REGIONAL AGGLOMERATION IN THE TEXAS CORE TRIANGLE

by

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TEXAS CORE TRIANGLE

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ABSTRACT

Previous research indicates that the Texas Core Triangle – DFW, Houston, Austin, and San Antonio – is the largest functionally integrated megalopolis in the US. This thesis will use GIS technologies to map out a cluster analysis of industries on regional and local scales to determine if agglomeration is occurring throughout the Texas Core Triangle. If agglomeration is occurring on a regional as well as local level, then each city contains unique economic bases, which act as a whole greater than the sum of its parts.

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Introduction

Business and industry agglomeration is a well-studied field that explores how firms position themselves spatially regarding their business partners and competitors to gain both tangible and intangible benefits. Benefits vary by firm, such as reduced transportation costs, or locating closer to competitors so that a firm's employees can trade industry information that would otherwise be inaccessible. While not all industries agglomerate, firms that have the largest financial incentives to do so attempt to maximize their effective service range while reducing costs of agglomeration, principally real estate costs. For instance, in the financial services sector, firms agglomerate near one another and serve wide geographic regions, like in New York City in the Northeast megalopolis, which stretches from Boston to Washington D.C. This research project aims to replicate and build on the results of a paper published by the Houston branch of the Dallas Federal Reserve in 2004 claiming that the four 'cities' of the Triangle: Dallas/Fort Worth, Austin, San Antonio, and Houston form an integrated urban region, the Texas Triangle megalopolis. While the original paper did not apply Geographic Information Systems (GIS) to connect the metropolitan areas, this project will employ them extensively. While most previous research focused on regional scales, GIS visualization allows for an analysis of agglomeration within regions as well as within cities, at a local level. The data employed comes exclusively from the United States government, specifically the Bureau of Economic Analysis and the United States Census Bureau. Whether the area is currently functionally integrated and, if so, to what extent have massive policy and planning implications on local, state, and federal governments. If the region is economically integrated, then one city will have a higher density of a certain industry than the other four cities of the Triangle. Conversely, if this study finds equal disbursement of industries amongst the cities of the Core Triangle, then it will reject the claim that the region is economically

integrated. The process of incorporating municipalities together to facilitate economic prosperity has occurred previously, like the North Central Texas Council of Governments, but never in such a wide-reaching capacity. In the case of state and federal planning, officials could work together to decrease the geographic separation of the region through improved infrastructural mechanisms. As the relative distance, meaning transportation costs including travel time, continues to fall between the cities, greater degrees of economic integration can occur, creating jobs, opportunities, and growth.

Literature Review

The origin of the term 'Texas Core Triangle' comes from Donald Meinig's *Imperial Texas: An Interpretive Essay in Cultural Geography*. "The rest of Texas is bound to that Core through the mediating functions of Houston, San Antonio, and Dallas-Fort Worth," Meinig wrote in 1969, although primarily concerned with population groups and culture (Meinig 111). Previous scholarship generally combined the two cities together because of geographic distance rather than economic integration. Meinig explicitly outlined them together as a single entity, although principally cultural rather than economic, in relation to San Antonio and Houston.

While there was some research pertaining to the region that centered on an economic analysis, it generally occurred through industry case studies. For instance, from 2001, *Agglomeration Effects and Performance: A Test of the Texas Lodging Industry* takes a view of an industry to determine if hotel agglomeration was mutually beneficial for all firms. The author's conclusions varied by region: in rural markets, agglomeration was highly beneficial, while benefits in denser urban markets were not as great. Additionally, the report advises that "optimal location choice is not only a function of a location's traits, but also of the firm's own traits" recognizing that different types of lodging, such as bed and breakfasts or chain hotels, will benefit differently

from agglomeration (Chung and Kalnins 986). However, the authors never identify the Texas Core Triangle as a functionally or economically integrated region.

The research that put the Core Triangle into a mathematical and economic perspective came through a 2004 paper from the Houston Branch of the Dallas Federal Reserve. *The Simple Economics of the Texas Triangle* by Richard Gilmer argues that the cities in this region form "a megalopolis in the sense that we can add the pieces together with a minimum of duplication … [and] they don't really overlap much in their economic roles" (Gilmer). This paper indicates the role each city plays in the Triangle. Starting with the largest city in the Core Triangle, "Houston is home to Texas' international business community" established through oil and shipping, but also "[t]he Texas Medical Center and [the] Johnson Space Center" (Gilmer). Dallas-Fort Worth effectively connects the Core Triangle to the rest of the United States, "[t]he metroplex still plays its original role as a major inland transportation hub and distribution and service center for the surrounding area … [but also] the state's banking and financial center" (Gilmer). In Austin, the University of Texas has oriented the city towards Silicon Valley: "Austin's major strength has historically been a robust government sector … [later] developing a significant presence in high technology" (Gilmer). San Antonio connects Texas to Latin America, a relationship that "has grown with the rapid expansion of the maquiladora industry and the implementation of NAFTA … [t]ourism … [and] a major military presence" which has likely grown in size influence due to the War on Terror (Gilmer).

To understand what is meant by the term 'megalopolis,' *The New Metropolis: Rethinking Megalopolis* characterizes a Megalopolis region as one which "networks of up to 50 cities and towns, physically separate but functionally networked, clustered around one or more larger central cities" that benefit from "a new functional division of labour" (Lang, Knox). The authors do not

consider or mention the Texas Core Triangle as a 'megalopolis' region. They do define two megalopolis regions within the Core Triangle, the "Gulf Coast" encompassing Houston and New Orleans, and the "I-35 Corridor" between Dallas and Oklahoma City (Lang, Knox). The paper mentions San Antonio and Austin briefly as beginning to show urban integration, indicated by commuting patterns, and predicts that future research will consider the two integrated in a similar pattern to Dallas and Fort Worth.

The most recent special report from the Federal Reserve of Dallas, *At the Heart of Texas*, released in December 2018, concerns the urban economic activities of the state. The analysis includes the regions of the Core Triangle, using Gilmer's approach of "[l]ocation quotients (LQs) … [to] compare the relative concentration of industry clusters locally and nationally" (Orrenius 5). However, this report does not mention the Texas Core Triangle, or consider it as a distinct entity. Instead, it individually considers thirteen distinct metropolitan regions throughout the state, splitting the Dallas-Fort Worth area into two different regions: Dallas – Plano – Irving and Fort Worth – Arlington.

Heavily citing the work of Gilmer, *Connecting the Texas Triangle: Economic Integration and Transportation Coordination* empirically verifies that the Texas Core Triangle forms a megalopolis. Additionally, the report expands Gilmer's analysis to include the movement of resources and people around the Texas Core Triangle to reinforce the conclusion. Zhang, Steiner, and Butler conclude with policy recommendations to integrate the region, including a dedicated Core Triangle planning committee and infrastructure improvements like toll roads and railway expansions between the municipal regions.

While primarily concerned with ecological sustainability, the paper *Texas Urban Triangle: Framework for Future Growth* concludes that the five largest cities of Texas form a functionally

integrated region. It suggests problems that will likely emerge by 2030, including water usage and energy consumption. The job projections only indicate the general region; there is no subdivision of current employment by city. Backing Gilmer's conclusions, the report *Reinventing the Texas Triangle: Solutions for Growing Challenges* by the University of Texas School of Architecture accepts that there is limited competition between the cities, but "the cities do compliment each other in their economic roles" (Butler et al.). The report went further to suggest that a high-speed rail network connecting the major cities would advance integration for the region.

Previous studies of economic geography such as *Agglomeration Economies and Industrial Location: City-Level Evidence* indicates that industries do agglomerate within regions. Different types of firms agglomerate more aggressively, "technologically advanced sectors (e.g., Office & Computing Machinery), urbanization agglomeration economies are the most important factors determining location" (Viladecans-Marsal 580). Should this result hold true for the Texas Core Triangle, technology firms will demonstrate more agglomeration than the firms of other industries. Scale is an important concept for understanding various degrees of agglomeration and *Scale and Geographic Inquiry: Contrasts, Intersections, and Boundaries* address the issue of dealing with different layers of analysis, in this case regional and local. The authors describe an ongoing debate of scale within human geography, which this paper does not intend to address explicitly. The authors Sheppard and McMaster argue that in the digital age local information is more valuable to businesses than data on a larger scale, which might indicate trends but does not assist with customer acquisition.

Both the *Economies of Network, Urban Agglomeration, and Regional Development: A Theoretical Model* and *Planning for Agglomeration Economies in a Polycentric Region: Envisioning an Efficient Metropolitan Core Area in Flanders* concluded that firms agglomerate

near infrastructure connecting several municipalities together. The first uses statistical data of East Japan to track production along highways connecting larger municipalities; it concludes that increases in production occur in tandem with the growth of nearby metropolitan cores. The second analyzes how planning might occur to facilitate the development of agglomeration economies while still allowing for local municipal autonomy in the Netherlands. The latter is important for Texas, as regional integration cannot occur unilaterally with the expectation that several municipalities will receive disproportionate gains.

The 2013 study *Location Strategies for Agglomeration* Economies looked at foreign entrants into the American market to determine where firms were likely to locate. Their results indicated that firms were more likely to locate closer to potential high-skilled employees, rather than to suppliers, although surprisingly "locations in which suppliers and knowledge were concentrated in fewer firms are substantially less attractive than locations where these factors were more dispersed" (Alcácer and Chung 1759-1760). This conclusion indicates that a larger region would see less agglomeration around dense urban cores, especially among the region's largest firms. Knowing where firms locate, and which types of firms benefit from their location strategy is the research question for *Who Benefits from Agglomeration?* The results of the report conclude that smaller and newer businesses gained more economic benefits from agglomeration than larger, older businesses did, although rather interestingly considering the results of Alcácer and Chung, "older firms, regardless of size or complexity, derive the largest benefit from having upstream suppliers nearby" (Rigby and Brown 41). The paper *Multilevel Approaches and the Firm-Agglomeration Ambiguity in Economic Growth Studies* concluded that agglomeration economies themselves do not foster economic growth, but rather increased firm performance as a result of agglomeration contributed to the local economy.

Technology Intensity and Agglomeration Economies considers whether firms benefit more from the highest concentrations of workers of the same sector, or a more economically diverse area. According to their study, non-high-tech firms benefited more from higher concentrations, but firms requiring specialized high-tech labor benefitted the most from a more diverse economic structure. Although this study looked only on the effects of job growth over time and conceded that agglomeration's "contributions of specialization on productivity ... can be negatively correlated with employment," meaning that the agglomeration may negatively affect job creation (Liang and Goetz 1994). This information reinforces the conclusion that not all firms agglomerate, and firms that require larger numbers of highly skilled workers are more likely to agglomerate.

A paper from 2009, *The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States*, also asserts that firms agglomerate regionally, but that information technology will lessen the extent to which firms agglomerate. *The Wealth of Cities* challenges assumptions and previous models, such as Weber's Least Cost Theory, about the agglomeration of firms dealing with costs. Manufacturers, for instance, were not as sensitive to transportation costs as service sector firms were, and that overall "[s]killed industries are more likely to locate in urban areas" (Glaeser and Gottlieb 1023). *Local Multipliers, Mobility, and Agglomeration* consider the differences in the agglomeration of basic industries on job creation in non-basic industries. The author of the study confirms the hypothesis that the effects of agglomeration benefit job creation in non-basic industries.

Considering that the effects of agglomeration on productivity will vary by study, *A Meta-Analysis of Estimates of Urban Agglomeration Economies* considers 34 separate studies to reveal how their characteristics might contribute to different results, concluding that "study characteristics do matter," and that "values that are published tend to emphasize larger positive

effects" (Melo et al. 341). With this, it is important to consider that the results of agglomeration mentioned throughout this literature review might vary from actual results.

Applying these lessons of agglomeration to the state of Texas, *A State Transformed by Information: Texas Regional Economy in the 1990s* mentions the Texas Core Triangle and how technological infrastructure like the Internet furthered agglomeration in "the Texas economy during the 1990s … [through] a widening development gap between the core [Triangle] and periphery" (Tu and Sui 541). This conclusion directly contradicts the findings of *The Wealth of Cities.* While the study looked at data, which is now more than 20 years old, the findings of the meta-analysis might help conclude that trends towards agglomeration in the Texas Core Triangle have likely not slowed.

More recently, *The Creative Economies of Texas Metropolitan Regions: A Comparative Analysis Before, During, and After the Recession* looks at the high-tech and entrepreneurial environment fostered through Austin's connection with Silicon Valley and compares the greater municipal regions of Texas to those around the country while considering the temporal aspect of national economic prosperity. Seman and Carroll found that the start-up culture of Austin created a positive feedback loop with the other cities of Texas, which facilitated the state's economic growth more quickly than similar metropolitan regions and states out of the Recession of 2008.

Although not all industries agglomerate, agglomeration for certain industries will occur in the Texas Core Triangle. By replicating Gilmer's study to confirm the studies result and using recent data, this research can conclude whether the Core Triangle does exist and if the region has become more economically integrated over the last fifteen years. Next using GIS, this study will map employee distributions on a regional level and on a local, metropolitan level to found the claim that the Texas Core Triangle is a megalopolis and a functionally and economically integrated

region, whereas the region unified is economically more powerful than the sum of its parts. If no agglomerations on either scale occur, then this study must reject the claim. If agglomerations occur on a local level but not on a regional scale, then this study can reject the claim. If agglomerations occur on a regional but not local scale, then this study can reject the claim. In that case, significantly more research will be required into understanding the result. If both regional and local agglomerations occur, this paper can conclude that firms are intentionally locating to maximize the benefits of agglomeration as well as to serve the greater Texas Core Triangle region, making the whole region greater than the sum of its parts. This conclusion contributes to the question of scale within geography in support of a hierarchical model of agglomeration.

Methods

First, the project will recreate locational quotient (LQ) results from Gilmer. Locational quotients divide the income earned by a certain industry in a certain city as a percentage of the total income of the city, by the income earned by a certain industry in the United States as a percentage of the total income of the country. The formula for locational quotients is in the appendix under Figure 1. This analysis indicates if there is more of a certain industry than the national average in a city. While retrieving data from the Bureau of Economic Analysis, this project was unable to match the exact statistics for metropolitan areas for population, citywide income, and per capita income in 2001. Additionally, the classifications used by Gilmer are not the same classifications listed by the Bureau of Economic Analysis for the 2001 data set. As a result, it was impossible to replicate the exact locational quotients. The appendix contains the results of both Gilmer and this study. Additionally, the Bureau of Economic Analysis redacted large quantities of data for both 2001 and 2017. In the original paper, Gilmer also notes that some redactions occurred, but does not describe to what degree it might influence the dataset. To

conclude whether the results of the LQ study are valid, Gilmer performed a single tailed F-test to ensure that the results are significant, which this study will replicate.

Second, the study will compare the densities of industries described as being key to each city within each metropolitan area. This will occur through mapping of Census Blocks using LODES WAC, or the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics Workplace Area Characteristic data from 2015, the most recent year available. The dataset is freely available online through the United States Census Bureau. This dataset indicates how many workers are working in a Census Block, and thus allows this study to identify which types of jobs are in which locations. By looking at these Census Blocks, this study will obtain a fine level of detail suitable for an analysis of micro-agglomerations. The first set of maps use proportional symbols to indicate the portion of workers in an area relative to the total number of workers in that industry for the Texas Core Triangle. By normalizing by population, the study avoids bias towards regions that are more populous and reflect where industries are agglomerating. The second set of maps take an in-depth look at each NAICS category and cities within which it appears that industries agglomerate to determine if there is any micro-level agglomeration occurring in any industry. The analysis used here is heat mapping, specifically Kernel Density, which uses the density of points within an area, in this case the Census Blocks, and the employment by an industry to locate clusters of agglomeration. The ‘hottest’ points on the map will indicate several Census Blocks near one another with a high number of employees in that industry. While this negates the functional visualization of several businesses clustered within a single Census Block, the resulting density will be enough to indicate agglomeration without the presence of nearby high-employment Census Blocks. The presence of micro-agglomerations within these cities confirms that industries are agglomerating to serve the Texas Core Triangle on

a local level. GIS allows for a more dynamic representation of distributions than mathematical models can offer as the scale changes between regional and local levels. This facilitates a high level of accessibility, by effectively reducing the technical knowledge required for practical interpretation, while not decreasing the scientific validity of the results.

Locational Quotient Results

To replicate the results using different datasets, Figure 2 in the appendix demonstrates how Gilmer calculated figures. As noted, Gilmer only presents data through two decimal points, and as a result, the calculations for figures like 'Per Capita' reflect Gilmer's calculations rather than independent calculations. A major issue is reflecting "Share," which Gilmer describes as "based on each city's contribution to wages, salaries, and employer-paid benefits in the combined region" (Gilmer). However, the exact calculations used to obtain that studies derived values are unknown. With data set from the Bureau of Economic Affairs that this study used, share is the personal income for each city divided by the sum of the personal incomes for the Triangle Cities. For this study's calculations, pictured in Figure 3, this results in a total difference of .05 between the four metropolitan areas.

