seen in Figure 1, which is a compilation of snapshots of the interactive GIS map for the various ERTs (8, 15, 30) and hospital arrival times (15, 30, 60). More specifically, the underserved counties include Arthur, Grant, Hooker, Thomas, McPherson, Logan, Blaine, Loup, Garfield, Wheeler, Greeley, Sherman, Sioux, Banner, Deuel, Hayes, Frontier, Hitchcock, Gosper, Clay, Cedar, and Dixon county, which all do not have a hospital located within 15 minutes of the county, are only served by volunteer EMS agencies, and are considered to be rural counties. Additionally, SVI scores for Pierce, Gage, Lancaster, and Hitchcock County can be found in Table A1 and A2 in Appendix A.

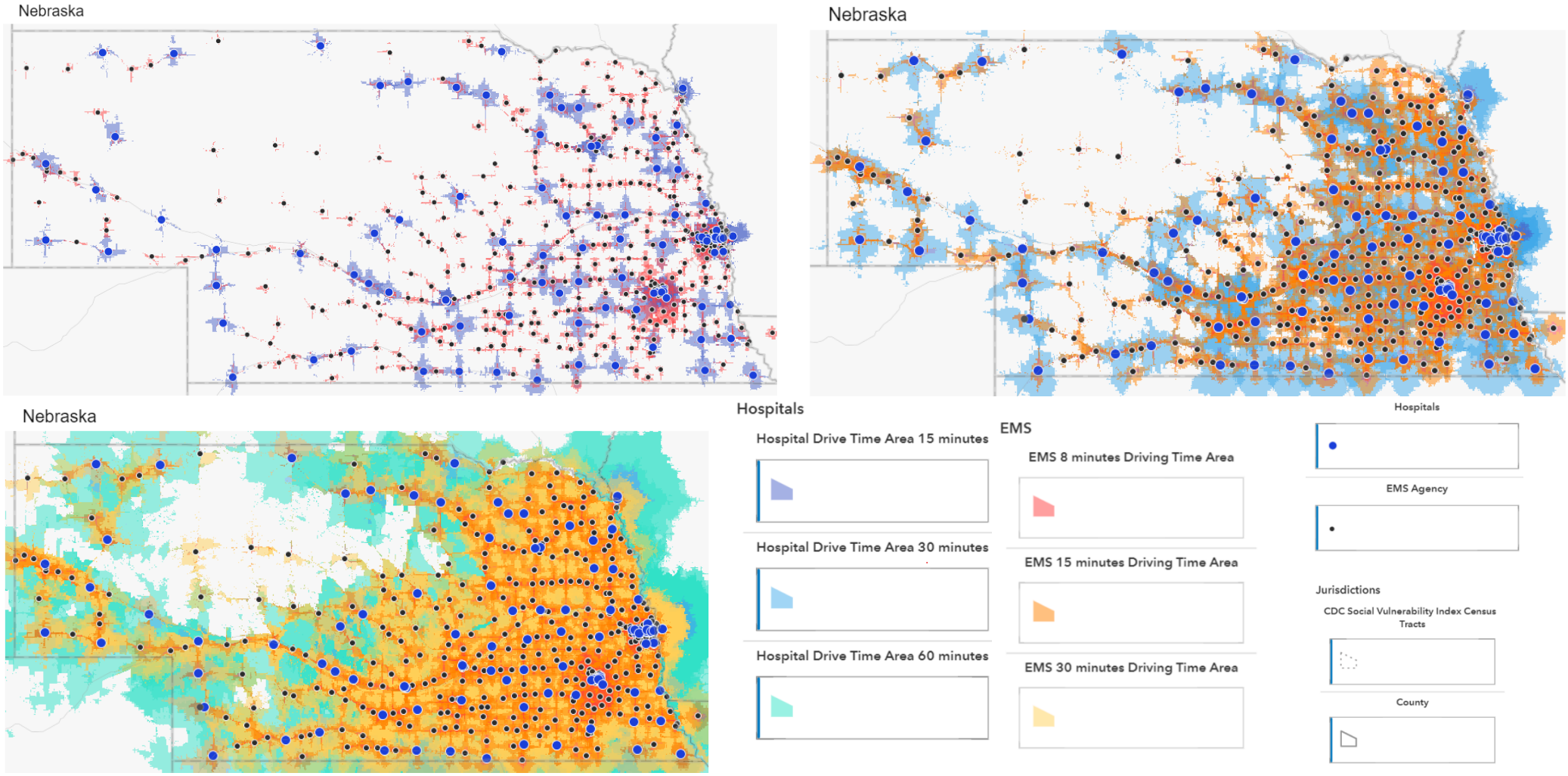

Figure 1: Estimated ERTs and Hospital Arrival Times for Nebraska EMS Ambulances

Blue dots are hospital locations, and blue zones are estimated hospital arrival times of 15 minutes. Black dots are EMS locations, and red zones are estimated emergency response times of 8 minutes.

Gage County

The results of the GIS map for Gage County can be seen in Figure 2. With an initial visual analysis of it, the overall underserved census tracts in Gage County are most of Census Tract 9646, except for the northeast corner, the central region of Census Tract 9647, most of Census Tract 9652 (except the western region), and the northwest and southeast corner of 9648. The EMS resources and hospitals in Gage County can be found in Table A6 and A7 in Appendix A. The underserved EMS census tracts are most of Census Tract 9646 (except for the northeast corner), the central region of Census Tract 9647, most of Census Tract 9652 (except the western region), and most of Census Tract 9649 (except for the southwest corner). The underserved hospital census tracts are most of Census Tract 9647 (except for the northeast corner), Census Tract 9652, the southeast corner and the western border of 9648, and Census Tract 9646.

However, upon further analysis of the individual facility coverage, the underserved EMS census tracts in Gage County are 9646 and 9647, with no non-volunteer EMS facilities serving these areas. The underserved hospital census tracts are 9650 and 9649, which have no hospital coverage, and all the census tracts lack access to a trauma designated and stroke center hospital.

Figure 3 highlights the SVI scores for the census tracts in Gage County, with the map indicating that the highest vulnerability states are centrally located within census tract 9649. The statistical analysis of the correlation between the number of EMS agencies serving the area and the SVI score showed that there is a strong, positive relationship ($r=0.886$) and the p-value of 0.00793 indicated that the relationship is significant. No statistical analyses were conducted for the hospitals because there are no trauma designated or stroke center hospitals. The statistical results can be seen in Table 2.

