Geographical Connectivity in the United States

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WPI-CS-TR-17-01

June 2017

Abstract

This work takes a comprehensive approach to compute, analyze and visualize multi-modal time travel maps from any location in the United States to any other. The comprehensive aspect of the work allows us to compute the relative connectivity, to either geographic area or population, for all locations, at the granularity of counties, in the U.S.

The results demonstrate that while concepts such as geographic and population centers are relatively easy to compute, they are based on the premise that it is equally easy to travel between any two points equidistant from each other. Our results show that for the U.S., and for any geographic region, locations are connected by land via a network of roads and by air via a network of airports and air routes.

Our work is unique in that we consider each of these transportation networks allowing interesting and enlightening analysis on the connectivity of the nation. Centralized regions near major airports such as Denver, Minneapolis/St. Paul and Dallas/Fort-Worth have the best connectivity to the geographic area of the continental 48 states with locations around the edges of the U.S. generally having the worst connectivity. Extending this analysis to all 50 states, shows the regions of Denver, Minneapolis/St. Paul and Salt Lake City with the best connectivity and locations in Alaska and Hawaii with the worst.

The best connectivity to the population of the continental 48 and all 50 states is in the Atlanta metropolitan region with the regions of Chicago, Charlotte and Washington, DC also having relatively shorter average travel times to the U.S. population.

The results also allow the mode of transportation to be determined with roughly 9% of the U.S. population reaching the remainder of the U.S. population in minimal travel time by driving. The remaining 91% of trips include an airline flight with ORD (Chicago) and LAX (Los Angeles) the most likely airports for origination of flights. Determining the primary airport for each county, used to reach the largest segment of the U.S. population, allows us to divide the U.S. into catchment areas for each airport.

Note: All maps shown in the report are available at the project website at `http://geoconnected.cs.wpi.edu/`.

1 Introduction

Internet connectivity has become increasingly important as people spend more time living in a virtual world interacting with others who are located literally anywhere on the planet. However this virtual connectivity is still ultimately layered on physical connectivity where people meet and interact in person with each other. This notion of physical connectivity motivates this project, which we call GeoConnected. The project uses data analysis, mapping and visualization techniques to better understand geographical connectivity, the amount of time to physically travel from one point to another.

The initial focus of the project is on geographical connectivity in the United States, but the approach could be extended on a worldwide basis. In our work, connectivity between two points in the United States is not about the distance between them, but rather the real transportation routes that exist to travel between them. We focus on two modes of transportation: driving by automobile and flying via scheduled commercial air service.

This project is related to previous work in areas such as transport and urban geography. One direction of work of previous work has been to examine time-space transformations [21, 1] and representations [4, 25, 23, 5] as a means to create maps where distances represent travel times. Other work has examined worldwide connectivity of cities via airlines [34, 10, 28, 9, 18, 15, 2]. Work has looked at U.S. air connectivity, particularly for the impact on smaller airport accessibility [26, 14, 16, 19, 32]. Finally, work has examined geographical characteristics of Internet activity [17] as well as spatial variations in the U.S. communication broadband and commercial air service infrastructures [13].

Time-space maps, one type of cartogram, are a means to represent travel time between places, but may distort actual distance and shapes. Another type of map showing the amount of time to travel from one location to other locations maintains actual distance and shapes, but uses other representation for time. These maps are called *time travel* or *isochrone* maps. Examples include an historical map showing the evolution of train travel in the U.S. [8], driving maps [24] and a collection of maps showing travel times at different points in history [20].

For our project, simply creating an isochrone map for travel in the U.S. is potentially interesting, but not novel. However there are a number of distinctive aspects of our project that do make it both interesting and novel.

1. We consider more than one frequently-used mode of transportation compared to previous work that has focused on rail, automobile or air travel. In reality, people typically travel to relative nearby destinations by driving a car, but as the distance to a destination grows large enough then flying becomes the more realistic option. In fact one question of interest is where that transition from driving to flying to a destination takes place.