Figure 4 is from Gilmer's original paper, showing which industries score above 1.15 for the LQ analysis. Figures 5 and 6 are the LQ analyses using the Bureau of Economic Analysis's dataset, specifically for the purposes of replications CAINC5 for the United States as a whole, as well as the four metropolitan areas of the Core Triangle. Because the labeling for Gilmer's results and this study's results are different, this study individually examines and analyzes important categories for each metropolitan area. Gilmer uses these specific industries to create a narrative behind each city, but upon closer investigation the realities of which industries occupy which spaces is much more complicated. Oil and gas play a major role in the Texas economy, much more

so than other cities in the United States and significantly more so in Houston. However, Mining, quarrying, and oil and gas extraction as a portion of the total economy of the Texas Triangle decreased from 2001 to 2017 from 3.3% to 2.14%, perhaps demonstrating that the focus on this portion of the economy is overstated.

For the Austin economy, Gilmer characterizes it as Texas' technology center, driven by state investment in the educational system in the University of Texas at Austin. While there are other University of Texas schools throughout the state, UT Austin is the state's premier research university. In 2001, the LQ of the state government was 2.37, and for unknown reasons the state government spending in Austin is undisclosed for 2017. However, in 2001, the LQ supports Gilmer's assertion that the economy of the city is dependent in some capacity on the state government. Furthering Gilmer's claim of the city functioning as a technology hub, Austin has a higher LQ for computer manufacturing than any other city in the Core Triangle. Although, that shrank from an LQ of 5.41 in 2001 to 3.78 in 2017, indicating either that the city is moving away from that industry, or that while Austin was on the cutting edge of computer manufacturing in the early 2000s, and since then other cities in the US have also developed that capacity.

Gilmer describes the Dallas/Fort Worth economy as the principal node that connects the Texas megalopolis to the rest of the country, as both a transportation hub, as well as a finance hub. One major reason for the growth of transportation is the Dallas-Fort Worth Airport, which united the two geographically close but relatively independent cities. DFW has the largest LQ for Air Transportation of any of the cities in the Core Triangle. Amplifying the cities' financial strength is the fact that Dallas is the seat of the branch of the Federal Reserve that serves the Texas Core Triangle. The data indicates that finance today is a bigger part of the economy than it was in 2001.

Houston, according to Gilmer, is the city that connects the Texas Core Triangle to the rest of the world through its port as well as its major airport. The dominant industry in the city is oil, which despite the relatively recent boom of natural gas and fracking in the American market, remains heavily under the influence of international actors, like OPEC. The data supports this narrative, with a great deal of the city's economic activity centering on fossil fuels, as well as transportation. Gilmer also describes the city as a medical hub; however, this study's dataset does not reflect that conclusion, with the LQs of all healthcare related fields under 1.00, and none close to the 1.15 indicated by Gilmer to describe a city as a hub of an industry. Finally, Gilmer lists the Johnson Space Center as a major hub, which certainly builds the narrative that the city connects the megalopolis to the global community, however federal spending is a similar proportion to the economy as the other cities of the Core Triangle, indicating that the Space Center is less important to the city than Gilmer indicates.

Finally, Gilmer designated San Antonio as a connection point between Texas and Mexico, facilitated by NAFTA. In the dataset, transportation is not as important as indicated by Gilmer, except for gas stations. This is likely because San Antonio serves as an early stopping place inside the US as trucks drive into the United States on Interstate 35, towards Dallas-Fort Worth. Gilmer mentions the effects of military spending on the economy briefly. Federal government and military spending are relatively large sections of the economy of San Antonio, more than any other city in the Core Triangle.

Comparing the total locational quotient analysis for Gilmer to that of this study for 2001 demonstrates remarkably similar results; especially given that different datasets are used. In the original study Austin, San Antonio, and Dallas-Fort Worth all demonstrated LQs close to 1.00, indicating that there is proportional representation of major industries in these compared with

others around the United States, and Houston, with a higher LQ, having industries that are less commonly found around the US. This study's calculations demonstrate similar results for Austin and San Antonio, but slightly higher for Dallas/Fort Worth, and significantly higher for Houston. The individual cities do not totally speak to the megalopolis, which requires a comparison between the weighted average of the LQs and the LQ of the sum of the four metropolitan areas. Gilmer's results indicate that the LQs are the same for both weighted average and sum; however, the results of this paper show that the LQ for the sum of the cities is smaller than the weighted average. This result is likely unremarkable, the weighted average would place greater emphasis on larger cities with more unique industries, specifically Houston with petroleum. To assert a positive conclusion for the hypothesis, Gilmer compares the higher variance for the weighted average to the lower variance of the Triangle through an F-test to demonstrate that the decrease in variance is significant, and thus that the cities are functionally integrated. This study then replicates Gilmer's calculations and finds that the variance is lower for the Triangle than for the weighted average.

Using the same techniques for the dataset from 2017 delivers similar results to that of the one from 2001, as shown in Figure 3. Comparing the weighted average to the LQ of the entire Triangle creates an interesting result a sharp decrease, with the LQ of the Triangle of 0.79. It is possible that when the cities are combined, because each city has so effectively incorporated with one another, that the three undeveloped cities for an industry outweigh the developed industry of a single city. The result occurs because each city is taken as a quarter of the whole, rather than as a share proportional to the income or population of the city. Variance once again decreases for the Triangle compared to the weighted average, and this result is statistically significant. This study thus concludes using LQs with the finding, that Gilmer's original results were correct, that the Texas Core Triangle was a functionally economically integrated region in 2001. Additionally,

using a LQ analysis in 2017 demonstrates that the region remains economically integrated, even more so than sixteen years prior.

Geographic Information Systems Results

While the first section of results pertained to replicating Gilmer's study with up-to-date data, this section is original research using Geographic Information Systems. The results will cover each city and the industries for which it demonstrates a high-degree of regional or local agglomeration. First, under each city with the industry it pertains to are proportional symbol maps that indicate where jobs are in the Triangle. Then, a local analysis of industry focused on the city's metropolitan area. Because there were two industries that agglomerated between Austin and San Antonio to an unusual degree, the combined cities will have their own section after the individual cities. The first map in the appendix Figure 7 is a distribution of where employees work, and their total distribution throughout the region.

Houston

The city of Houston serves several functions for the Texas Core Triangle, most notably for mining, oil, and gas, but also for professional, scientific, and technical services employment, management, and health care and social assistance. Houston is the largest city on its own in the Core Triangle but decreases to second largest when considering Dallas-Fort Worth as a single city. While oil and gas employment are intuitive, regional agglomeration for health care and social assistance appears strange. While primarily referring to Houston for each of these industries, for the portions covering the regional map include commentary on distributions throughout the region.

Figure 8 establishes that the city of Houston dominates the region for mining, oil, and gas employment. There are several larger clusters west of Fort Worth and south of San Antonio, both places on the triangle oriented away from Houston, although this could be a geographic quirk.

Comparing total employment to this industry, the starkest contrast occurs around Dallas, where there is limited employment in mining, oil, and gas. Austin and San Antonio also have less employment in this industry, but the contrast is most visible around Dallas, which indicates that for this industry the region is economically integrated. Figure 9 takes a closer look at the city of Houston, revealing the industry's employment centers. In this case, companies for this industry do not agglomerate around the Central Business District, but instead around the periphery of the city. The area around the Energy Corridor is the most obvious example of this phenomenon. This result conclusively establishes that micro-agglomeration is occurring in the city of Houston for the mining, oil, and gas industry.

Professional, scientific, and technical services, Figure 10, is a very broad category that covers highly skilled employees like engineers and lawyers. Because of its broad definition, it is more difficult to make conclusions about agglomeration. The major outlier of the cities is San Antonio. Even though the city has several other industries, like finance and insurance that would presumably pair well with employees that fall under this category, like lawyers and accountants, there is not proportional representation of this employment sector. There is strong representation for the city of Austin; however, it is difficult to understand the basis for employment because the category is large. Figure 11 takes a closer look at the city of Houston. There is an agglomeration approximately along Houston's Energy Corridor, and while there are other groupings, it is difficult to determine agglomeration for workers in such a varied category. Law firms will likely agglomerate close together, as will architects, and accounts, however because the data is combined, determining if such local agglomerations are occurring is impossible without refined categories.

Employees of businesses that derive value through the ownership of securities or other businesses are the management of companies and enterprises sector, shown in Figure 12. Houston

is the largest center of this sector in the Texas Core Triangle. Neither San Antonio nor Austin features much business. Dallas, especially reaching towards North Dallas, does have some representation in this industry, but not to the same degree as Houston. This result indicates that Houston serves the rest of the Core Triangle in various capacities, meaning that regionally, for the management of companies and enterprises, there is functional integration. Management services are a key part of the economy of Houston as indicated by Figure 13 and by Gilmer. There are major agglomerations in southwest Houston, along the Energy Corridor, and north, around the Greenspoint Mall, although other smaller agglomerations exist. This information indicates that micro-agglomeration is occurring in certain areas around Houston; however, the reason behind the greater distributions of the micro-agglomerations is unknown.

Due to the necessity of immediate care, a valid assumption about health care might be that it would not agglomerate. However, the distribution of health care and social assistance, Figure 14, indicates a high degree of regional agglomeration. The regional map includes that Houston is the major center of this agglomeration, but it is unknown if Houston is effectively serving the health care needs of the other cities of the Core Triangle. Looking closer at the city of Houston, Figure 15, employees are quite scattered across the city. In certain cities, there are clusters of medical activity, although these often occur because of government funding for hospitals rather than explicit need for agglomeration. There is good reason, however, for micro-agglomeration to occur, as a health care professional can quickly refer a patient to another hospital. The Texas Medical Center, located southwest of downtown, is visible on the map; however, the data mapped in Figure 15 does not indicate that it is a major employer in comparison to other clusters around the greater Houston area, including to the north and the northeast.

While there are characteristics that make the other cities a global city, like the Dallas-Fort Worth International Airport, the city that certainly connects the Texas Core Triangle to the greater, international community is most certainly Houston. While other oil and gas agglomerations exist within the Core Triangle, the GIS analysis indicates that these agglomerations occur in areas geographically distant from or oriented away from the city of Houston. For professional, scientific, and technical services, as well as management services, although these are broad categories, agglomerations are occurring on the metropolitan level to service the primary internationally oriented industry, oil and gas. While this study expected micro-agglomerations for health care services, the regional agglomeration that occurred around Houston is perhaps the most surprising result of this research. To understand why the result occurred, future research might focus on a case study analysis of the health care industry for this city.

Dallas-Fort Worth

Until the construction of the Dallas-Fort Worth Airport, the two cities functioned independently of one another. After the construction of the airport between the two cities they began to grow closer together, although the growth was oriented toward the airport rather than one another. At the same time as the creation of the airport, the cities created a regional authority that introduced the term Metroplex to develop the identity of the region. This study has assigned more industries to Dallas-Fort Worth than the other cities in the Core Triangle, because even when agglomeration trends were not clear, the region has greater employment for those industries than the other cities. The industries detailed are construction, manufacturing, wholesale trade, transportation and warehousing, and real estate.

Construction employment refers to offices of construction companies rather than ongoing work sites. Figure 16 shows this industry for the Core Triangle. Dallas, especially North Dallas

extending through Flower Mound and to Denton has the highest concentration of construction firms. The proportion of firms in Dallas indicates that there is a reasonable capacity of functional integration for construction, with these firms serving the other cities. Houston has a smaller number and wider distribution of construction firms, particularly south, towards the coast. Gilmer described Houston as a city oriented towards the rest of the world, and the location of construction firms as represented by the number of people they employ complies with this narrative. This coastal grouping of construction firms is more remote relative to Dallas than any other part of the Triangle, and this grouping likely helps serve other cities on the Gulf Coast. Figure 17 shows a close view of the construction industry in Dallas-Fort Worth. One main agglomeration occurs, in Irving between downtown Dallas and the airport. However, other than this large cluster, there are no major agglomerations. There are trends, such as a grouping running along Interstate 35 West north of Fort Worth; however, the map does not depict this area as a significant cluster but rather an area with above-average density. In contrast to Figure 7, which has the proportional representation dot extend to encompass Denton, there are no major clusters that extend far north upon closer inspection. Given the dispersion of businesses and employees around the Metroplex, and despite the agglomeration that is occurring in Irving, Figure 17 indicates that the construction industry is not agglomerating on a micro-scale. Intuitively, construction industries will locate closer to construction sites and the firms that they serve. However, firms in other industries are not constantly in need of a construction firm. Using this information, the research indicates that there is no agglomeration in the construction industry for the Texas Core Triangle, nor would firms gain any major advantage by heavily concentrating in a single city.

Generally, in the case of manufacturing, businesses do not benefit from agglomeration given that the industry often requires a great deal of square footage. As shown in Figure 18,

manufacturing is occurring not only on the urban peripheries, but also along the infrastructural corridors between the cities, such as in Waco and Temple. Manufacturing firms locate in these locations to minimize real estate costs while locating as close as possible to employees and customers. Gilmer identified Austin as a location for electronics manufacturing. While Austin when compared to the total employment map has an outsized influence, the city falls short of the Metroplex, which demonstrates a very high degree of local agglomeration. Figure 19 looks at the Dallas-Fort Worth Metroplex to take a closer view at the western growth encompassing Fort Worth. The agglomeration in Dallas begins with the Design District and extends north and west towards the airport. South of the Dallas-Fort Worth airport is agglomeration in Arlington, set up likely to serve nearby customers in Dallas and Fort Worth, and benefitting from the airport. Finally, south of Fort Worth, manufacturers agglomerate on the eastern side of Interstate 35 West. These instances of micro-agglomeration confirm, at least for manufacturing, that the Metroplex in addition to the entirety of the Texas Core Triangle is functionally integrated.

Wholesale trade refers to business-to-business transaction, where the products are non-retail goods, shown in Figure 20 for the Core Triangle. While Dallas is the largest center of wholesale trade, there is a notable grouping in and north of Austin, as well to the west of Houston. The grouping north of Austin is interesting due to its size in relation to Dallas, which seems to serve the entire region for this industry. Figure 21 focuses on Dallas because of the size of the regional agglomeration, but also because Gilmer identified this category as one of the integrated industries within the Core Triangle based in Dallas-Fort Worth. There are several groupings, but the strongest agglomeration occurs from downtown towards Northwest Dallas, extending to Farmers Branch. The World Trade Center is a major wholesale location: to enter the upper levels a consumer must be a verified, professional buyer. Both wholesale vendors and consumers benefit

from agglomeration in this industry. Thus, perhaps what is most interesting about this map is the lack of agglomeration that occurs, at least as indicated by sector employment. There are other groups of clusters in and around independent municipalities, such as both north and south of Fort Worth, in Arlington south of the airport, and east of downtown towards Mesquite. However, none of them represents larger agglomerations. In this case, while the Core Triangle distribution indicates that agglomeration occurs, micro-agglomeration is not occurring to a high degree.

When referring to businesses that move people as well as goods and materials around from place to place, the NAICS employment code pertaining to that employment is transportation and warehousing, shown in Figure 22. Dallas is quite obviously the regional hub for transportation and warehousing in and out of the region. Houston has a limited presence, likely due to the airports and access to the ocean. Relatively, Dallas-Fort Worth and Houston service both Austin and San Antonio for their transportation and warehousing needs. In most cases, they have local transportation and warehousing infrastructure, but are dependent on the Metroplex for connecting flights in the case of transportation, and deliveries from the much larger warehouses in North Texas. Given that the major center of employment for transportation and warehousing is in Dallas-Fort Worth, Figure 23 centers on this region. The central point of the map is the Dallas-Fort Worth Airport, which employs slightly more than eight percent of the total transportation and warehousing employees in the Core Triangle. The density of that single region distorts the levels of employment around the airport, which are all quite high for this industry. The regions immediately around Dallas extending towards Irving employ approximately five percent of all industry employees for the Core Triangle. While typically not much business occurs in south and southeast Dallas, there are smaller industry clusters located in these areas. These are probably

newer developments that intend to supply downtown and surrounding areas while avoiding higher real estate costs.

Looking at the Texas Core Triangle and real estate employment, Figure 24, regional agglomeration does not appear to occur. This result is because most relators develop personal relationships with the clients and customers, and require frequent interaction, which would not be conducive to agglomeration on a regional scale. The proportional representations for employment ratios for real estate are approximate to those for population. While regional agglomeration does not occur, micro-agglomeration is occurring, as shown in Figure 25, focused on Dallas. There are several dense agglomerations, all near one another. Because real estate is not commonly bought or sold for most consumers, sellers are willing to shop around for the best realtor to market their home, and buyers might speak to many different realtors about the properties they have listed before settling on a single property. Because of these factors, it makes a great deal of sense for micro-agglomerations to occur for real estate. There are agglomerations stretching from downtown Dallas to around the airport, and two other hotspots in northern Dallas. There are no major agglomerations of real estate employment in or around Fort Worth, likely because the market is smaller, with realtors showing properties in Southlake closer to Dallas and the airport rather than in Fort Worth.

Dallas was founded as a city by a natural ford on the Trinity River. Many future residents of Texas would pass through the city and cross this ford as they made their way further into the state. The city has grown, so much so that it subsumed another city, Fort Worth, originally a military base about a day's horseback ride from Dallas. Later, Dallas, although primarily Fort Worth served as key stopping points for cowboys moving northward, taking cattle from the south of Texas towards rail lines connected to Chicago and the east coast of the United States. Despite

the growth in a huge number of industries, the region of Dallas-Fort Worth retains its original character of connecting Texas to the United States, through industries like transportation and wholesale trade.