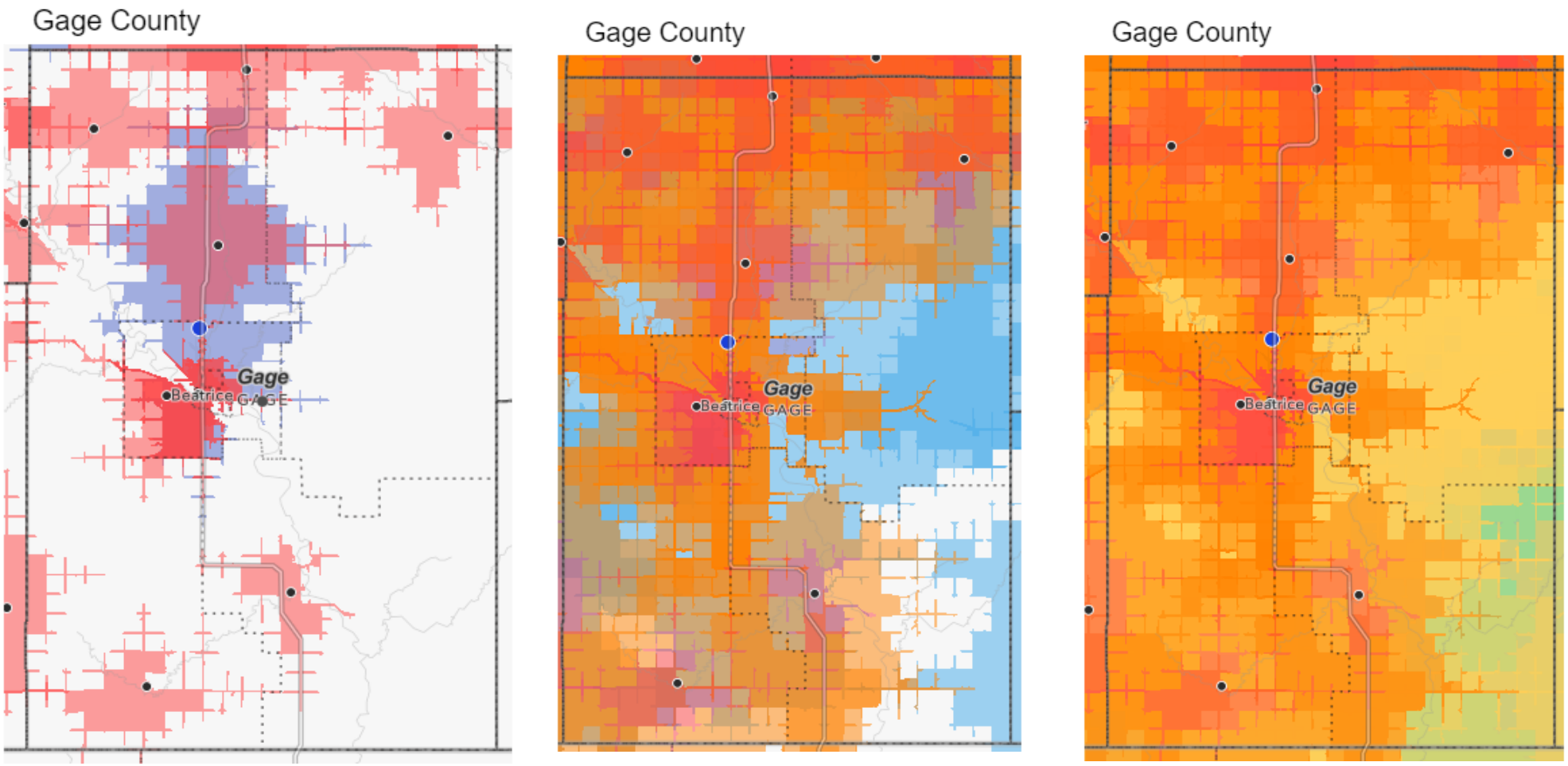

Figure 2: Estimated ERTs and Hospital Arrival Times for Gage County

The blue dot is a hospital location, and the blue zone is the estimated hospital arrival time of 15 minutes. Black dots are EMS locations and red zones are estimated emergency response times of 8 minutes.

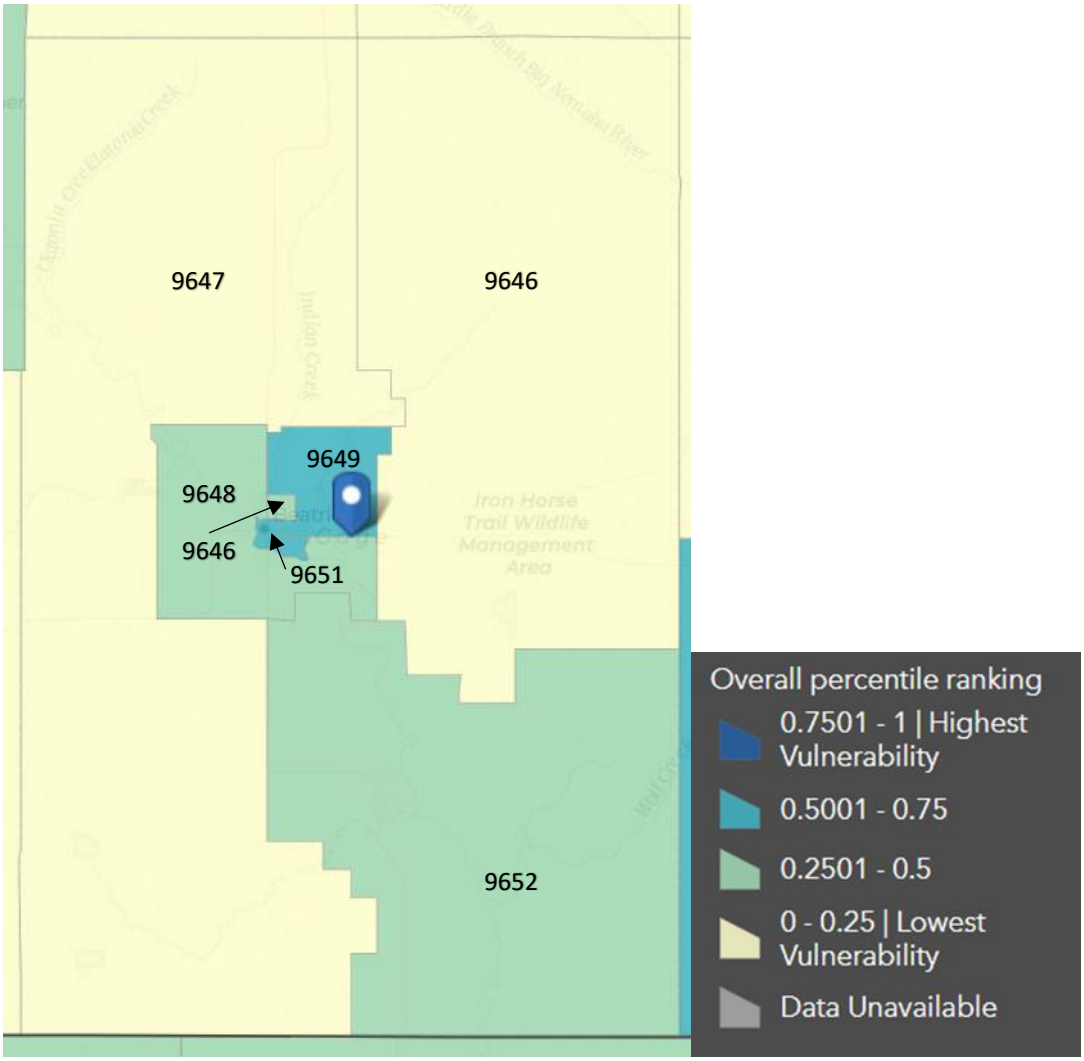

Figure 3: Gage County Census Tract Numbers and 2018 Social Vulnerability Index Score Percentile Rankings

The SVI score level of moderate to high is indicated by the turquoise color, low is yellow, and low to moderate is green. Actual SVI scores for these census tract numbers can be seen in Table A1. Source: https://svi.cdc.gov/map.html