2. We do not consider a single airport for each location, but rather build into our analysis to consider both smaller airports, which are closer, as well as larger airports, which may be further away but offer better connections.

3. We do not consider just a small number of locations as a source, but rather take a systematic approach where we compute and visualize mode of transportation and travel time maps for all locations, at the granularity of counties, within the United States.

4. The availability of a complete set of travel time maps for all locations is not only interesting, but affords other type of analyses that are not possible without a complete set. For example, we can and do characterize higher-level characteristics of relatively strong and weak connectivity. Previous work has examined accessibility of counties to airports [26] and accessibility of world cities via airlines [15]. We can determine which locations have the best connectivity in terms of the smallest expected travel time to other locations in the U.S. Similarly, we can determine the locations that have the worst connectivity meaning they are the most isolated. Others have identified isolated locations in the U.S. based on closest towns or roads [29, 33, 30, 27].

5. Not only can we identify relatively connected and disconnected locations, but we can do so in a quantitative manner. This approach both allows us to measure and quantitatively compare expected travel times as well as to visualize them on a map of the U.S.

6. By considering multiple airports for each location, we can determine catchment basins for each commercial airport based on actual road and airline connectivity rather than simply based on determination of the closest airport.

7. Finally, we can and do compare measures of connectivity for different metrics of interest. In particular, we examine the connectivity of each location to all geographic area of the United States as one metric. We also examine the connectivity of each location to all population of the U.S. Different metrics lead to different connectivity results.

In the remainder of this paper we describe our methodology used to obtain data, analyze it, then map and visualize the results. We go on to describe the mode of transportation and travel time maps that are created for each county location within the United States. We use the data for these maps to determine the geographical area and population connectedness of each location within the U.S. We both visualize these results and highlight locations that are the most and least connected. We also examine travel time between locations relative to distance between locations. Finally, we examine the frequency in which different modes of transportation are employed across all locations. In the conclusions, we summarize the work and point to directions of future work.

Note: All maps shown in the paper are available at the project website at `http://geoconnected.cs.wpi.edu/`. The site allows mode of transportation and travel time maps to be viewed for any location within the U.S. It also allows summary connectedness and airport catchment maps to be viewed.

2 Methodology

We define geographical connectedness as the amount of time to physically travel from one point to another. In this work we apply this concept to the 50 states of the U.S. and consider two modes of transportation: driving a car and flying via commercial air service. Other modes of transportation such as bus, train and boat are not considered.

In determining how to gather and analyze data on geographical connectedness in the U.S. it soon became apparent to use county data as the best level of granularity. County-based analysis has two primary advantages for our work:

1. Counties divide the United States geography into relatively small discrete units (albeit of varying size) with data available on population and the county seat (or some other principal city/town) for each county.

2. Software is available to visualize the results of analysis. D3.js (`d3js.org`) is a small, free JavaScript library for manipulating data-driven documents. In particular we can use the d3 county choropleth library [6] to easily visualize data represented on a per-county basis. As an added benefit, all created visualizations are Web documents both viewable and interactive via a browser.

We obtained data for counties from the U.S. Census Bureau [31], which assigns a FIPS (Federal Information Processing Standards) code to each county. The data set of 3143 FIPS codes is primarily of counties (and we describe it as such), but does include a few cities. Conveniently, FIPS codes are also used by the d3.js library to visualize a county.

We used the 2010 data files because they included more information for each county than more recent versions. Among the information for each county is a county name, 2010 population, land/water area, and latitude/longitude, which based on observation appear to be in roughly the center of the county. This data set does not include information regarding the county seat or a principal city in each county. In computing travel time to/from a county we wanted to use a primary city for calculations. We were able to obtain a principal city/town, typically the county seat, from an ancestry roots website [22]. This principal city information was merged into the county database.

We used the principal city for each county as a representation for the county size and population meaning that for purposes of analysis, we assume that all area and population of the county are located at that principal city. This assumption allows us to treat a county, an area identified with a FIPS code, as a single entity for analysis and visualization.