Austin

Austin is the state capital for the state of Texas that runs along the Balcones Escarpment between Dallas-Fort Worth and San Antonio. The city is famous for its unique culture and for festivals including Austin City Limits (ACL) and South by Southwest (SXSW). The University of Texas at Austin is a very large and prestigious research university located in Austin responsible for educating tens of thousands of undergraduate and graduate students. The university helps cultivate the vibrant culture of the city. Some companies based in Silicon Valley, including Facebook, Apple, and Google have offices in Austin, going so far as to gain the nickname the 'Silicon Hills.'

Figure 26, showing educational services, include schoolteachers to university professors. Because this includes all public-school teachers, areas with greater populations and population density will have a higher percentage of the total workforce. In Dallas-Fort Worth, there is a clear disparity between the two cities, likely the result of the University of Texas at Dallas in the north. For the first time in these representations, there is representation for College Station at the same levels as the cities of the Triangle. Houston appears to have the most educational service employees, likely driven by the University of Houston. Figure 27 focuses on Austin. It is very clear that the university is responsible for the ratio of education service employees represented in Figure 27 due to the very high density on the campus. In this case, these groups are not a result of agglomeration, but exist in these locations due to funding for educational centers.

Public administration, Figure 28, refers to employees at all levels of government, including local, state, and federal. Houston has the most public administration employees, because in addition to all the government bureaucrats in every city, Houston is also home to NASA at the Johnson Space Center. One interesting feature of the map is the cluster north of Houston on Huntsville, the location of the Texas State Penitentiary. Once again, in this case it is disingenuous to declare that agglomeration is ongoing at these locations, because they are not subject to market forces and pressures. The metropolitan analysis, Figure 29, focuses on Austin. This map is included only as a point of reference.

Austin is the capital of Texas and the seat of the state's most prestigious research university, the fact that the city has a large concentration of educational services as well as public sector employees is unsurprising. The city has benefited enormously from the presence of the university, such as with the countercultural spirit that permeates the city. While this study did not produce results that indicated higher degrees of micro-agglomerations for Austin in the information and manufacturing industries, the city is certainly more oriented towards another major hub of counterculture and technological innovation, the Silicon Valley, than any other city in Texas. Future research might focus on a case study analysis of the city and the university, and if enrollment numbers for certain majors might correlate to technology startups like Facebook opening offices in the city.

San Antonio

San Antonio is the third largest metropolitan area in Texas and is an extremely dynamic city, featuring the historic Alamo, the downtown River Walk, several major corporate headquarters including USAA, and several major military instillations. San Antonio hosted the corporate headquarters for AT&T until 2008. The city serves as a major stopping point for trucks heading

north into the United States from Mexico. While the city has always had the closest connection to Mexico compared to the other cities of the Core Triangle, the trade facilitated by NAFTA has boosted the economy of the city.

The information industry, Figure 30, includes employment related to the distribution of information, such as telecommunications and the Internet. In this case, it appears that Houston may in fact have the lowest ratio of employment compared to any of the other municipalities in the Core Triangle. Dallas is home to AT&T, Austin the Silicon Hills. There is less recognition for San Antonio than the other two cities for their information and technology presence, however, the city benefits from the presence of a National Security Agency facility. While the information field does not count NSA employees, it is probable that employees working in this facility will begin their own projects, likely related to cybersecurity and hacking. One issue with the NAICS codes is how they encompass many different types of employees. For information, each of these cities has their own information subcategory, Dallas-Fort Worth for telecommunications, Austin for start-ups, and San Antonio for cybersecurity.

Although Dallas has the highest percentage of all information workers in the Core Triangle, Figure 31 – the municipal map for information – centers on San Antonio because Gilmer identified information as a key industry in San Antonio, and the patterns of micro-agglomeration are very interesting. The largest agglomeration on the metropolitan map centers on Lackland Air Force Base, to the west and southwest of downtown. The most likely explanation of why the agglomeration exists is that the base needs many independent information contractors, and as a result, businesses that exclusively or principally serve the base agglomerate around this location. Another explanation is that the property values around the base are cheaper than around other areas closer to downtown San Antonio where better transportation infrastructure is located, and

information technology firms are taking advantage of these costs to open call centers. There are other agglomerations in the city, which indicates that firms, which are less likely to serve military functions, are agglomerating elsewhere.

Finance and insurance, in Figure 32, certainly indicates a high degree of regional agglomeration and functional integration, centered on San Antonio. Based solely on the proportional representations of the distributions, it appears as if roughly half of the Texas Core Triangle's finance and insurance employees work in San Antonio. Finance and insurance are an industry that because it depends in large part on personal relationships with clients and competitors, tends to agglomerate aggressively. However, when taking a closer look at San Antonio, in Figure 33, the results are for whatever reason, very confusing. The hot spot north of downtown is a corporate office of JP Morgan Chase. Missing in Figure 33 are the corporate campuses that are east of downtown, including Capital Group, The Hartford, Aetna, and Chase Bank. North of downtown is the corporate headquarters for USAA, also absent on Figure 33. The reason for this technical difficulty is unknown; there was no issue representing the total figures for the entire Core Triangle. The corporate campuses in this case serve as a local command center for these businesses from which to communicate with local branches in the other Core Triangle cities. This means that regional agglomeration is occurring for this industry. Despite the issue with Figure 33, it is very clear that micro-agglomeration is occurring for finance and insurance in San Antonio.

While San Antonio is smaller than Dallas-Fort Worth and Houston, the city has an outsized impact on the industries of the Core Triangle, principally finance and insurance. Due to the presence of the Federal Reserve branch, the financial hub of the Core Triangle should seem to be Dallas. However, the military aspect of San Antonio has led to agglomerations for this industry, because of USAA's headquarters. Other finance and insurance firms take advantage of the

presence of the skilled workforce, as well as firms that serve the financial services giant. Unfortunately, the metropolitan analysis of the city was inconclusive for finance and insurance, however based on the locations of firms in and around San Antonio, it is evident that firms are agglomerating at a local scale to serve the Texas Core Triangle. Additionally, the presence of the military as well as the NSA created the space for information services firms to open and operate to serve the greater Core Triangle. San Antonio has historically been oriented towards Mexico and Latin America, and the city will likely benefit more so than any other city in the Triangle because of increased militarization of the southern border.

San Antonio/Austin

Perhaps indicative of a growing economic integration between the two cities, two categories, retail trade and accommodation and food services encompassed both Austin and San Antonio, especially the area between the two cities. While either of the cities might feature these industries, this research paper includes the metropolitan area of both cities on a local scale, because the growth of agglomerations is perhaps indicative of a larger trend, whereby the spaces between the cities of the Core Triangle are progressively urbanizing.

The wide and varied distribution of retail trade employment in Figure 34 is indicative of an industry that does not necessarily agglomerate. Based upon employment, while there is certainly a greater concentration around population masses, there are also quite noticeable larger clusters in rural areas. Because consumers are usually not willing to travel very far for retail goods, firms locate accordingly to provide convenient access. Figure 35 closes in on San Antonio and Austin, specifically on the area between them New Braunfels and San Marcos. Amongst the four cities there are three population groups, one centered on northern San Antonio, one approximately located between New Braunfels and San Marcos, and the third in northern Austin. San Antonio's

cluster appears to center on the North Star Mall, undoubtedly a large source of employment, and extend away from there. The area just south of San Marcos features multiple large box stores, in addition to an outlet mall. Due to the age of the data, now four years old, the cluster that appears in northern Austin is no longer a major source of retail employment. At that location, which was formerly the Highland Mall, Austin Community College has opened a campus. While online retailers had a large amount of power in 2015, continued pressure from online retailers like Amazon, which now has a distribution center south of San Marcos, has forced many brick-and-mortar retailers and malls out of business.

There are large groups in both San Antonio and Austin in accommodation and food services employment, Figure 36. This sector includes lodgings like hotels, as well as restaurants. In this case, the distributions around Dallas-Fort Worth and Houston are small in comparison to those around San Antonio and Austin. Taking a closer look at this region in Figure 37 does not provide a great deal of insight. There are significant concentrations around downtown San Antonio, due to the River Walk, as well as north of the city, closer to the airport. While the tourism industry never had a clear showing in San Antonio, as per Gilmer's analysis, there is clearly a route between San Antonio and Austin along I-35. This result further confirms an earlier conclusion of this paper that the city serves as a stopping point along the drive north from Mexico towards Dallas. In Austin, most jobs are downtown, with offshoots that branch off west and north.

While San Antonio will benefit from growing military expenditures and hostility towards Mexico, the region connecting San Antonio to Austin along I-35 will likely lose out more than any other region. The study *The New Metropolis: Rethinking Megalopolis* by Lang and Knox identified the two cities as growing towards a state of economic integration, like Dallas and Fort Worth. While the two cities will likely continue to grow closer together regardless of changes to

international trade deals, instability in the relationship between Mexico and the United States due to immigration and the militarization of the border will slow the growth of agglomerations between the two cities.

Conclusion

The results of this study confirm the hypothesis that the Texas Core Triangle forms an economically integrated region, and that the whole is greater than the sum of its parts. Businesses are locating intentionally in certain cities of the Core Triangle to agglomerate together and serve the greater region, such as transportation and warehousing in Dallas-Fort Worth or finance and insurance in San Antonio. By increasing the geographic distribution of these agglomerations, the cities of the Core Triangle will not experience inflated real estate costs to the degree that would otherwise occur in a unified metropolitan area with a high degree of agglomeration, like New York City. This analysis considers scale on regional and local levels and confirms the wider literature about industry agglomeration at both levels. While much of the previous research has advocated for increased transportation links, specifically a high-speed rail network, between the cities of the Core Triangle for greater economic integration and wealth creation, this research cannot make that assertion. By observing agglomerations between the cities of the Core Triangle rather than just the cities themselves, advocates for a high-speed rail network should consider a stakeholder analysis for their proposition. By unifying the four largest cities of the Core Triangle, planners are implicitly passing by smaller municipalities that benefit from the interstate highway system. While these roads would remain in use, the decreased traffic will have several effects. It would allow the construction of homes further away from major cities, but it would decrease the economic prosperity of the smaller cities, like Waco or San Marcos. The residents of these cities, as landowners, are major stakeholders in the construction of a high-speed rail network, which would

decrease the value of their real estate because of lessened highway traffic. Future research topics might contend with other proposed megalopolitan regions from the literature, to determine if their economic integration is greater than or less than that of the Core Triangle.

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Appendix

Figure 1

$$LQ_{ij} = \frac{\text{percent share of income earned in industry } i \text{ in city } j}{\text{percent share of income earned in industry } i \text{ in the United States}}$$

(Source: "The Simple Economics of the Texas Core Triangle" Gilmer, 2004)

Figure 2

Economic Characteristics of Texas Triangle Cities, 2001* **				
	Population (millions)	Employment (millions)	Personal Income (billions)	Per Capita
Texas	21.37	10.06	608.5	28,472
Triangle Cities	13.18	6.81	433.4	32,897
Austin	1.32	0.71	41.7	33,247
Dallas/Fort Worth	5.42	2.91	180.1	31,511
Houston	4.81	2.39	168.0	34,916
San Antonio	1.63	0.80	43.7	26,887
Variance Change Among Location Quotients in the Texas Triangle * **				
	Average LQ	Variance	Share	
Austin	0.79	0.45	0.09	
San Antonio	0.99	0.55	0.10	
Dallas/Fort Worth	0.98	0.48	0.43	
Houston	1.26	3.59	0.38	
Weighted Average	1.07	1.67		
Triangle Combined	1.07	0.92		
* Numbers only computed in the original table through 2 decimal points				
** Calculations are not reflected, only data presented in original table				

Figure 3

Economic Characteristics of Texas Triangle Cities, 2001*

	Population	Employment	Personal Income (millions)	Per Capita
Texas	21,319,622	12,284,685	625,351.8	29,332
Triangle Cities **	13,263,667	8,220,391	443,206.3	32,744
Austin	1,321,316	863,762	46,276.7	35,023
Dallas/Fort Worth	5,376,413	3,485,148	183,847.6	34,195
Houston	4,817,815	2,877,532	164,765.8	34,119
San Antonio	1,748,123	993,949	48,316.2	27,639

Economic Characteristics of Texas Triangle Cities, 2017 *

	Population	Employment	Personal Income (millions)	Per Capita
Texas	28,322,717	16,962,938	1,340,569.4	47,332
Triangle Cities **	18,881,890	11,890,937	982,659.9	51,346
Austin	2,115,827	1,422,990	115,982.3	54,817
Dallas/Fort Worth	7,399,662	4,947,059	392,145.5	52,995
Houston	6,892,427	4,084,715	363,677.1	52,765
San Antonio	2,473,974	1,436,173	110,855.0	44,808

Variance Change Among Location Quotients in the Texas Triangle 2001

	Average LQ	Variance	Share ***
Austin	0.97	0.45	0.10
San Antonio	1.01	0.55	0.11
Dallas/Fort Worth	1.15	0.66	0.41
Houston	1.70	14.07	0.37
Weighted Average	1.32	5.61	
Triangle Combined	1.11	2.19	

Variance Change Among Location Quotients in the Texas Triangle 2017

	Average LQ	Variance	Share ***
Austin	0.96	0.79	0.12
San Antonio	0.96	1.07	0.11
Dallas/Fort Worth	1.05	0.42	0.40
Houston	1.42	4.65	0.37
Weighted Average	1.17	2.10	
Triangle Combined	0.79	0.93	

* In this table, data collected in April 2019 is presented

** Numbers obtained for Triangle Cities by summing the four groups, origins for Gilmer's totals unknown

*** What data Gilmer used to obtained the percent share is unknown, this project uses personal income for each city divided by the personal income sum for the Triangle Cities

Figure 4

Table 2

Export Sectors in Texas Triangle Cities as Indicated by Location Quotients

Austin. Industrial machinery and equipment (3.69); electronic and other electrical equipment (3.32); communications (1.17); wholesale trade (2.08); business services (1.47); state government (2.27).

Dallas/Fort Worth Metroplex. Oil and gas extraction (4.82); electronic and other electrical equipment (2.47); trucking and warehousing (1.17); transportation by air (2.49); transportation services (2.12); communications (1.82); wholesale trade (1.47); home furniture and furnishings stores (1.38); depository and nondepository institutions (1.16); insurance agents, brokers and services (1.16); real estate (1.54); holding and other investment offices (1.16); business services (1.35); miscellaneous services (1.37).

Houston. Oil and gas extraction (13.81); heavy construction (3.03); industrial machinery and equipment (1.26); chemicals and allied products (2.43); petroleum and coal products (4.97); water transportation (3.38); transportation by air (1.40); pipelines, except natural gas (6.78); transportation services (3.32); electric, gas and sanitary services (3.69); real estate (1.27); holding and other investment offices (2.10); miscellaneous repair services (1.58); legal services (1.34); engineering and management services (1.40).

San Antonio. Oil and gas extraction (1.30); general building contractors (1.16); heavy construction (1.18); miscellaneous manufacturing (1.18); transportation services (2.85); communications (1.96); electric, gas and sanitary services (3.13); general merchandise stores (1.19); food stores (1.29); auto dealers and service stations (1.28); eating and drinking places (1.35); miscellaneous retail (1.18); insurance carriers (2.35); holding and other investment offices (1.72); private households (1.28); auto repair, services and parking (1.19); federal civilian (1.84); military (4.70); local government (1.16).

NOTE: Location quotients are shown in parentheses; only LQs greater than 1.15 are shown.

SOURCE: Author's calculations.

(Source: "The Simple Economics of the Texas Core Triangle" Gilmer, 2004)

Figure 5

Export Sectors in Texas Triangle Cities as Indicated by Location Quotients 2001

Austin. Mining, quarrying, and oil and gas extraction (1.28); Oil and gas extraction (1.39); Construction (1.80); Construction of buildings (1.73); Heavy and civil engineering construction (1.18); Specialty trade contractors (1.96); Manufacturing (1.35); Durable goods manufacturing (1.88); Nonmetallic mineral product manufacturing (1.34); Machinery manufacturing (1.20); Computer and electronic product manufacturing (5.41); Miscellaneous manufacturing (1.91); Wholesale trade (1.94); Motor vehicle and parts dealers (1.20); Furniture and home furnishings stores (1.48); Gasoline stations (1.31); Nonstore retailers (1.61); Information (1.15); Publishing industries (except Internet) (1.74); Data processing, hosting, and related services (1.29); Real estate and rental and leasing (1.16); Real estate (1.34); Professional, scientific, and technical services (1.39); Religious, grantmaking, civic, professional, and similar organizations (1.25); Private households (1.15); State and local (1.32); State government (2.37).

Dallas/Fort Worth Metroplex. Mining, quarrying, and oil and gas extraction (4.50); Oil and gas extraction (6.39); Construction (1.24); Construction of buildings (1.17); Specialty trade contractors (1.29); Manufacturing (1.22); Durable goods manufacturing (1.37); Nonmetallic mineral product manufacturing (1.25); Computer and electronic product manufacturing (2.21); Miscellaneous manufacturing (1.46); Food manufacturing (1.16); Printing and related support activities (1.28); Wholesale trade (1.54); Motor vehicle and parts dealers (1.17); Furniture and home furnishings stores (1.25); Electronics and appliance stores (1.82); General merchandise stores (1.50); Transportation and warehousing (1.51); Air transportation (3.73); Rail transportation (1.45); Information (1.51); Telecommunications (2.29); Data processing, hosting, and related services (2.51); Credit intermediation and related activities (1.54); Insurance carriers and related activities (1.38); Professional, scientific, and technical services (1.23); Administrative and support and waste management and remediation services (1.33); Administrative and support services (1.35); Accommodation and food services (1.19); Food services and drinking places (1.29); Repair and maintenance (1.18).