Table 2: Pearson Correlation Coefficient Results

Statistical Results	Gage County EMS and SVI	Lancaster County EMS and SVI	Lancaster County Trauma-Designated Hospitals and SVI	Lancaster County Stroke Center Hospitals and SVI
r value	0.886	0.287	0.0415	0.0442
p-value	0.00793	0.017	0.735	0.718

Lancaster County

The results of the GIS map for Lancaster County can be seen in Figure 4. With an initial visual analysis, the overall underserved census tracts in Lancaster County are the northeast corner of Census Tract 103 near Denton, the northeast and northwest corner and the southwest border of Census Tract 102.02, and the northeast corner and northwest border of Census Tract 101. All the EMS resources and hospitals found in Lancaster County can be seen in Table A8 and A9 in Appendix A. The underserved hospital Census Tracts are the northeast corner of Census Tract 101, north region of Census Tract 102.02, northeast and southern corner of Census Tract 103, and southern region of Census Tract 104. The underserved EMS Census Tracts are the northeast corner of 103 near Denton, the northeast and northwest corner and southwest border and corner of 102.02, and the northeast corner and northwest border of 101.

However, upon further analysis of the individual facility coverage, the underserved hospital census tracts regarding access to a trauma-designated hospital include 27.01, 30.02, 30.03, 31.02, 31.03, 31.04, 33.01, 36.01, 36.08, 37.13, 38.01, and 38.02. The underserved hospital census tracts regarding access to a stroke center include 23, 33.02, 36.01, 102.02, 103,

and 9832. Lastly, all the census tracts have at least one EMS facility with transportation capabilities serving the area, but some census tracts have partial coverage, which is indicated by the areas with no color and can be seen in Figure 4.

Figure 5 highlights the SVI scores for the census tracts located in Lancaster County, with the map indicating that the highest vulnerability states are centrally located within the city of Lincoln. The statistical analysis of the SVI score and the number of EMS agencies with transportation capabilities serving the tract in Lancaster County showed a weak to no correlation relationship ($r=0.286615$), and the p-value of 0.01696 indicated that the relationship was significant. Additionally, the statistical analysis of the correlation between SVI score and the number of trauma-designated hospitals serving the tract showed a weak to no correlation relationship ($r=0.41547$), and the p-value of 0.734642 indicated that this relationship was not significant. Lastly, the statistical analysis of the correlation between the SVI score and the number of stroke center hospitals serving the tract showed a weak to no correlation relationship ($r=0.442$) and the p-value of 0.718 indicated that this relationship was not significant. The statistical results can be seen in Table 2.

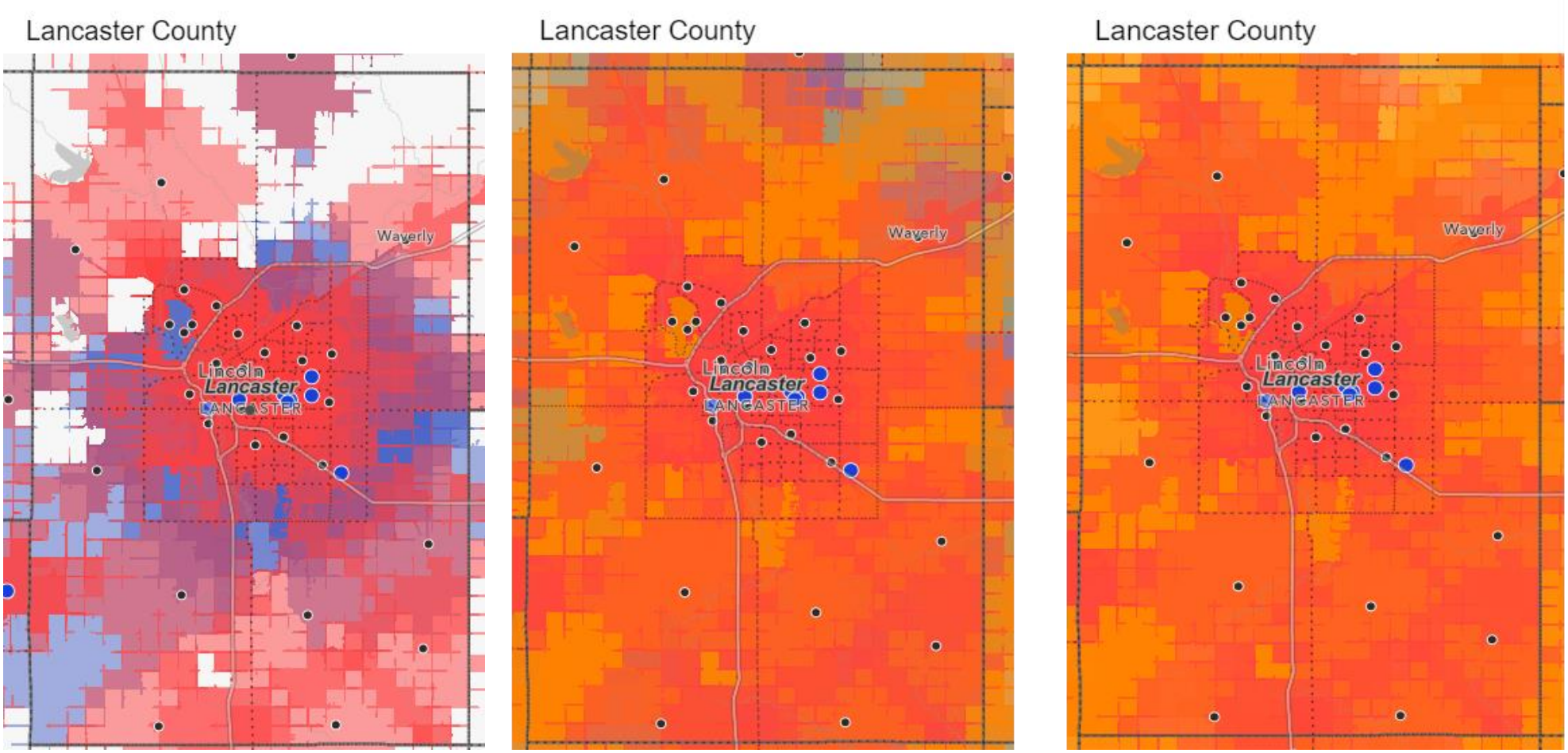

Figure 4: Estimated ERTs and Hospital Arrival Times for Lancaster County

Blue dots are hospital locations, and the blue zones are the estimated hospital arrival times of 15 minutes. Black dots are EMS locations and red zones are estimated emergency response times of 8 minutes.