In our work, all travel times between principal cities of two counties are computed based on the smaller of:

1. the time to drive a car from the first principal city to the second principal city, and

2. the time to drive to a nearby airport of the first principal city, plus the time to fly to destination airport nearby the second principal city, plus the time to drive to the second principal city from that destination airport.

The remainder of this section provides more details on how each of these components of travel time are obtained and computed.

2.1 Determination of Drive Times Between Cities

We did not use simple straight-line distance and drive time approximations between cities. Rather we used actual data taking into account available roads. We primarily used data obtained from `mapquest.com` for drive times with augmented data from `google.com/maps` and `travelmath.com` as needed. We did not determine travel times between all combinations of cities in the over 3000 counties to reduce the scale and minimize unnecessary work. We know that cities further away from a source will be reached via air travel rather than only via driving. Therefore we initially determined driving times for cities initially within a radius of 400 miles and extended that radius for portions of the Midwest and West where airport availability is less.

In obtaining and analyzing drive times between two cities:

1. We assume the drive time between two cities is symmetric so that the time from City A to City B is the same as from B to A.

2. We gather drive time information at low traffic periods so that drive time tends to best case.

3. We add an additional 15-minute break for every two hours for journeys over three hours based on advice such as [3]. For example, six hours of drive time adds an additional 30 minutes (two breaks) to the total drive time.

2.2 Determination of Flight Times

Air travel is the second mode that we consider. Commercial air travel occurs between airports. The Federal Aviation Administration (FAA) classifies primary commercial service airports (those with more than 10,000 passenger boardings each year) into four categories based on percentage and number of boardings [11]: Large (1% or more), Medium (0.25-1%), Small (0.05-0.25%) and Nonhub (more than 10,000, but less than 0.05%). They also provide the classification for each airport in the U.S. [12]. We used this data set to include all Large, Medium and Small airports in our work as well as Nonhub airports with at least 200,000 boardings. We adopt the term "Smaller" for this last category. As part of the work, we subsequently added six Smaller airports each with at least 100,000 boardings. These airports were added to reduce airport drive times for remote locations to less than three hours. In total we considered 182 airports in this work with a complete listing of them in Appendix A.

Figure 1 shows a d3 county choropleth map with those counties containing one of the four categories highlighted based on their category. Counties containing multiple airports (such as Harris County in Texas) are shown as the larger category. The colors for this map and all maps developed for the project were chosen using ColorBrewer, a site specifically designed for picking color schemes for cartography [7].

Air travel times between these airports were primarily obtained for regularly scheduled flights from `travelocity.com`. In gathering data we considered multiple days of the week. As done for drive times, we determined the shortest duration (best case) flight between two airports. However, unlike for drive times, we treated each direction of travel as a distinct case because the airline schedules may vary and the prevailing winds cause times to vary significantly between west-to-east and east-to-west flights. For example, the flight time from Boston (BOS) to San Francisco (SFO) is almost one hour more than from SFO to BOS. We also add two additional hours for