Houston. Mining, quarrying, and oil and gas extraction (9.82); Oil and gas extraction (10.42); Support activities for mining (15.24); Utilities (3.35); Construction (1.55): Construction of buildings (1.93); Heavy and civil engineering construction (1.99); Specialty trade contractors (1.30); Fabricated metal product manufacturing (1.61); Machinery manufacturing (1.66); Nondurable goods manufacturing (1.55); Petroleum and coal products manufacturing (6.99); Chemical manufacturing (2.63); Transportation and warehousing (3.31); Air transportation (2.14); Water transportation (4.97); Truck transportation (1.77); Pipeline transportation (31.92); Support activities for transportation (3.01); Professional, scientific, and technical services (1.38); Administrative and support and waste management and remediation services (1.16); Administrative and support services (1.15); Waste management and remediation services (1.27); Repair and maintenance (1.15); Private households (1.15).

San Antonio. Mining, quarrying, and oil and gas extraction (2.26); Oil and gas extraction (2.65); Construction of buildings (1.21); Retail trade (1.17); Motor vehicle and parts dealers (1.36); Gasoline stations (1.22); Nonstore retailers (1.94); Pipeline transportation (5.67); Telecommunications (1.86); Other information services (1.31); Credit intermediation and related activities (1.16); Insurance carriers and related activities (1.99); Accommodation and food services (1.45); Food services and drinking places (1.56); Government and government enterprises (1.33); Federal civilian (1.61); Military (4.52); Local government (1.16).

Figure 6

Export Sectors in Texas Triangle Cities as Indicated by Location Quotients 2017

Austin. Mining, quarrying, and oil and gas extraction (3.98); Oil and gas extraction (5.97); Construction (1.50); Construction of buildings (1.63); Heavy and civil engineering construction (1.52); Specialty trade contractors (1.44); Durable goods manufacturing (1.27);Computer and electronic product manufacturing (3.78);Wholesale trade (1.50); Motor vehicle and parts dealers (1.18); Data processing, hosting, and related services (2.31); Funds, trusts, and other financial vehicles (2.61); Lessors of nonfinancial intangible assets (except copyrighted works) (1.42); Administrative and support services (1.16); Accommodation and food services (1.26); Food services and drinking places (1.35); Religious, grantmaking, civic, professional, and similar organizations (1.24); State and local (1.21).

Dallas/Fort Worth Metroplex. Oil and gas extraction (3.81); Support activities for mining (1.87); Construction (1.35); Specialty trade contractors (1.30); Durable goods manufacturing (1.26); Computer and electronic product manufacturing (1.85); Furniture and related product manufacturing (1.32); Leather and allied product manufacturing (1.28); Furniture and home furnishings stores (1.19); Gasoline stations (1.18); Transportation and warehousing (1.45); Air transportation (2.94); Pipeline transportation (1.27); Couriers and messengers (1.16); Warehousing and storage (1.54); Data processing, hosting, and related services (1.72); Finance and insurance (1.29); Insurance carriers and related activities (1.30); Real estate and rental and leasing (1.23); Real estate (1.22); Rental and leasing services (1.15); Lessors of nonfinancial intangible assets (except copyrighted works) (3.47); Administrative and support and waste management and remediation services (1.40); Ambulatory health care services (1.20); Food services and drinking places (1.19).

Houston. Mining, quarrying, and oil and gas extraction (9.51); Oil and gas extraction (10.11); Construction (1.66); Construction of buildings (1.96); Heavy and civil engineering construction (2.64); Specialty trade contractors (1.32); Nonmetallic mineral product manufacturing (1.57); Fabricated metal product manufacturing (1.80); Nondurable goods manufacturing (1.49); Petroleum and coal products manufacturing (6.23); Chemical manufacturing (2.56); Wholesale trade (1.37); Motor vehicle and parts dealers (1.23); Air transportation (2.05); Truck transportation (1.83); Pipeline transportation (14.09); Support activities for transportation (2.55); Rental and leasing services (1.35); Lessors of nonfinancial intangible assets (except copyrighted works) (1.40); Professional, scientific, and technical services (1.15); Management of companies and enterprises (1.16); Administrative and support and waste management and remediation services (1.20); Repair and maintenance (1.28).

San Antonio. Oil and gas extraction (8.74); Support activities for mining (1.87); Construction (1.23); Construction of buildings (1.41); Heavy and civil engineering construction (1.30); Nonmetallic mineral product manufacturing (1.26); Motor vehicles, bodies and trailers, and parts manufacturing (2.04); Motor vehicle and parts dealers (1.44); Gasoline stations (1.25); General merchandise stores (1.24); Pipeline transportation (3.57); Warehousing and storage (1.25); Data processing, hosting, and related services (2.51); Finance and insurance (1.22); Credit intermediation and related activities (1.16); Rental and leasing services (1.26); Accommodation and food services (1.20); Food services and drinking places (1.26); Government and government enterprises (1.31); Federal civilian (1.70); Military (3.76).

Figure 7

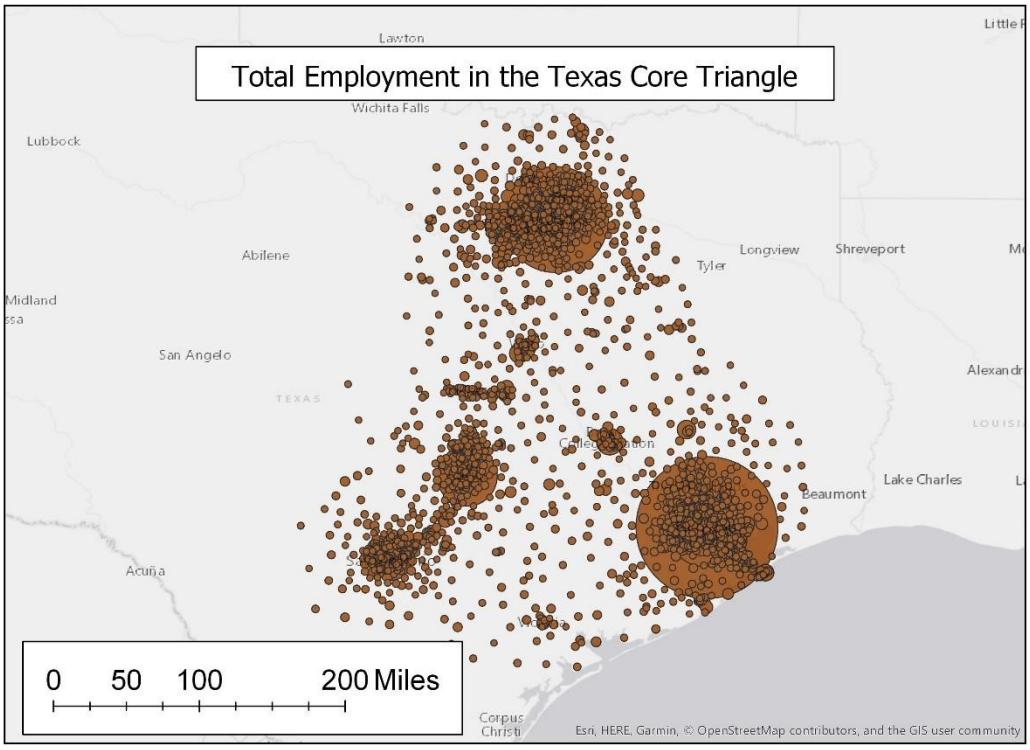

Total Employment in the Texas Core Triangle
Lawton
Wichita Falls
Lubbock
Abilene
Midland
San Angelo
Longview
Tyler
Shreveport
Lake Charles
Beaumont
Acuña
Corpus Christi
0 50 100 200 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 8

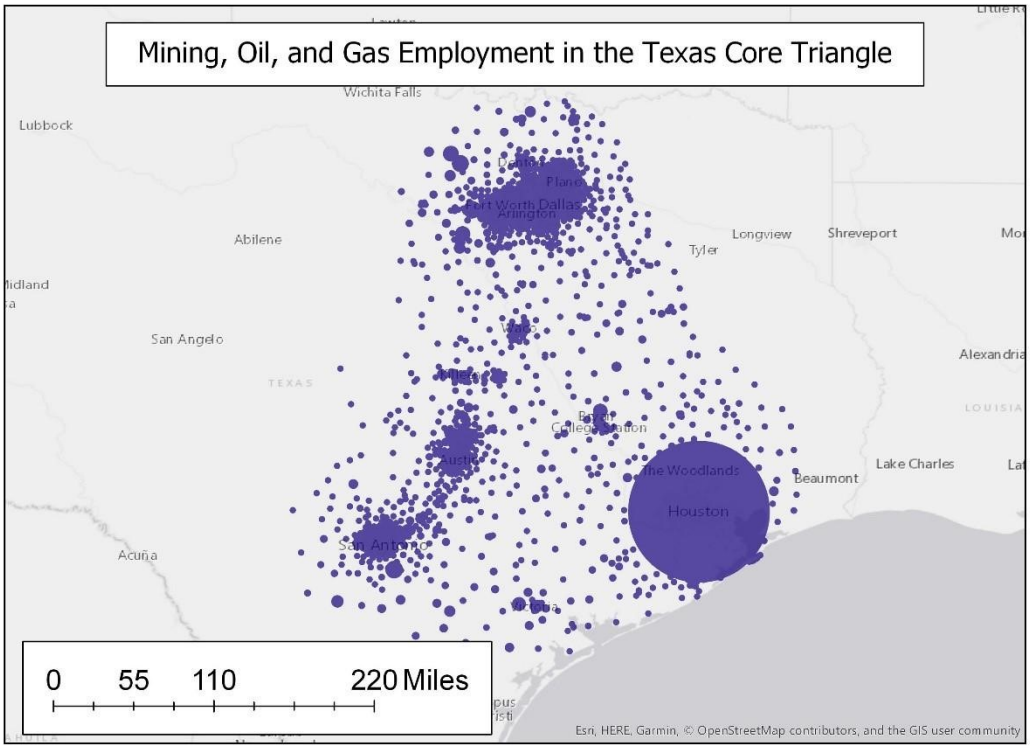

Mining, Oil, and Gas Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Abilene
Longview
Shreveport
Tyler
San Angelo
Alexandria
TEXAS
Lake Charles
Beaumont
The Woodlands
Houston
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 9

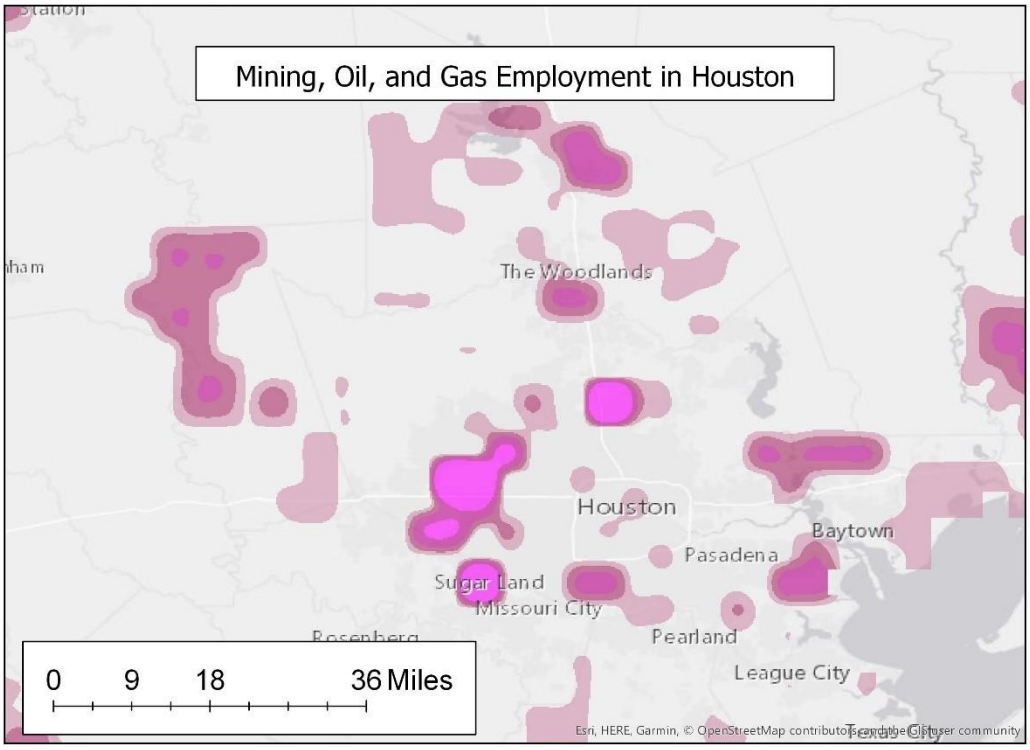

Mining, Oil, and Gas Employment in Houston
The Woodlands
Houston
Baytown
Pasadena
Sugar Land
Missouri City
Pearland
League City
0 9 18 36 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 10

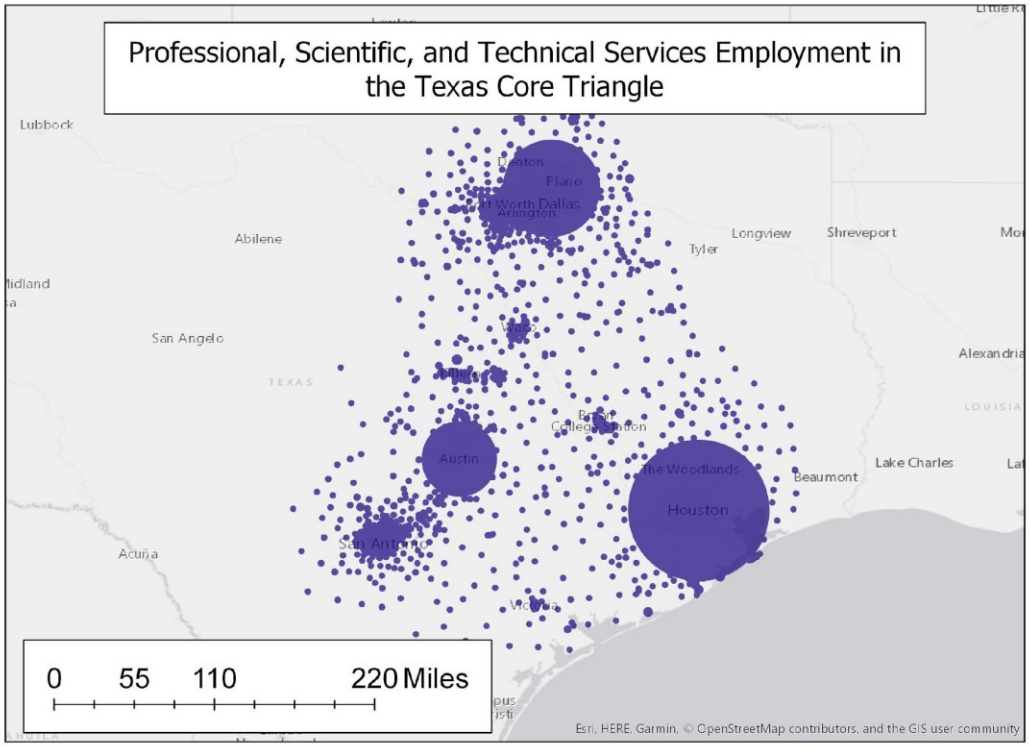

Professional, Scientific, and Technical Services Employment in the Texas Core Triangle
Lubbock
Abilene
San Angelo
Longview
Shreveport
Tyler
Alexandria
Lake Charles
Beaumont
Austin
The Woodlands
Houston
Acuña
TEXAS
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 11

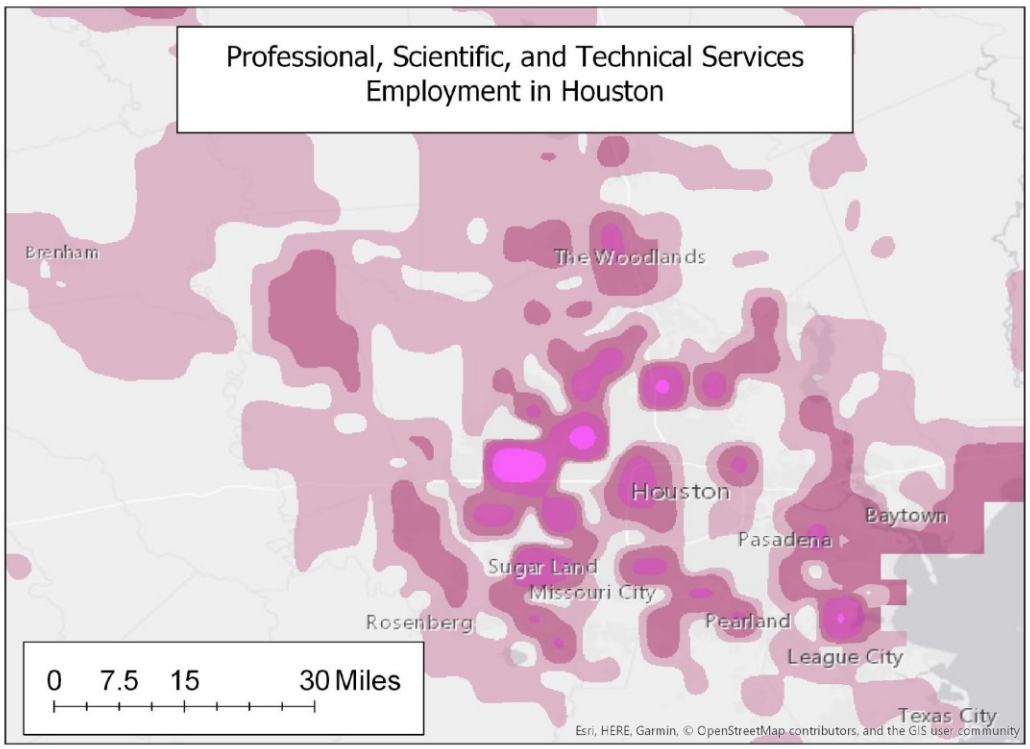

Professional, Scientific, and Technical Services Employment in Houston
Brenham
The Woodlands
Houston
Baytown
Pasadena
Sugar Land
Missouri City
Rosenberg
Pearland
League City
Texas City
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 12