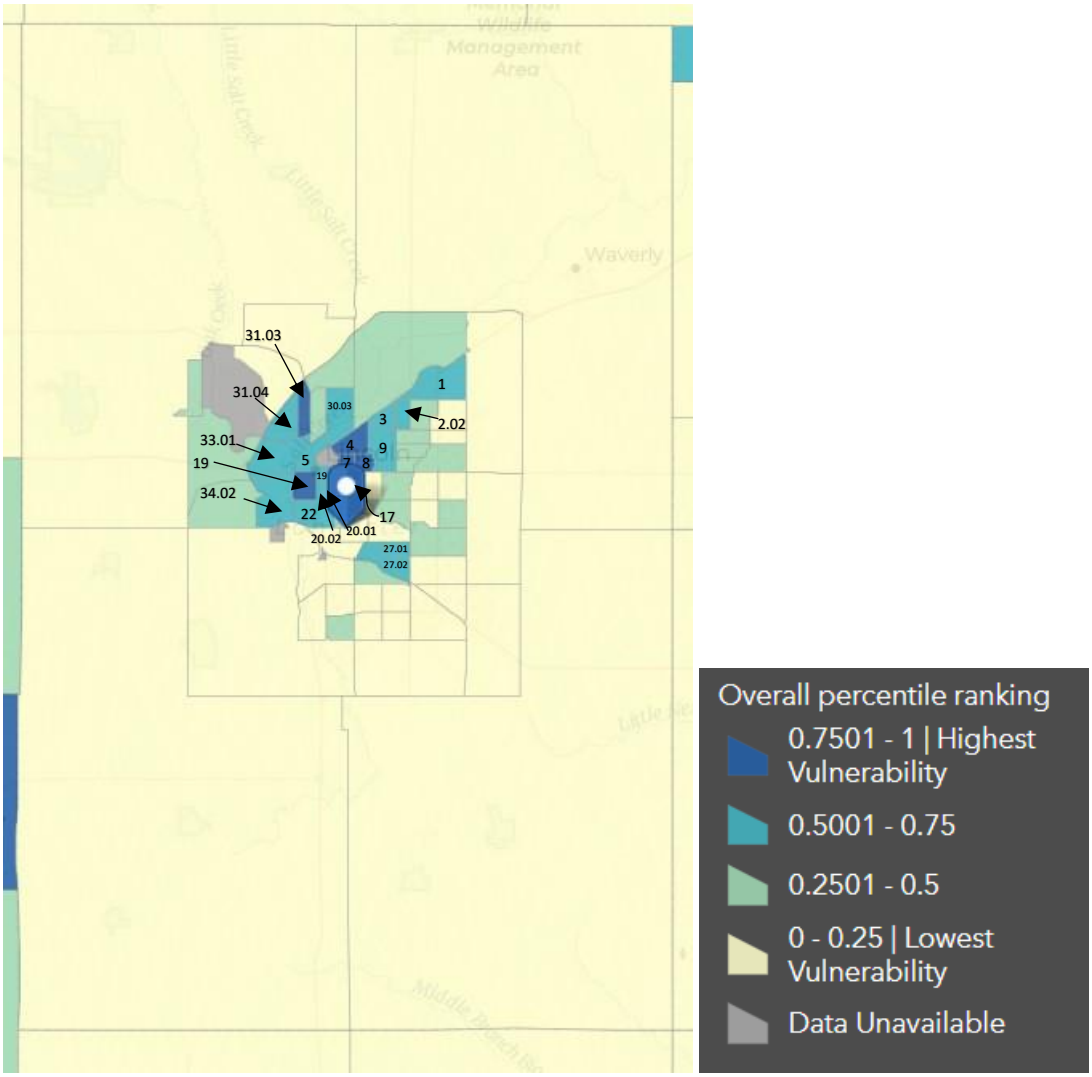

Figure 5: Lancaster County Census Tract Numbers and 2018 Social Vulnerability Index Score Percentile Rankings

The turquoise color indicates the SVI score level of moderate to high, and the level of high is indicated by the dark blue color. Actual SVI scores for these census tract numbers can be seen in Table A2. Source: https://svi.cdc.gov/map.html

Pierce County

The results of the GIS map for Pierce County can be seen in Figure 6. With an initial visual analysis of it, the overall underserved census tracts in Pierce County are the southern region of Census Tract 9792 and the central and eastern region of Census Tract 9791. The EMS and hospital resources found in Pierce County can be seen in Table A4 and A5 in Appendix A. The underserved EMS census tracts are most of Census Tract 9792 (except for the northern region along the main road), and the northern region of 9791. The underserved hospital census tracts are the southern region of Census Tract 9792 and most of Census Tract 9791 (except the northern region along the main road).

Additionally, upon further analysis of the individual facility coverage, the underserved EMS census tracts in Pierce County are confirmed to be both 9791 and 9792 because zero non-volunteer agencies serve the area. The underserved hospital census tracts are both 9791 and 9792 as well because there is no access to a trauma designated and stroke center hospital.

No statistical analyses were conducted for the relationship between SVI scores and EMS agencies and hospitals because there are no non-volunteer EMS agencies, and trauma designated or stroke center hospitals located in the area. Therefore, the county as a whole is underserved and independent of the SVI score.

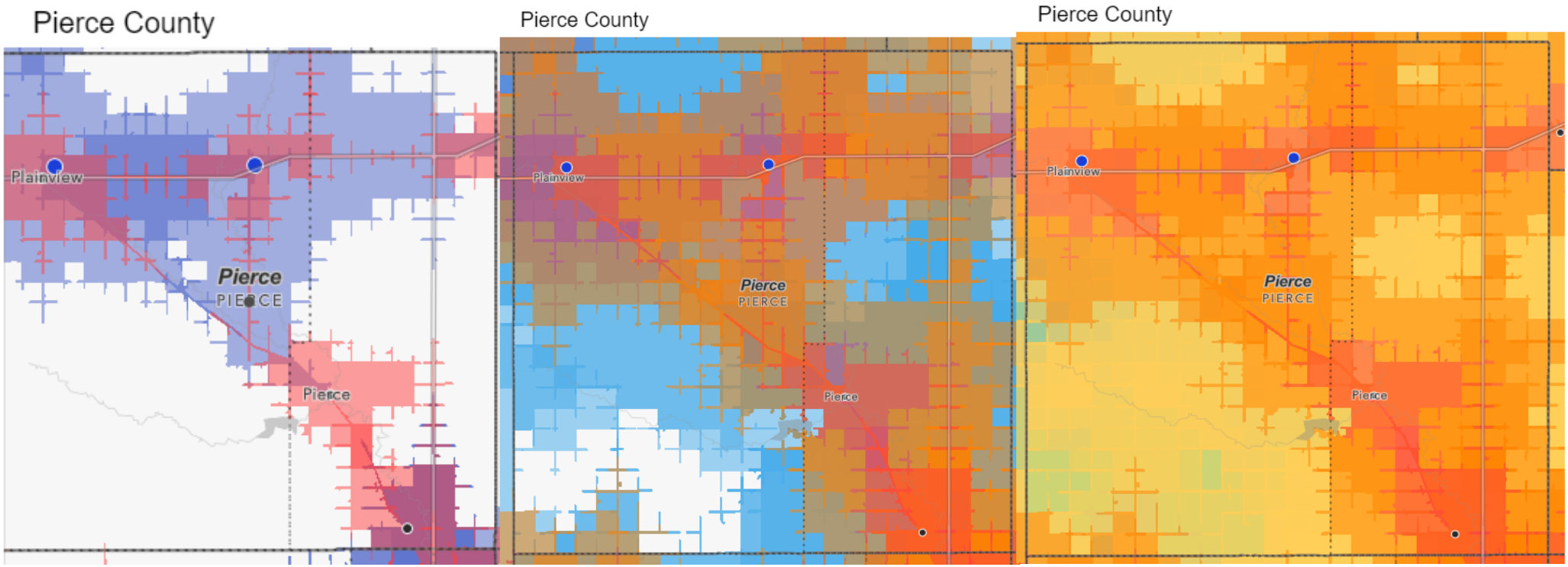

Figure 6: Estimated ERTs and Hospital Arrival Times for Pierce County

The blue dots are hospital locations, and the blue zones are the estimated hospital arrival times of 15 minutes. Black dots are EMS locations and red zones are estimated emergency response times of 8 minutes.