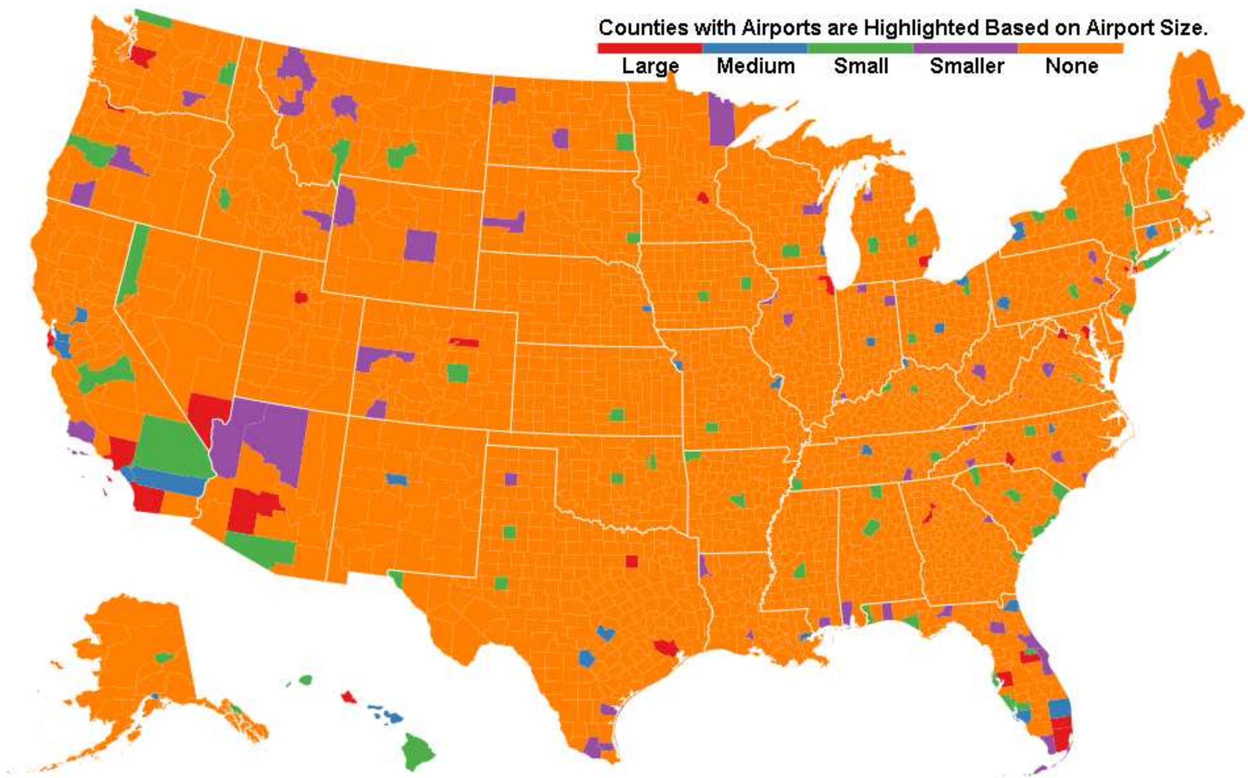

Figure 1: Counties and Primary Commercial Airports in the United States

all air travel based on time required to be at the airport before departure and time to get away from the airport after arrival. We also experimented with a value of three additional hours, which increased the overall travel time, but did not change the tone of the results. All results shown use two additional hours for flying.

In some cases the shortest duration between two airports is via a direct flight while in other cases one or more layovers are required. The total flight time from initial take-off to landing in the last airport is the air travel time. In cases where a flight between Airport A and Airport B cannot be found then we do augment the database by considering all directly connected airports from Airport A to see if any of those airports have flights to Airport B. If so, we include such an augmented entry in our air travel database with the time for both sets of flights as well as an additional delay for this connection. We experimented with a two- and four-hour additional delay with little difference in the overall results. A two-hour delay is used for all results.

2.3 Multi-Modal Travel Times

Once we had obtained drive times between principal cities of counties and air travel times between primary commercial airports, the next step was to determine the time to drive from a principal city of a county to a nearby airport. In some cases the nearby airport for a location is clear. For example a location close to only one primary commercial airport will use that airport exclusively for all air travel. On the other hand, using an airport that is further away, but provides better flight connections may result in shorter travel times.

We used the categories of airports described in Section 2.2 as a basis to determine up to four airports to consider for each county. We did so by first finding the closest Large category airport within the state or in a nearby state with a typical maximum range consideration of 300 miles. If such an airport exists then that airport was added to the county database as the Large category airport to consider for that city. We next examined the set of Medium category airports within the same range and if one of these Medium airports is closer than the closest Large airport then it was added. We repeated this process for Small airports and then again for Smaller airports. The result is that up to four airports, one from each size category, were added to the database for each county. We then obtained the drive time between each principal city and one to four of its closest airports. Note that for remote regions of Alaska local flights and ferries are used for "drive" time to reach the three primary airports in the state.