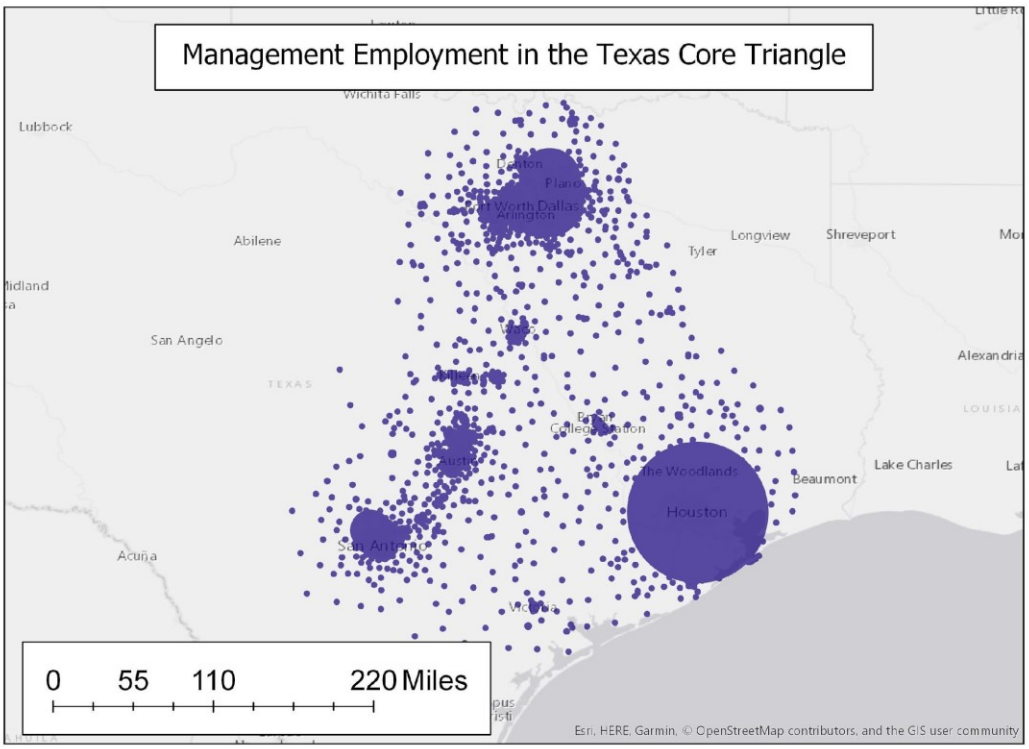

Management Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Alexandria
Lake Charles
Beaumont
The Woodlands
Houston
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 13

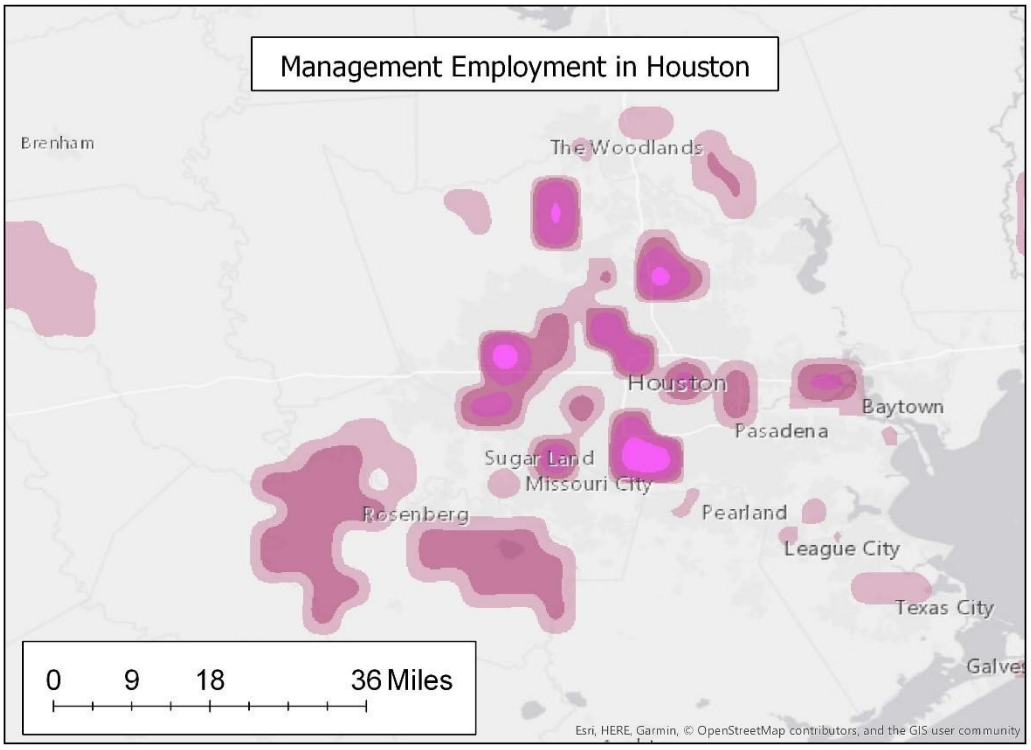

Management Employment in Houston
Brenham
The Woodlands
Houston
Baytown
Pasadena
Sugar Land
Missouri City
Rosenberg
Pearland
League City
Texas City
0 9 18 36 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 14

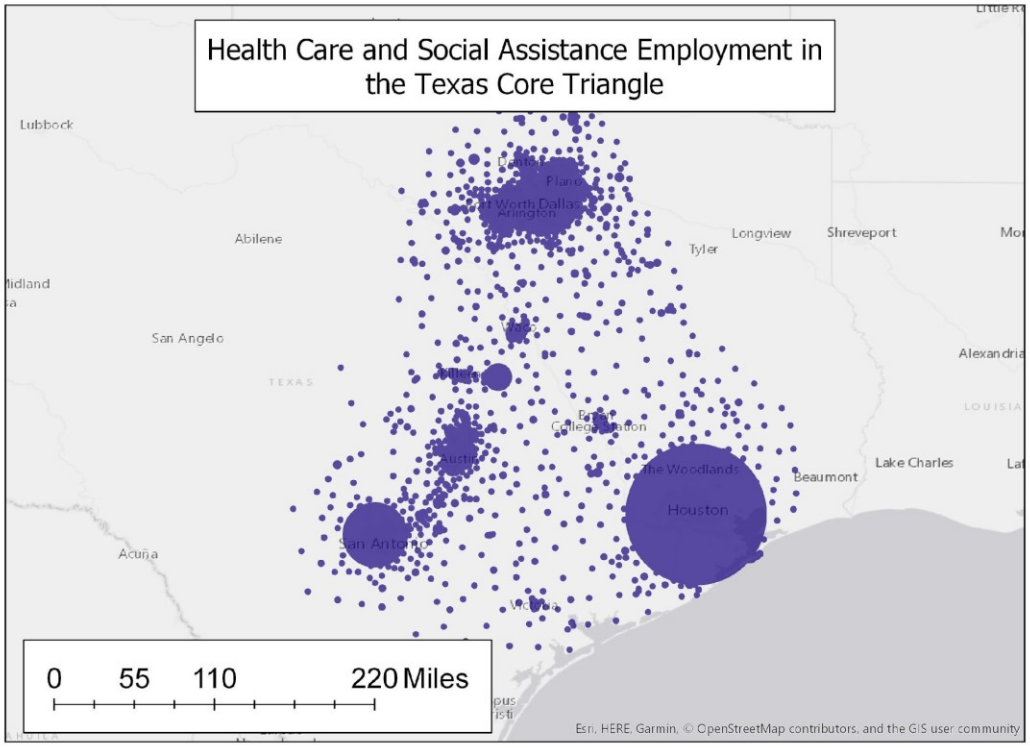

Health Care and Social Assistance Employment in the Texas Core Triangle
Lubbock
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Alexandria
Lake Charles
Beaumont
The Woodlands
Houston
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 15

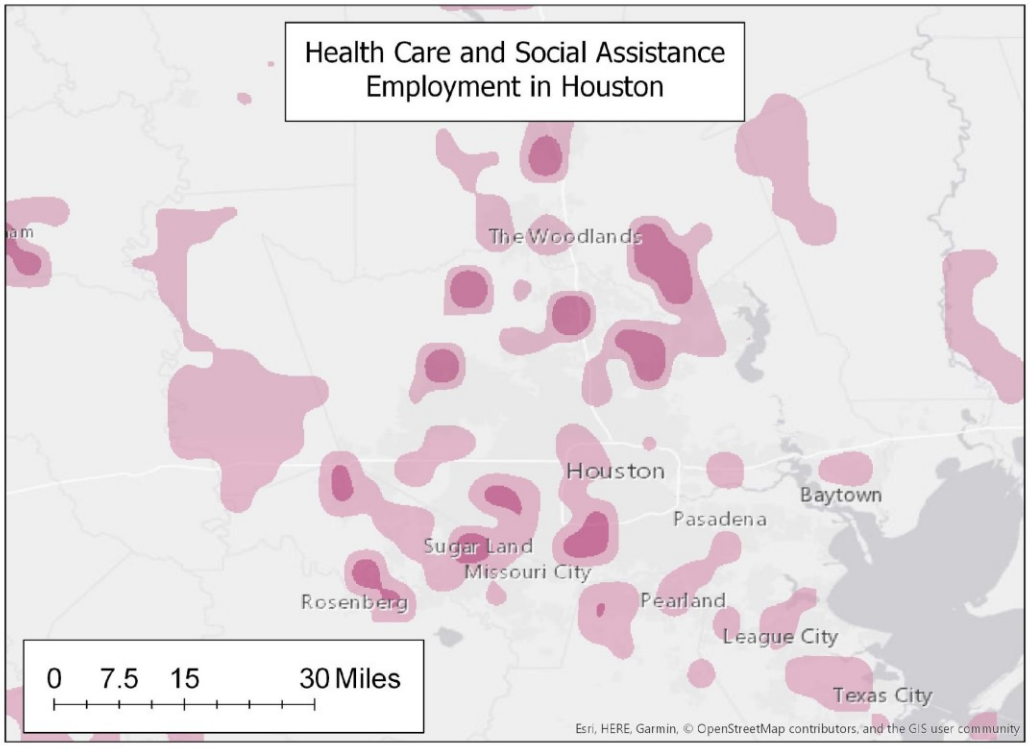

Health Care and Social Assistance Employment in Houston
The Woodlands
Houston
Baytown
Pasadena
Sugar Land
Missouri City
Rosenberg
Pearland
League City
Texas City
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 16

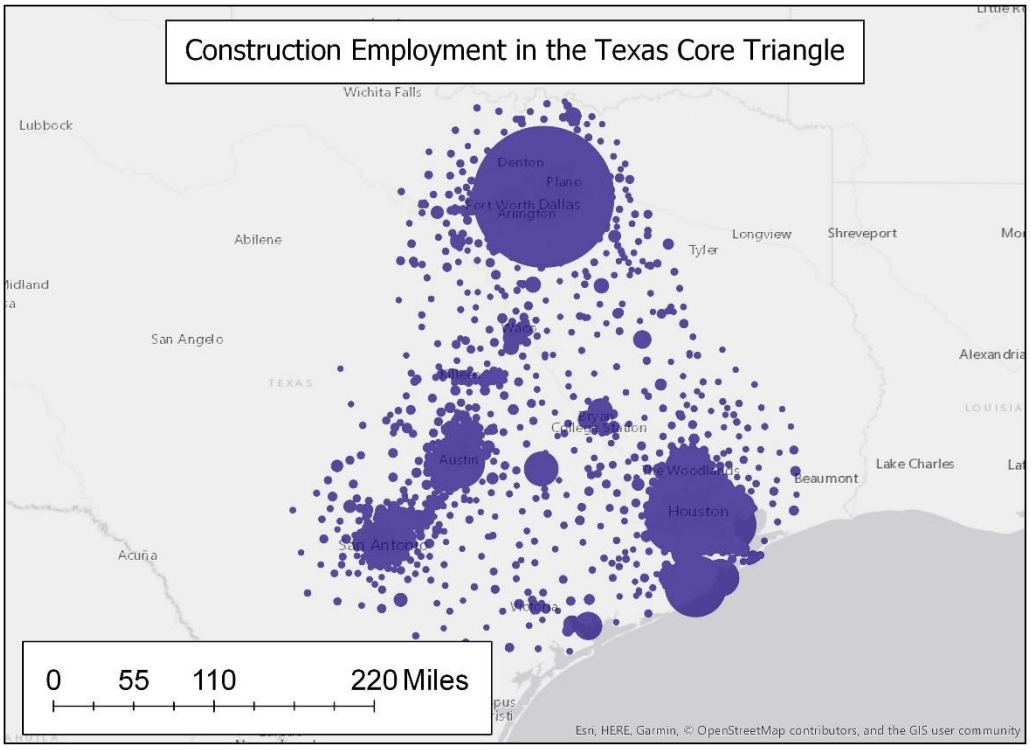

Construction Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Alexandria
Austin
Beaumont
Lake Charles
Houston
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 17

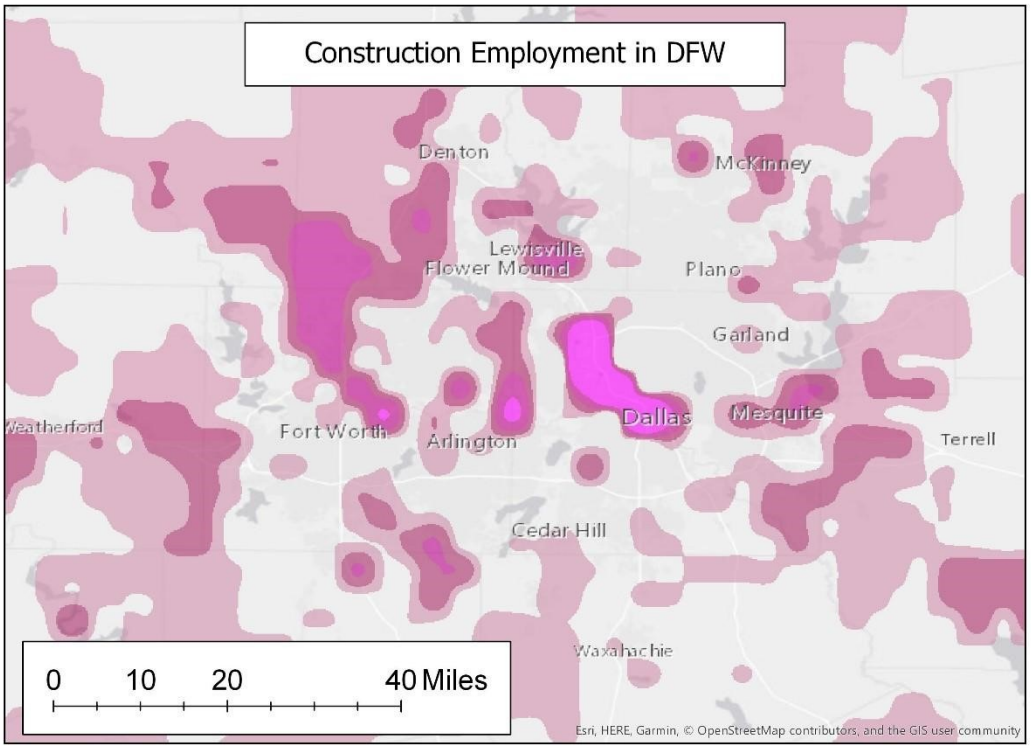

Construction Employment in DFW
Denton
McKinney
Lewisville
Flower Mound
Plano
Garland
Dallas
Mesquite
Terrell
Weatherford
Fort Worth
Arlington
Cedar Hill
Waxahachie
0 10 20 40 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 18