Hitchcock County

The results of the GIS map for Hitchcock County can be seen in Figure 7, and with an initial visual analysis of it, there is only one census tract, 9627, and the county as a whole is underserved. The resources found in Hitchcock County can be seen in Table A3 in Appendix A. No hospitals are located in the county, and four EMS agencies serve the county, but they are all volunteer based.

No statistical analyses were conducted for the relationship between SVI scores and EMS agencies and hospitals because there are no non-volunteer EMS agencies, and trauma designated or stroke center hospitals located in the area. Therefore, the county as a whole is underserved and independent of the SVI score

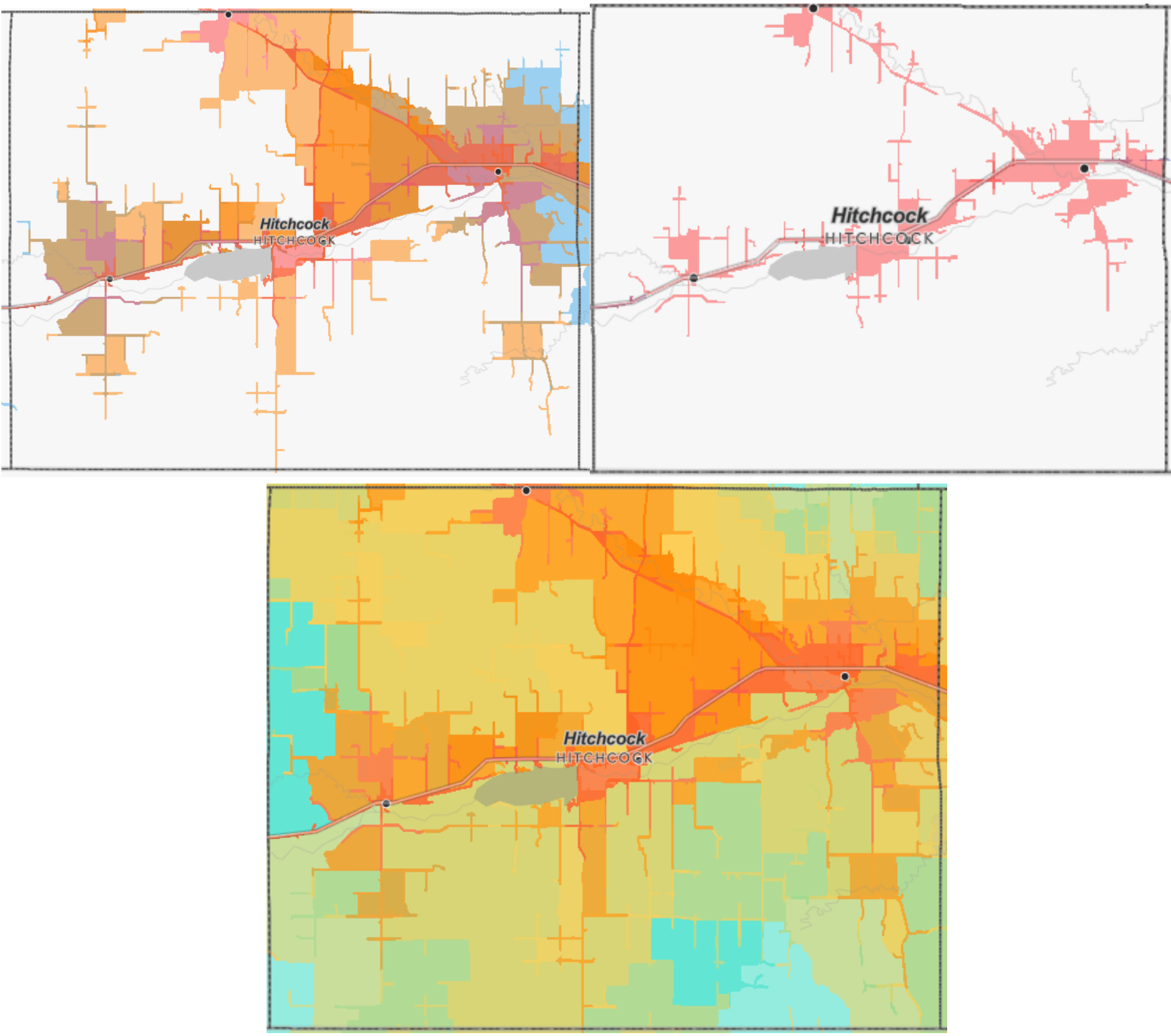

Figure 7: Estimated ERTs and Hospital Arrival Times for Hitchcock County

Black dots are EMS locations and red zones are estimated emergency response times of 8 minutes

Discussion

The results of this study indicate that there are areas in urban and rural Nebraska that have less timely access to EMS ground transport response and hospitals. For example, as seen in Figure 1, there are numerous areas throughout Nebraska without timely access to emergency resources on the first map, as indicated by the significant white space, since they do not have the 8-minute EMS response and 15-minute hospital arrival time coverage. Therefore, these results further validate how rural counties face the most challenges in access to emergency services due to delayed EMS response from the EMS agencies operating on a volunteer basis and increased distance to medical facilities, resulting in more extended response and transport times (Grossman et al., 1997). For example, as indicated in Table 1, Lancaster County is 92% urban, and the interactive GIS map suggests that an EMS facility serves all census tracts with transportation capabilities. The only resource lacking in this county is timely access (within 15 minutes) to a trauma-designated hospital.

In comparison, Gage County is 56% urban and 44% rural, and this county has two census tracts, 9646 and 9647, with no EMS coverage, 9649 and 9650 have no hospital coverage, and all the census tracts are lacking in access to a trauma-designated and stroke center hospital. Lastly, the two rural counties, Hitchcock and Pierce, have no access to a trauma-designated or stroke center hospital, and are only served by volunteer EMS agencies. The pattern that emerges with these results is that access to emergency services decreases as the urban percentage decreases and the rural percentage increases between the counties. This result is consistent with previous studies that have found urban areas were associated with significantly lower response times than

rural areas and urban patients receive EMS response on average eight minutes more quickly than rural patients (Aftyka et al., 2014; Masterson et al., 2015). This pattern is logical because as the urban percentage decreases, there is less economic viability to support non-volunteer EMS coverage and hospitals since these areas are not population dense. It's important to consider these results because many studies have displayed the detrimental health outcomes from delayed response and hospital arrival times. For example, one study showed that in rural motor vehicle crashes, increased EMS response time, time on scene, and distance to the scene are associated with higher rural trauma mortality rates (Gonzalez et al., 2006). Another example would be the study that reported a higher stroke death rate in rural areas than in urban areas, which was attributed to prolonged EMS arrival to the scene (Shultis et al., 2010).