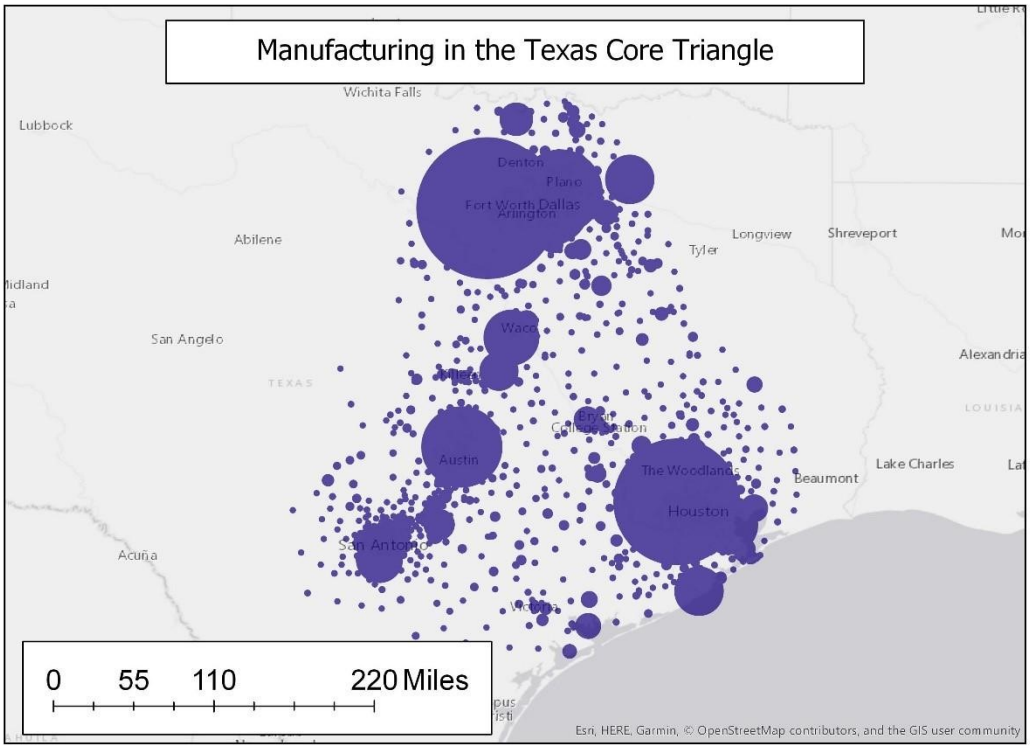

Manufacturing in the Texas Core Triangle
Wichita Falls
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
Waco
TEXAS
Alexandria
Austin
The Woodlands
Beaumont
Lake Charles
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 19

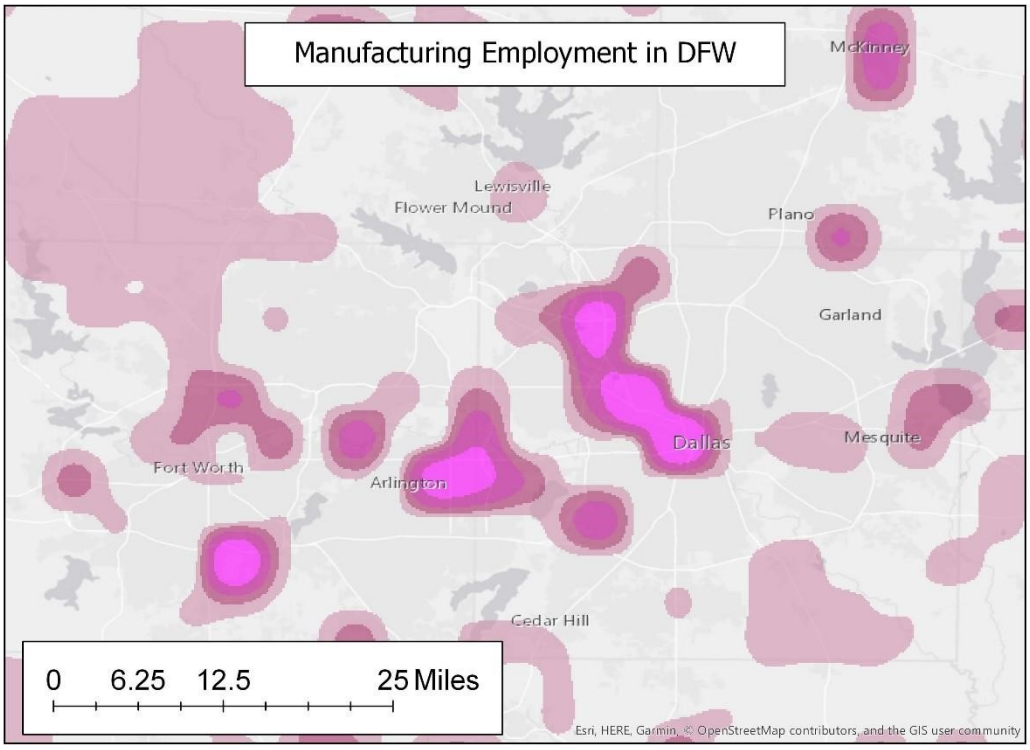

Manufacturing Employment in DFW
McKinney
Lewisville
Flower Mound
Plano
Garland
Dallas
Mesquite
Fort Worth
Arlington
Cedar Hill
0 6.25 12.5 25 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 20

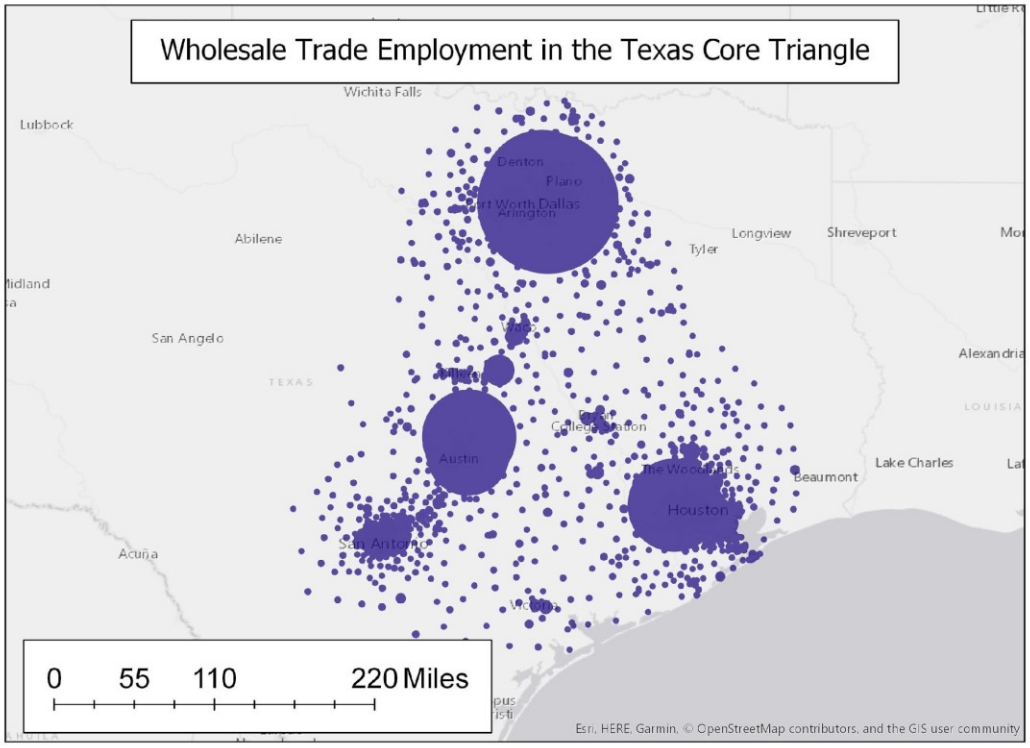

Wholesale Trade Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Austin
College Station
The Woodlands
Beaumont
Lake Charles
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 21

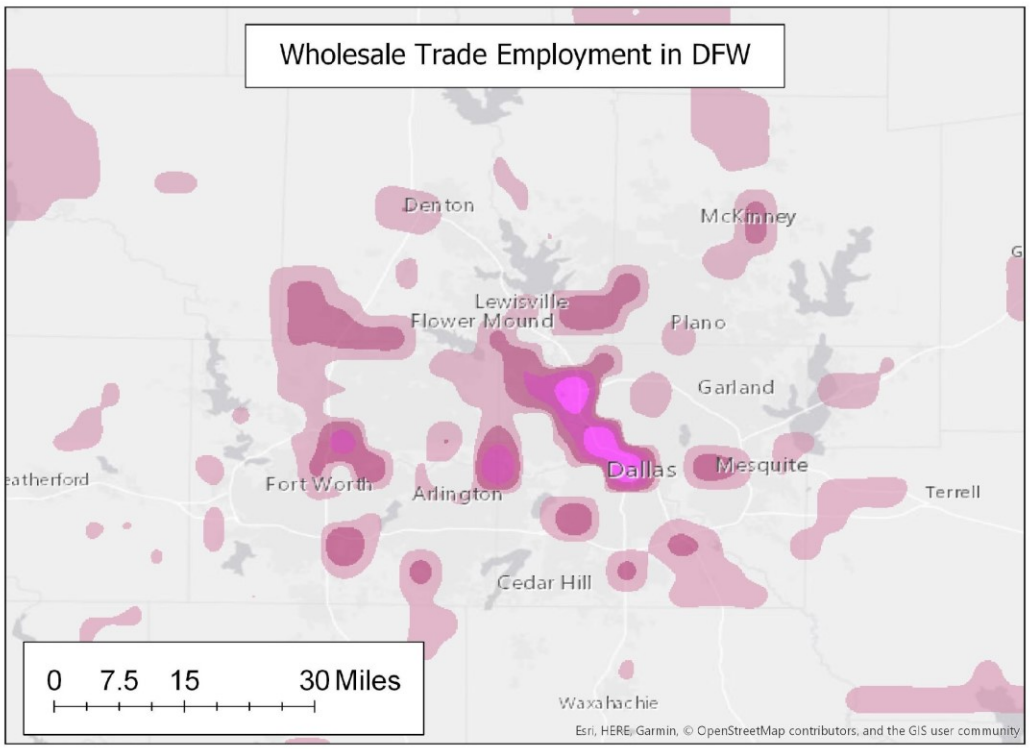

Wholesale Trade Employment in DFW
Denton
McKinney
Lewisville
Flower Mound
Plano
Garland
Dallas
Mesquite
Fort Worth
Arlington
Terrell
Cedar Hill
Waxahachie
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 22

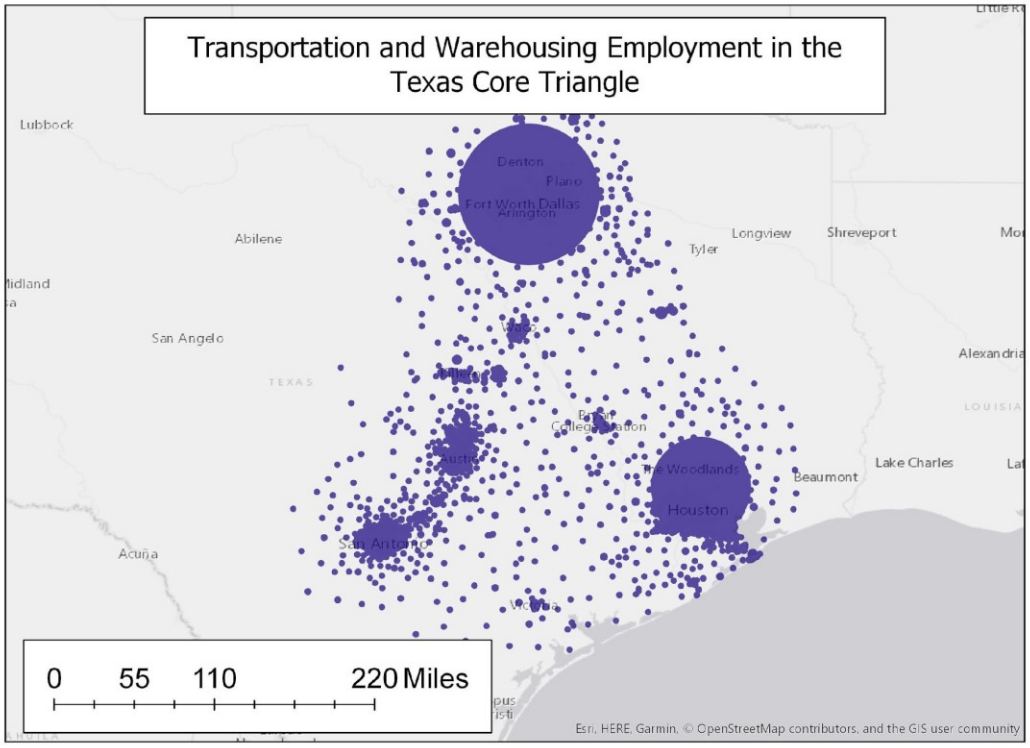

Transportation and Warehousing Employment in the Texas Core Triangle
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Alexandria
Lake Charles
Beaumont
The Woodlands
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 23

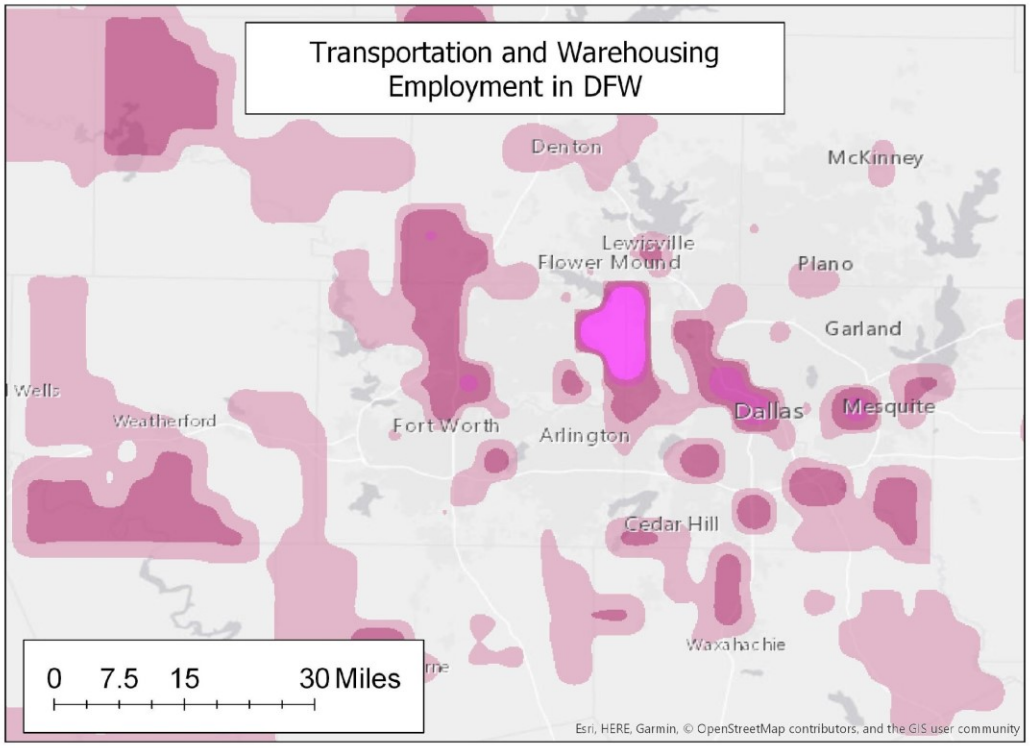

Transportation and Warehousing Employment in DFW
Denton
McKinney
Lewisville
Flower Mound
Plano
Garland
Wells
Weatherford
Fort Worth
Arlington
Dallas
Mesquite
Cedar Hill
Waxahachie
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 24

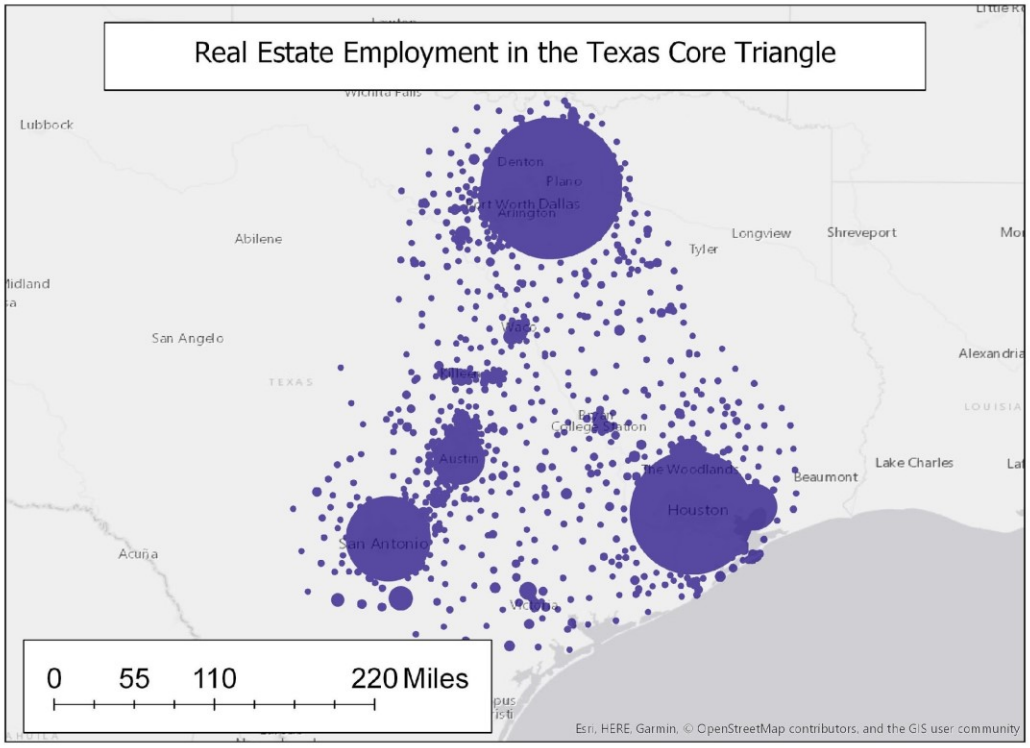

Real Estate Employment in the Texas Core Triangle
Lubbock
Abilene
San Angelo
Denton
Plano
Fort Worth
Dallas
Arlington
Longview
Tyler
Shreveport
Austin
Houston
The Woodlands
Beaumont
Lake Charles
San Antonio
Acuña
TEXAS
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 25

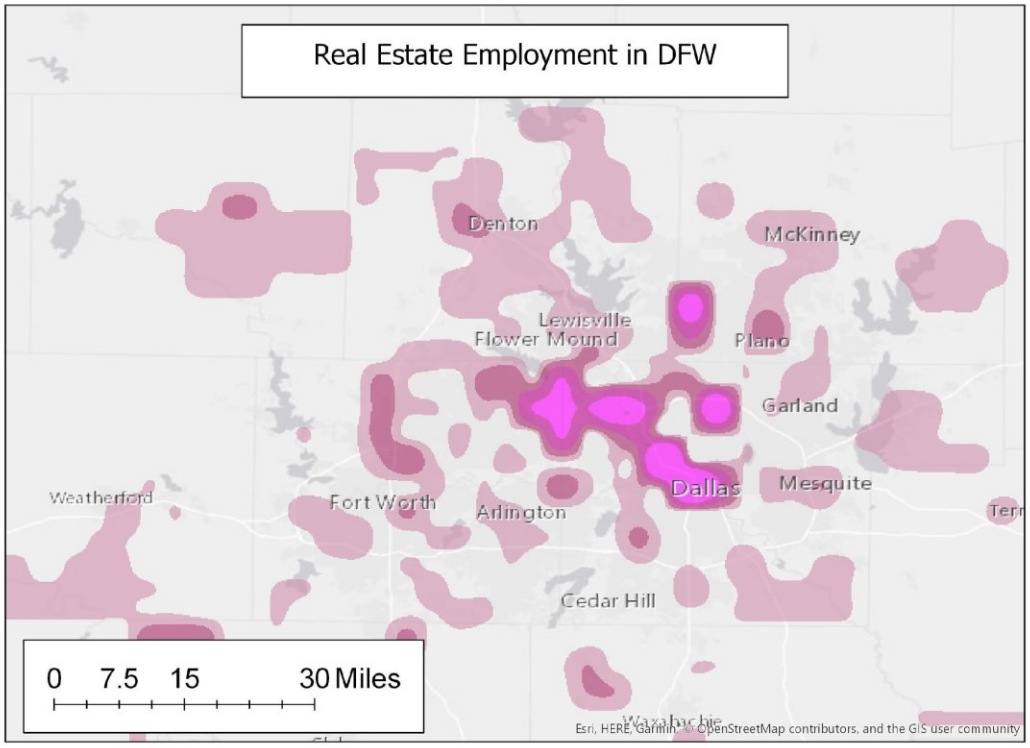

Real Estate Employment in DFW
Denton
McKinney
Lewisville
Flower Mound
Plano
Garland
Dallas
Mesquite
Weatherford
Fort Worth
Arlington
Cedar Hill
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 26

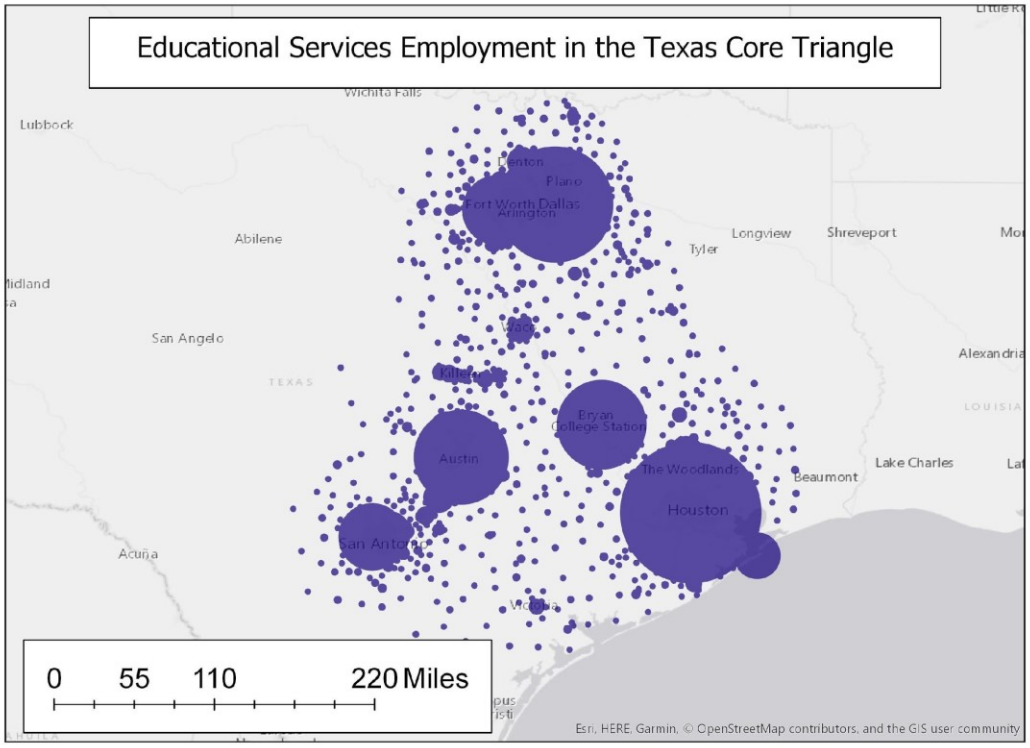

Educational Services Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Alexandria
Bryan
College Station
Austin
The Woodlands
Beaumont
Lake Charles
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 27

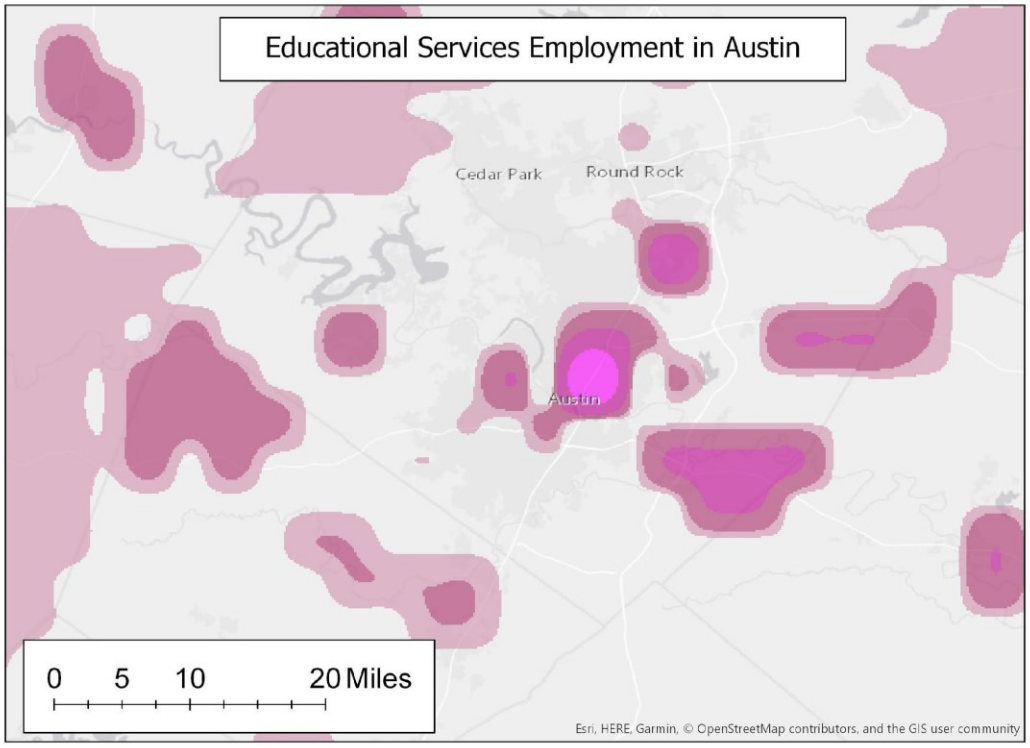

Educational Services Employment in Austin
Cedar Park
Round Rock
Austin
0 5 10 20 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 28

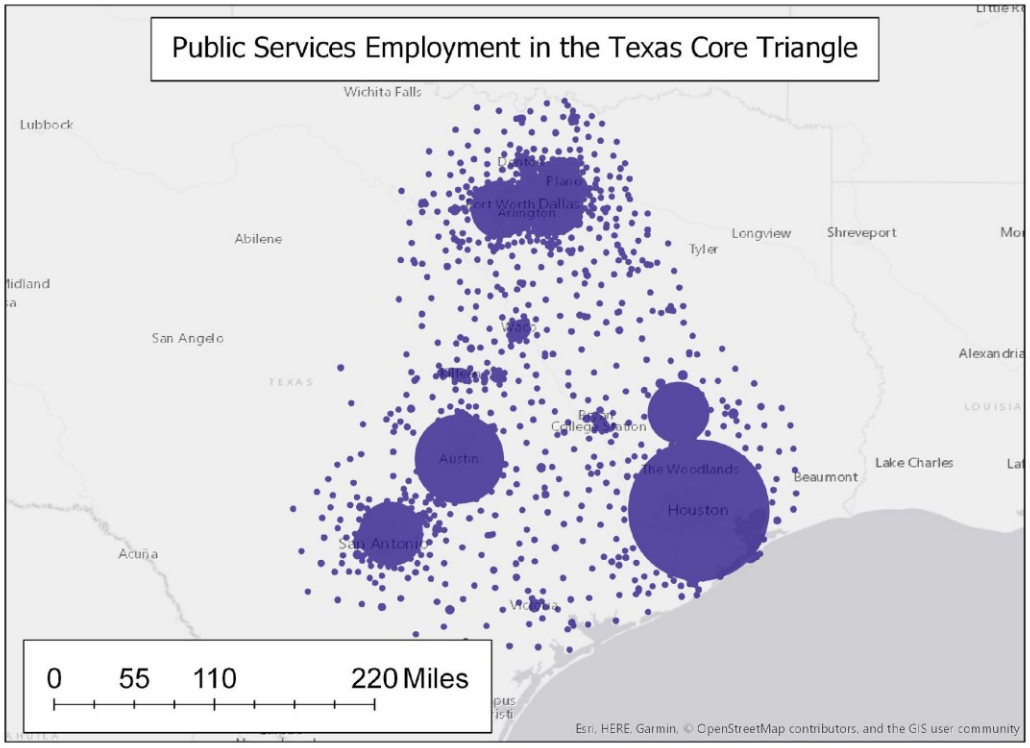

Public Services Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Austin
Houston
The Woodlands
Beaumont
Lake Charles
Alexandria
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 29

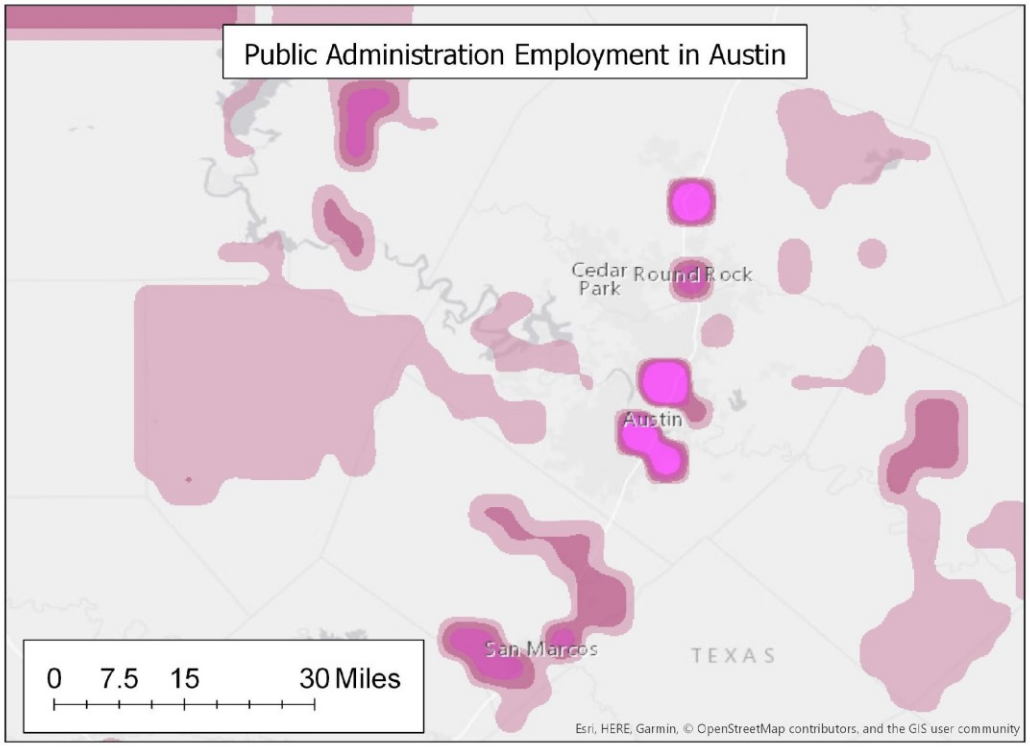

Public Administration Employment in Austin
Cedar Park
Round Rock
Austin
San Marcos
TEXAS
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 30

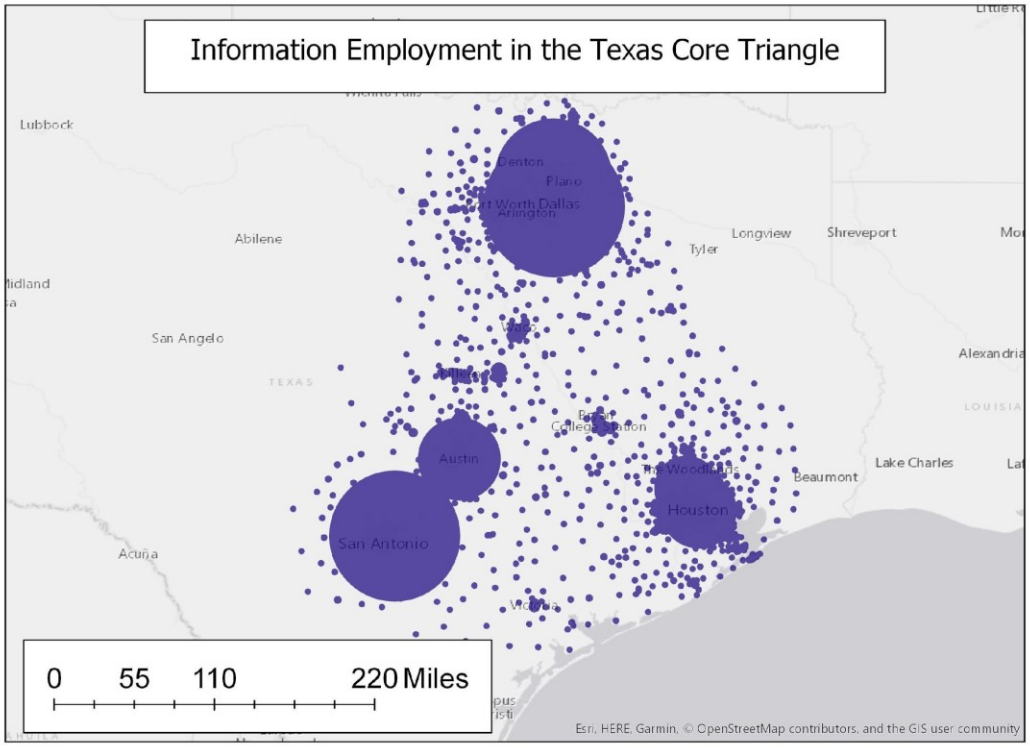

Information Employment in the Texas Core Triangle
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
TEXAS
Austin
Beaumont
Lake Charles
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 31