Additionally, SES measured by the SVI score of the county had mixed results in terms of statistical significance for Lancaster County in terms of the relationship between SVI, and EMS coverage and access to trauma-designated and stroke center hospitals, and Gage County had statistically significant results for the relationship between SVI and EMS coverage. For example, in Lancaster County, the relationship between the SVI score and the number of EMS agencies with transportation capabilities was found via Pearson's correlation to be 0.287, which meant that the relationship was a positive, but weak and likely unimportant correlation, and this relationship was found to be significant with a p-value of 0.0169 since it was a value less than 0.05. These results are inconclusive because the relationship is weak and unreliable, so this may not show the entire picture because each EMS facility has varying resources available and other inequities may be present and should be further analyzed in future studies. In comparison, the relationship between SVI and the number of trauma designated hospitals and stroke center hospitals in Lancaster County was both found to be a weak to no correlation relationship, but the

p-values indicated that these relationships were not significant due to the p-values being greater than 0.05. This result of rejecting the null hypothesis of having a weak to no correlation relationship for these two sets of relationships may be a result of the random variability in access to the stroke center hospital and trauma-designated hospital for the different SVI scores (e.g., low, moderate, and high), so further analysis would need to be conducted to confirm the presence of any relationship. Lastly, Gage County had statistically significant results with a p-value of 0.00793 for a strong, positive correlation between non-volunteer EMS agencies serving the census tract and SVI score with an r-value of 0.886. Based on these results, as the SVI score increases, the number of non-volunteer EMS agencies serving the census tract also increases, indicating no correlation between census tracts with the highest vulnerability and underserved EMS areas. However, further research needs to be conducted to validate these results.

The results are logical when comparing Figure A1 in Appendix A of the population distribution map of Nebraska with Figure 1. When comparing the figures, the underserved areas are typically rural counties with sparse population density, which makes it hard to maintain high levels of EMS response and hospital access because it's costly to provide care in areas with little call volumes and demand for care. As a result, it is essential to consider the interventions that can be used to supplement care in underserved areas and improve their access to emergency services. For example, Hitchcock County has no hospitals that serve the area, so it would be necessary for this rural county to implement an intervention that provides supplemental care, like community paramedicine. Community paramedicine can be used in rural counties like Hitchcock and Pierce County, where they primarily have volunteer EMS agencies, because it would allow the EMTs and paramedics to transition from being volunteers to full-time staff. To do so, the EMTs and paramedics would be integrated into the local health care system overseen by physicians,

allowing them to operate in a primary care setting while serving as EMS personnel when necessary (Health Resources and Services Administration, 2012). For example, in rural Nova Scotia, where there are no hospitals, a successful nurse practitioner/community paramedicine program was implemented where nurse practitioners and community paramedics operate local clinics to provide complex care (e.g. wound care, immunizations, injury prevention sessions, etc.), have offsite physician consultations when necessary, and community paramedic visits for patients with chronic conditions while maintaining EMS coverage when necessary (Guo et al., 2017). The success of this program is highlighted in a 3-year longitudinal study of the implementation of the nurse practitioner/community paramedicine program in Nova Scotia that found the program had reduced annual trips to emergency departments by 40%, doctor visits by 28%, and decreased overall annual expenses for healthcare from $2,380 to $1,375 per person (White & Wingrove, 2012). As a result, this program would be an excellent opportunity to improve access to healthcare in areas with primary care provider shortages and emergency services in the underserved rural areas of Nebraska.

Additionally, to improve EMS coverage in urban counties like Lancaster County, it will be necessary to either position new EMS facilities in the areas that lack coverage, which can be seen in Figure 3 in the first map with the ideal 8-minute ERT or relocate the pre-existing EMS facilities to improve the coverage. For partially urban counties like Gage and rural counties like Pierce and Hitchcock that lack timely access (within 15-minute hospital arrival times) to a stroke center hospital, an intervention could be to have mobile stroke units (MSUs) or improve critical access hospitals located in less urban counties and rural areas to have stroke ready certifications. An MSU would be an ambulance equipped with portable cranial CT imaging and is typically staffed with a CT technologist, EMT/paramedic, stroke expert, and stroke nurse (Shuiab &

Jeerakathil, 2018). MSUs can be deployed to a patient's location, or they can rendezvous with an ambulance transporting the patient. This would allow these patients to have timely access to emergency stroke care in rural and urban counties that lack access to stroke centers. In fact, the MSU and community paramedicine could be implemented together, which could help with the staffing demands of an MSU.

Additionally, counties with high stroke prevalence can improve their critical access hospitals to have stroke-ready certifications to improve the stroke care for their county. For example, the Illinois Critical Access Hospital Network brought rural health stroke treatment to the same level as larger, urban hospitals by obtaining Acute Stroke Ready certification for 100% of Illinois critical access hospitals, which resulted in almost 70% of rural hospital patients meeting the time protocol for stroke treatment (Lahr, 2018). Additionally, one study found that "obtaining certification reduces stroke mortality and overcomes the disadvantage of being smaller hospitals" (Man et al., 2017, p. 4). As a result, stroke-ready certifications for rural critical access hospitals would be an excellent intervention to standardize stroke care in these areas.

Lastly, an intervention that can be implemented to supplement care for the lack of access to trauma-designated hospitals would be to ensure access to other forms of transportation like helicopter pads for quicker transport to a trauma-designated hospital and the use of telehealth to aid rural hospitals and EMS with optimal evaluation, treatment, and transfer of patients (Beret et al., 2017). For example, one study followed the implementation of telemedicine at seven rural hospital emergency departments in Mississippi in conjunction with the state's sole level I trauma center and found that in comparison to before the telemedicine period, there was a decrease in length of stay at the rural hospital (1.5 vs 47 hours), decrease in time to transfer from the rural hospital to the trauma center (1.7 vs 13 hours), and total hospital charges for patients were

significantly higher before telemedicine than after ($7.53 million vs $1.13 million)" (Duchesne et al., 2008). Additionally, another study in Houston on the Emergency Telehealth and Navigation (ETHAN) program that deployed tele-EMS found that "equipping video conferencing software on all paramedic computer tablets for two-way communication with a board-certified emergency medicine physician resulted in $229.69 lower direct cost structure for the telehealth group ($450.08 for usual care vs $227.39 for telehealth due to more rapid response times for labor and vehicles, EMTS along with the vehicles they responded with returned to service quicker due to lower frequency of transports (mean turnaround time of 34 minutes for telehealth vs 81.7 minutes for usual care),..and the simulated savings for the 4-year period of this program were $4,712,000" (Persse et al., 2019).

Limitations

The results of this study primarily focused on four varying levels of urban to rural area percentage ratios, which may not be representative of other counties in Nebraska. Additionally, the proposed interventions may not be suitable for all counties and their budgets, so further discussions will be needed to determine if these interventions are achievable in underserved areas. Additionally, this study does not account for other factors that may vary between geographic areas and affect ERT (e.g., transport infrastructure, maintenance and physical conditions of roads, traffic, number and condition of ambulances, etc.), so further research needs to be conducted to account for these differences and its effect on the results. Lastly, this study was primarily a qualitative analysis of the interactive GIS map created and data available from the 2018 Census SVI data, so further research needs to be conducted to better understand any correlations between SES and other factors on underserved communities using methods like centroid analysis in the GIS program to better identify access to emergency services and its

relation to SVI data, and any relationships between access to EMS and hospital resources and health outcomes.