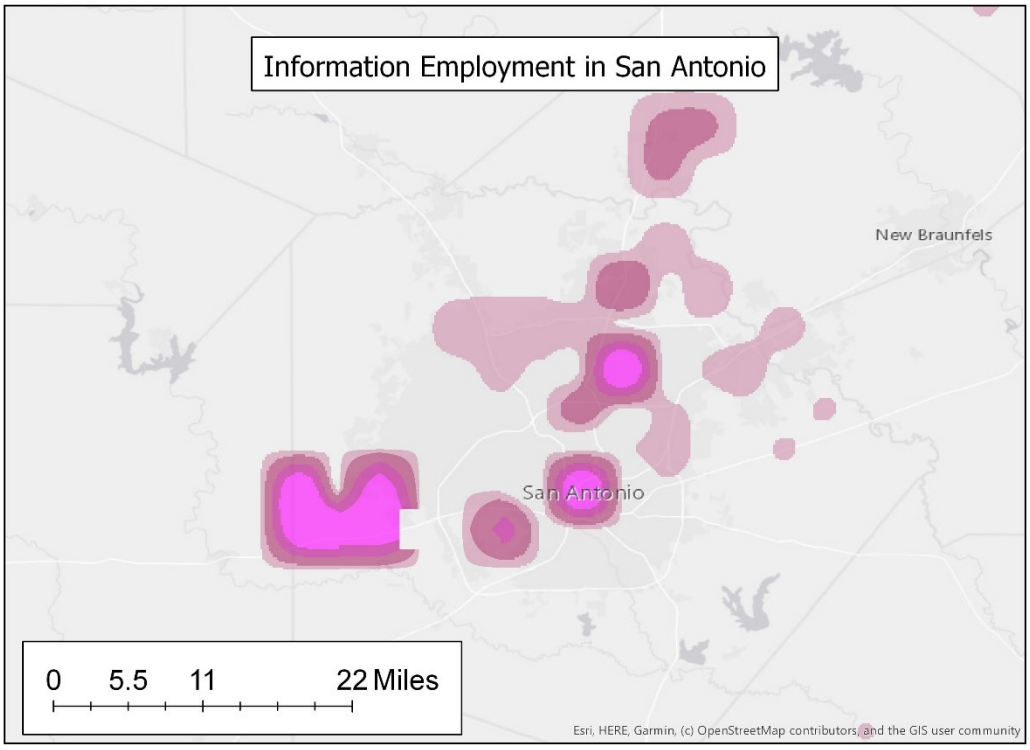

Information Employment in San Antonio
New Braunfels
San Antonio
0 5.5 11 22 Miles
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure 32

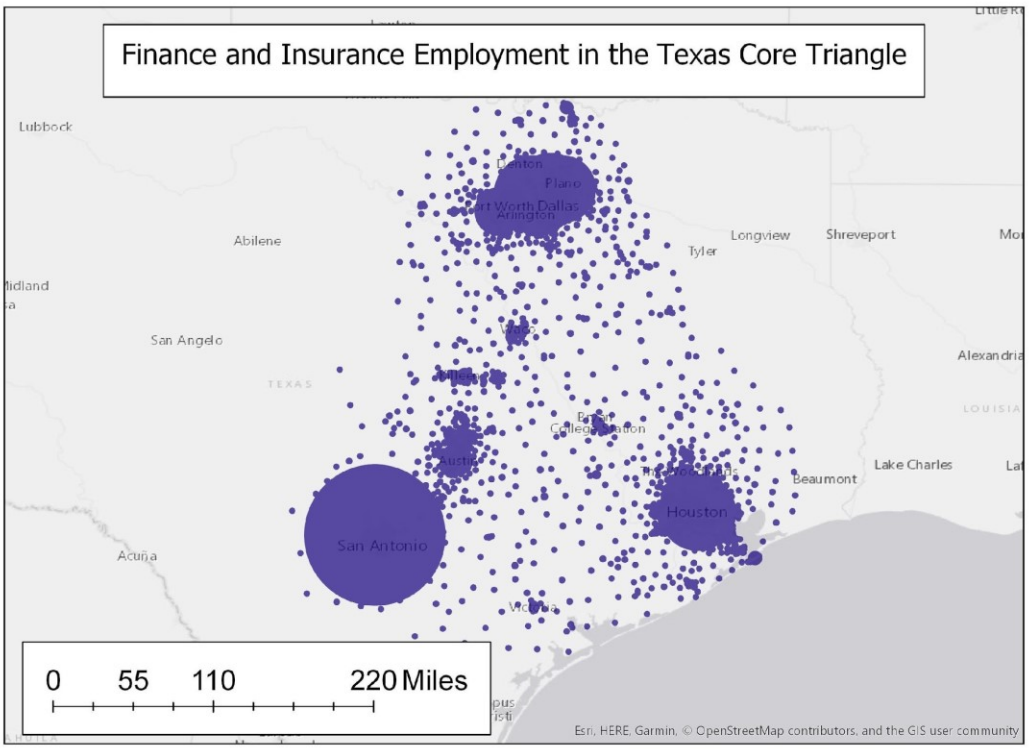

Finance and Insurance Employment in the Texas Core Triangle
Lubbock
Abilene
Longview
Shreveport
Tyler
San Angelo
Alexandria
Lake Charles
Beaumont
Houston
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 33

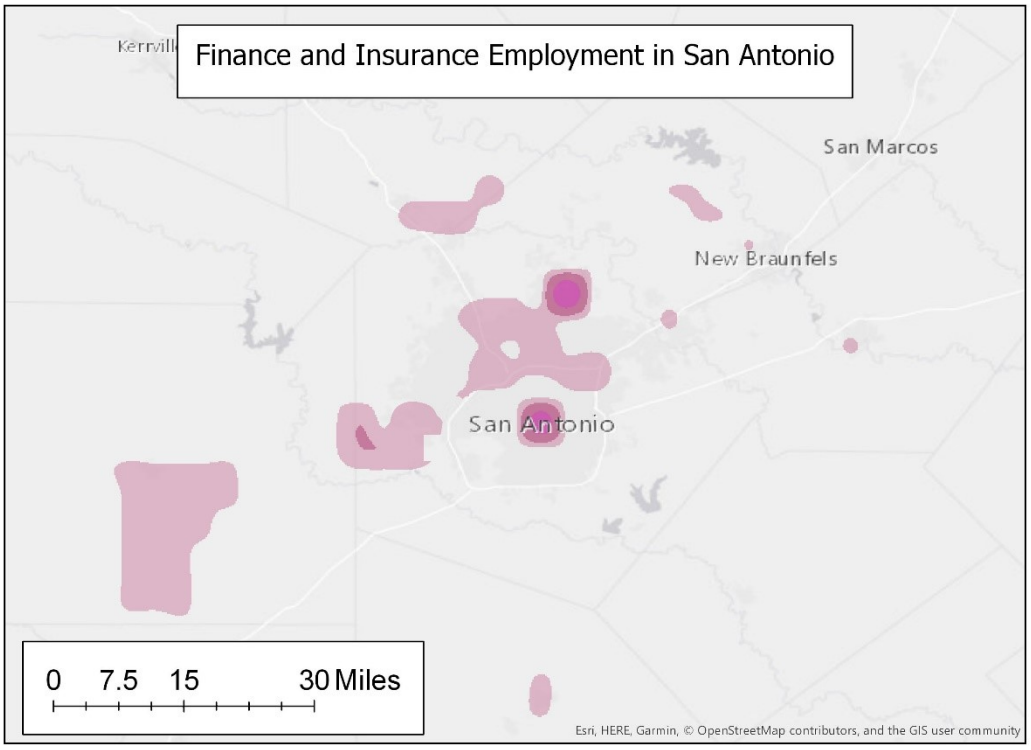

Finance and Insurance Employment in San Antonio
San Marcos
New Braunfels
San Antonio
0 7.5 15 30 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 34

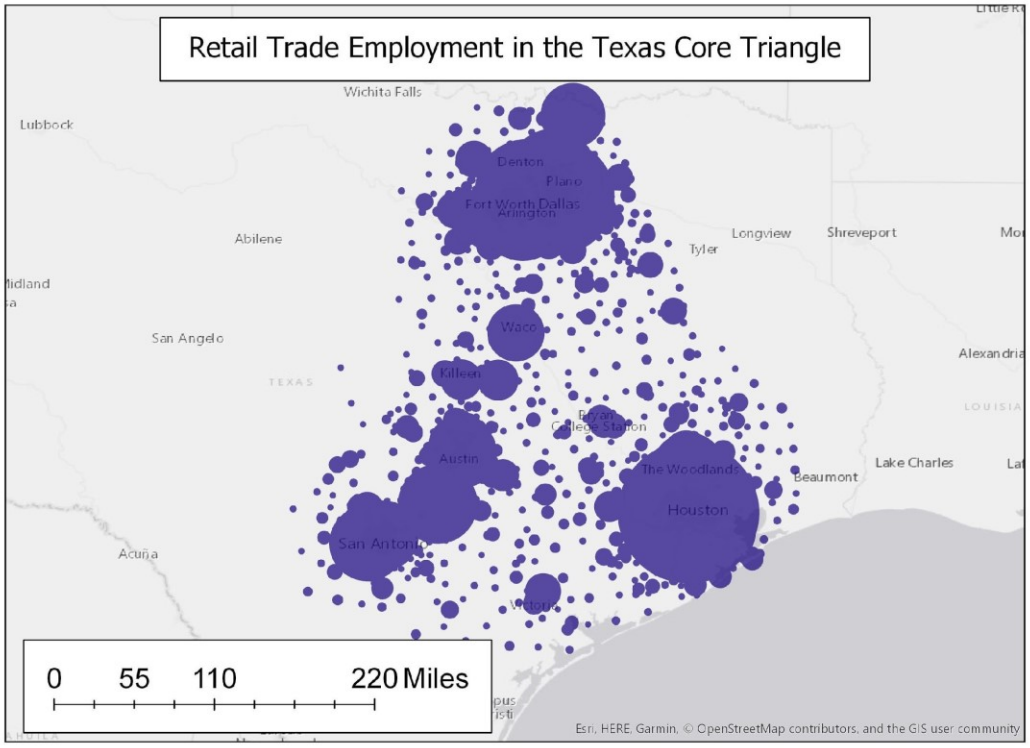

Retail Trade Employment in the Texas Core Triangle
Wichita Falls
Lubbock
Denton
Plano
Fort Worth
Dallas
Arlington
Abilene
Longview
Shreveport
Tyler
San Angelo
Waco
Killeen
TEXAS
Austin
The Woodlands
Houston
Beaumont
Lake Charles
San Antonio
Acuña
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 35

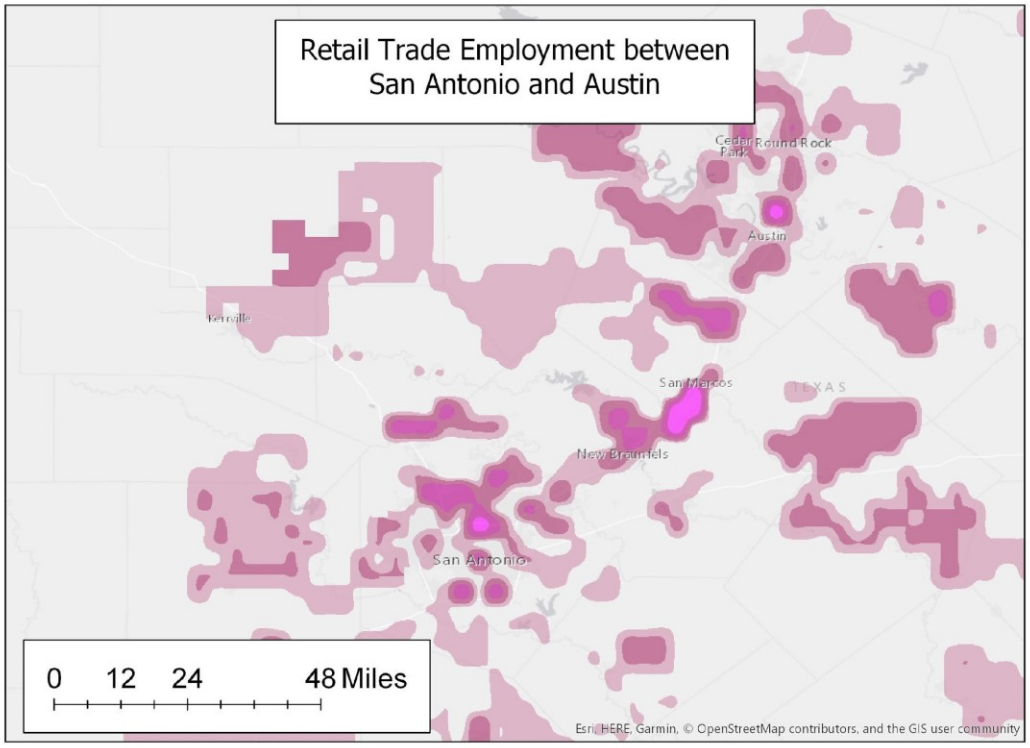

Retail Trade Employment between San Antonio and Austin
Cedar Park
Round Rock
Austin
San Marcos
TEXAS
New Braunfels
San Antonio
0 12 24 48 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 36

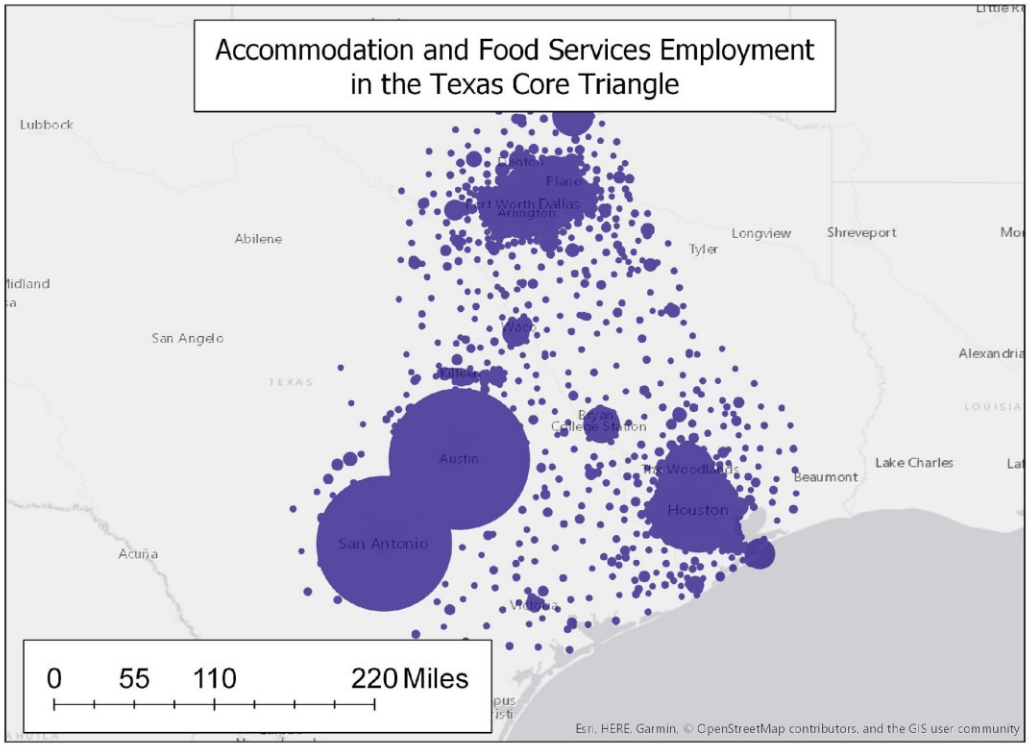
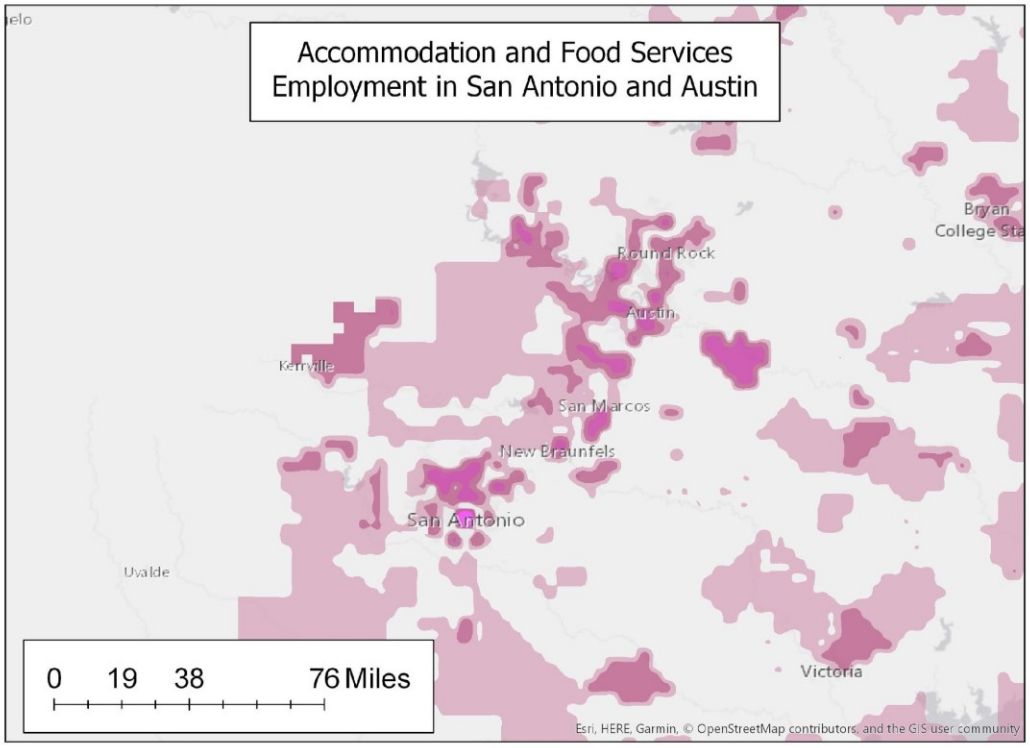

Accommodation and Food Services Employment in the Texas Core Triangle
Lubbock
Abilene
San Angelo
Longview
Shreveport
Tyler
Alexandria
Lake Charles
Beaumont
Houston
Austin
San Antonio
Acuña
TEXAS
0 55 110 220 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 37


Accommodation and Food Services
Employment in San Antonio and Austin
Bryan
College Sta
Round Rock
Austin
Kerrville
San Marcos
New Braunfels
San Antonio
Uvalde
Victoria
0 19 38 76 Miles
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community