Conclusion

Using interactive GIS mapping, this research report confirms that numerous areas in Nebraska, especially in the western and central rural regions, are underserved in terms of access to adequate EMS response and hospital arrival times to appropriate care facilities. As a result, this study highlights the need for interventions to supplement care and expand EMS coverage in these underserved areas, including community paramedicine, telemedicine for EMS and hospitals, stroke-ready certifications for rural critical access hospitals, and mobile stroke units. Further research and collaboration would need to occur to discuss the viability of implementing the proposed interventions in the underserved areas, and will be important in decreasing the inequitable access to emergency care in the counties identified.

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Appendix A

Table A1: 2018 Overall Social Vulnerability Index Scores

County	2018 Overall Social Vulnerability Index Score (0 to 1)	Level
Hitchcock County (Census Tract 9627)	0.525	moderate to high
Lancaster County	See Table A2	See Table A2
Pierce County (Census Tract 9792)	0.4592	low to moderate
Pierce County (Census Tract 9791)	0.1633	low
Gage County (Census Tract 9646)	0.0913	low
Gage County (Census Tract 9647)	0.0501	low
Gage County (Census Tract 9648)	0.3683	low to moderate
Gage County (Census Tract 9649)	0.5819	moderate to high
Gage County (Census Tract 9650)	0.4121	low to moderate
Gage County (Census Tract 9651)	0.5242	moderate to high
Gage County (Census Tract 9652)	0.4419	low to moderate

Source: https://svi.cdc.gov/map.html

Table A2: 2018 Overall Social Vulnerability Index Scores for Lancaster County

Lancaster County Census Tract Number	2018 Overall Social Vulnerability Index Score (0 to 1)	Level
1	0.7089	moderate to high
2.01	0.4711	low to moderate
2.02	0.6183	moderate to high
3	0.5986	moderate to high
4	0.7751	high
5	0.6959	moderate to high
6	Data unavailable	Data unavailable
7	0.9005	high
8	0.8319	high
9	0.5478	moderate to high
10.01	0.385	low to moderate
10.02	0.417	low to moderate
10.03	0.4892	low to moderate

11.01	0.1754	low
11.02	0.1921	low
12	0.3596	low to moderate
13.01	0.2494	low
13.02	0.0263	low
14	0.3412	low to moderate
15	0.3169	low to moderate
16	0.1905	low
17	0.7979	high
18	0.8803	high
19	0.5488	moderate to high
20.01	0.6964	moderate to high
20.02	0.7151	moderate to high
21	0.8333	high
22	0.6645	moderate to high
23	0.4138	low to moderate
24	0.0081	low
25	0.2337	low
27.01	0.6638	moderate to high
27.02	0.5225	moderate to high
28	0.1276	low
29	0.4391	low to moderate
30.01	0.4202	low to moderate
30.02	0.4407	low to moderate
30.03	0.7245	moderate to high
31.02	0.0451	low
31.03	0.8738	high
31.04	0.7168	moderate to high
33.01	0.5989	moderate to high
33.02	0.3376	low to moderate
34.01	0.4002	low to moderate
34.02	0.5698	moderate to high
35	Data unavailable	Data unavailable
36.01	Data unavailable	Data unavailable
36.04	0.0241	low
36.05	0.2412	low
36.07	0.4506	low to moderate
36.08	0.0545	low
36.09	0.0209	low
37.04	0.4158	low to moderate
37.06	0.2782	low to moderate
37.07	0.0744	low
37.08	0.2304	low
37.09	0.017	low
37.13	0.0163	low
37.14	0.0546	low

37.15	0.0419	low
37.16	0.206	low
37.17	0.0756	low
37.18	0.0028	low
37.19	0.0713	low
37.2	0.0064	low
38.01	0.2811	low to moderate
38.02	0.0919	low
101	0.142	low
102.01	0.1796	low
102.02	0.1791	low
103	0.0696	low
104	0.1493	low
9832	Data unavailable	Data unavailable

Source: https://svi.cdc.gov/map.html

Table A3: EMS Resources Located in Hitchcock County

EMS Agency	Service Status	Type of Service	Service	Service Type	Region (EMS)
Stratton Ambulance	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	West
Palisade Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	West
Trenton Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	West
Culbertson Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Private, nonhospital	West

Table A4: EMS Resources Located in Pierce County

Agency	Agency Type	Service Status	Type of Service	Service	Service Type	Region (EMS)
Hadar Volunteer Fire Department	EMS	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Northeast
Randolph Rescue Unit	EMS	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Northeast

Osmond Ambulance Service	EMS	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Northeast

Table A5: Hospitals Located in Pierce County

Hospital	Hospital Type	Trauma Designation	Stroke Center?
Osmond General Hospital	Critical Access Hospital	none	no
CHI Plainview	Critical Access Hospital	none	no

Tables A6: EMS Resources Located in Gage County

EMS Agency	Service Status	Type of Service	Service	Service Type	Region (EMS)	County Type	Serves
Beatrice Rural Fire & EMS	Volunteer	911 Response without transport Capability	Basic Life Support	Fire Department	Southeast	Small Urban	Center of Gage County
Beatrice Fire and Rescue	Non-Volunteer	911 Response with Transport Capability	Advanced Life Support	Fire Department	Southeast	Small Urban	Center of Gage County
Cortland Fire and Rescue	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Small Urban	N border of Gage County
Clatonia Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Southeast	Small Urban	NW corner of Gage County
Adams Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Southeast	Small Urban	NE corner of Gage County
Pickrell Fire and Rescue	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Small Urban	N area of Gage County
Dewitt Rescue	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Small Urban	NW border of Gage County
Nine Line EMS	Non-Volunteer	Medical Transport (Convalescent,	Advanced Life Support	Private, non-hospital	Southeast	Small Urban	Center of Gage County

		Interfacility Transfer Hospital and Nursing Home)					
Wymore EMS	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Southeast	Small Urban	S area of Gage County
Odell Volunteer Fire and Rescue Q.R.T	Volunteer	911 Response with Transport Capability	Basic Life Support	Governmental, non-fire	Southeast	Small Urban	SW corner of Gage County
Diller Rescue Unit	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Rural	SW border of Gage County
Firth Rural Fire District-Station 1	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Urban Large	N border of Gage County
Hallam Rescue Squad	Volunteer	911 Response with Transport Capability	Basic Life Support	Fire department	Southeast	Urban Large	N border of Gage County

Table A7: Hospitals Located in Gage County

Hospital	Hospital Type	Trauma Designation	Stroke Center?
Beatrice Community Hospital and Health Center	Critical Access Hospital	none	no

Table A8: EMS Resources Located in Lancaster County

Agency	Service Status	Type of Service	Service	Service Type	Region (EMS)	County Type	Serves
American Red Cross	Volunteer	Special Event Only	Private, Nonhospital	Basic Life Support	Southeast	Urban Large	Central Lancaster County
Bennet Fire and Rescue	Volunteer	911 Response (Scene) without Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	SE Region of Lancaster County (Bennett)

Duncan Aviation First Responders	Volunteer	Company Response Only	Private, Nonhospital	Basic Life Support	Southeast	Urban Large	Company Response Only
Firth Rural Fire District - Firth Station 1	Volunteer	911 Response (Scene) without Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	SE Corner of Lancaster County (Firth)
Firth Rural Fire District - Panama Station 2	Volunteer	911 Response (Scene) without Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	SE Corner of Lancaster County (Panama)
Hallam Rescue Squad	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	SW Border of Lancaster County (Hallam)
Hickman Volunteer Fire and Rescue	Volunteer	911 Response (Scene) without Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	SE Region of Lancaster County (Hickman)
Kawasaki Emergency Medical Response Team	Volunteer	Private Response without Transport Capability	Private, Nonhospital	Basic Life Support	Southeast	Urban Large	Kawasaki Company Response Only
Lincoln Fire & Rescue Station 1	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (Lincoln)
Lincoln Fire & Rescue Station 10	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (Lincoln)
Lincoln Fire & Rescue Station 11	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	NW area of Central Lancaster County (W Lincoln, Lincoln Airport)
Lincoln Fire & Rescue Station 12	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster (NE Lincoln)
Lincoln Fire & Rescue Station 13	Non-Volunteer	911 Response (Scene) with	Fire Department	Advanced Life Support	Southeast	Urban Large	SW Region of Central Lancaster County (Lincoln)

		Transport Capability					
Lincoln Fire & Rescue Station 14	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	NW Corner of Central Lancaster County (W Lincoln, near Lincoln Airport)
Lincoln Fire & Rescue Station 2	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (NE Lincoln)
Lincoln Fire & Rescue Station 3	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (Central Lincoln)
Lincoln Fire & Rescue Station 4	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County
Lincoln Fire & Rescue Station 5	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (Havelock)
Lincoln Fire & Rescue Station 6	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	SE Region of Central Lancaster County (College View)
Lincoln Fire & Rescue Station 7	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (Antelope Park)
Lincoln Fire & Rescue Station 8	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County
Lincoln Fire & Rescue Station 9	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (NE Lincoln)
Malcolm Fire and Rescue	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	NW corner of Lancaster County (Malcolm)
Midwest Medical Transport Co. - Lincoln	Non-Volunteer	Interfacility Transport with 911 Intercept Capability	Private, Nonhospital	Advanced Life Support	Southeast	Urban Large	Central Lancaster County (E Lincoln)

Nebraska Air National Guard Fire Department	Non-Volunteer	Rescue, non-transport	Private, Nonhospital	Basic Life Support	Southeast	Urban Large	Nebraska Air National Guard Only
Raymond Volunteer and Rescue	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	NW Corner of Lancaster County (Raymond)
Southeast Rural Fire District Station 1	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	SE Region of Central Lancaster County (Pine Lake)
Southeast Rural Fire District Station 2	Non-Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	Central Lancaster (NE Lincoln)
Southwest Rural Fire Dept Station 1	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	SW Area of Lancaster County
Southwest Rural Fire Dept Station 3	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Advanced Life Support	Southeast	Urban Large	SW Area of Lancaster County (Sprague)
Waverly Fire and Rescue	Volunteer	911 Response (Scene) with Transport Capability	Fire Department	Basic Life Support	Southeast	Urban Large	NE Area of Lancaster County

Table A9: Hospitals Located in Lancaster County

Hospital	License Type	Trauma Designation	Trauma Region	Stroke Designation Level	Burn Center	Heart Cath Lab
Madonna Rehabilitation Hospital Lincoln Campus	Rehabilitation Hospital	None	None	None	No	No
Select Specialty Hospital Lincoln	LTC hospital	None	None	None	No	No
Lincoln Surgical Hospital	Short-term	None	None	None	No	No
Lincoln Regional Center	Psychiatric	None	None	None	No	No
St Jane de Chantal LTC Svcs	Long-term Care Hospital/Distinct Part (No ER and does not take emergent patients)	None	None	None	No	No
CHI Health St Elizabeth	General Acute	Level III (General)	Region 2	Primary Stroke Center	Yes	24/7 Access
Bryan Medical Center East	General Acute	None	None	Primary Stroke Center	No	24/7 Access
Bryan Medical Center West	General Acute	Advanced Level II	Region 2	Primary Stroke Center	No	24/7 Access
CHI Health Nebraska Heart	General Acute	None	None	Percutaneous Coronary Intervention Center	No	24/7 Access

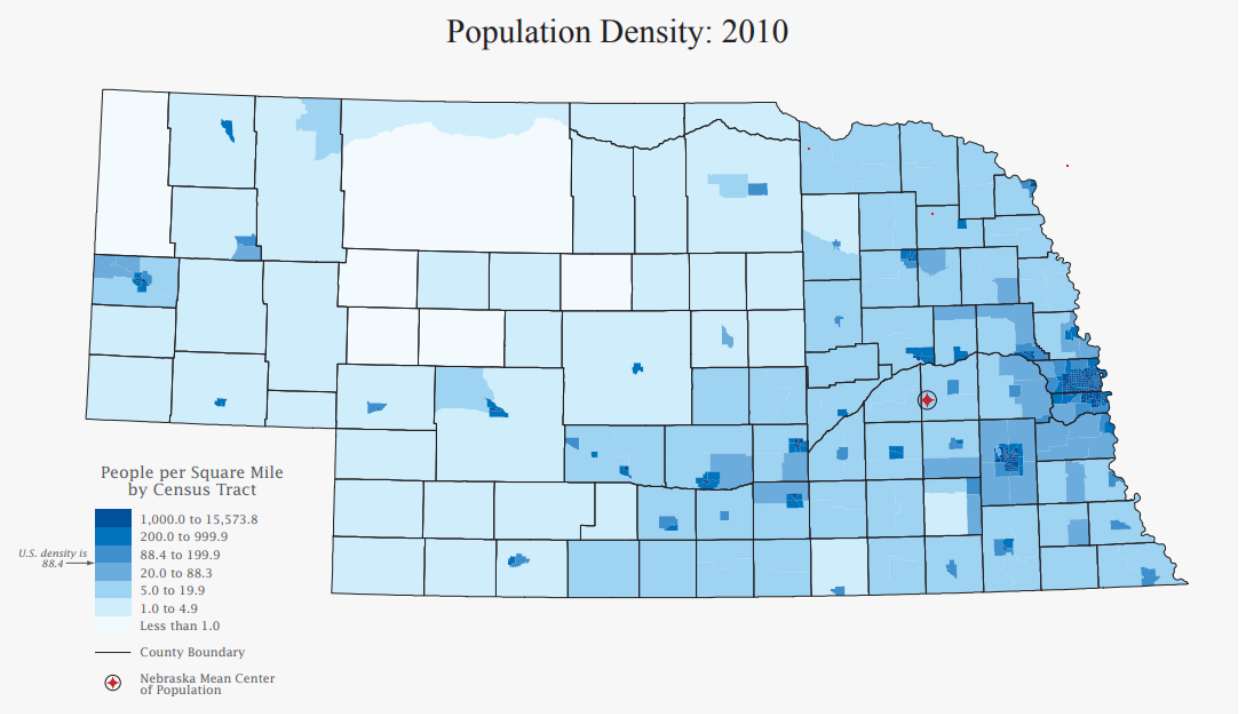

Figure A1: Population Density Map for Nebraska Based on the 2010 Census

Source: https://www2.census.gov/geo/maps/cong_dist/cd113/st_based/CD113_NE.pdf

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