As an example of this process, consider Smith Center, Smith County, KS. Smith County is notable as it is the geographic center of the 48 continental states of the U.S. The closest Large airport to Smith Center is DEN near Denver, CO with a driving distance of 5.65 hours. The closest Medium airport is OMA near Omaha, NE with a driving distance of 3.74 hours. The closest Small airport is ICT near Wichita, KS with a driving distance of 3.18 hours. There is not a Smaller category airport that is closer so in terms of computing the shortest travel time from Smith Center, travel via three airports are considered.

We consider two examples to illustrate how the data are used. First, to travel from Smith Center to St. Louis, MO, the three airports closest to Smith Center are considered as well as two airports, ORD (in Chicago) and STL (in St. Louis) are considered since ORD is a Large airport in an adjoining state and STL a Medium airport that is closer. Taking into account drive time between city and airport on each end (with 15-minute travel breaks added if appropriate) as well as air travel time, the shortest travel time of 9.47 hours is incurred by driving from Smith Center to ICT, flying to STL and then driving to St. Louis from STL. However, this time is longer than the 8.78 hours to simply drive from Smith Center to St. Louis so driving is the mode of transportation and 8.78 hours is the duration between these cities.

On the other hand, to travel from Smith Center to Washington, DC, the three airports closest to Smith Center are again considered as well as two airports, DCA (Reagan National) and IAD (Dulles), near Washington. We note that DCA and IAD are each classified as Large airports by the FAA, but in three cases where multiple Large airports exist in a metropolitan area (New York, Washington and Chicago), we artificially change the category of one airport to Medium to allow more than one airport to be considered for travel time calculations. In our work, these reclassified "Medium" airports are DCA, LGA (Laguardia in New York) and MDW (Midway in Chicago). The result is consideration of six possible airport combinations for travel between Smith Center and Washington. Again taking into account drive time between city and airport on each end as well as air travel time, the shortest travel time of 8.63 hours is incurred by driving from Smith Center to OMA, flying to DCA and then driving to Washington from DCA. Given the distance between these cities, we did not obtain the drive time between them because it is obviously longer than using air travel between the two cities.

3 Results

Employing the described methodology, we used our driving and air travel data sets to analyze various aspects of geographical connectivity in the United States. The results of our analysis are described, and in many cases visualized, in the following. The significance of the results are discussed as appropriate.

3.1 Mode of Transportation Maps

The first step in our analysis was to determine the mode of transportation in traveling from a principal city in each of the 3143 counties in our dataset to any other principal city in our dataset. The mode of transportation is either to drive directly from the first to the second city or to drive from the first city to a nearby Large, Medium, Small or Smaller airport; fly to a similarly described airport nearby the second city and drive to it.

Figure 2 shows one of over 3000 mode of transportation maps that were generated and are available at the project website. The map shows results for Smith Center, Smith County, KS with four modes of transportation used for the shortest travel to various parts of the U.S. Smith County, on the Nebraska border, is colored black with a large segment of surrounding counties across many states reached the fastest by driving. This region includes St. Louis as described in Section 2.3. Regions with the shortest travel based upon driving to and flying from DEN are in red. There are relatively few such regions. Blue regions show where it is fastest to drive to and fly from OMA, such as Washington, DC as previously described. The remaining regions are reached the fastest by driving to and flying from ICT airport near Wichita.

The large area best reached by driving is an indication that the closest airport is more than three hours away. The jaggedness of boundaries between regions is both due to the vagaries of county boundaries, which is the granularity of the data and visualization, but also an indication that at the region boundaries there is little difference in the travel time between the two travel modes. A slight variation in the obtained travel time or even where the principal city is located within its county can cause visual oddities at the boundaries, particularly that each county is visualized with only one mode regardless of whether there is a clear best travel mode or more than one that are close in outcome. While these variations have some visual effect they have little impact on higher-level connectivity analysis that we perform in our work.

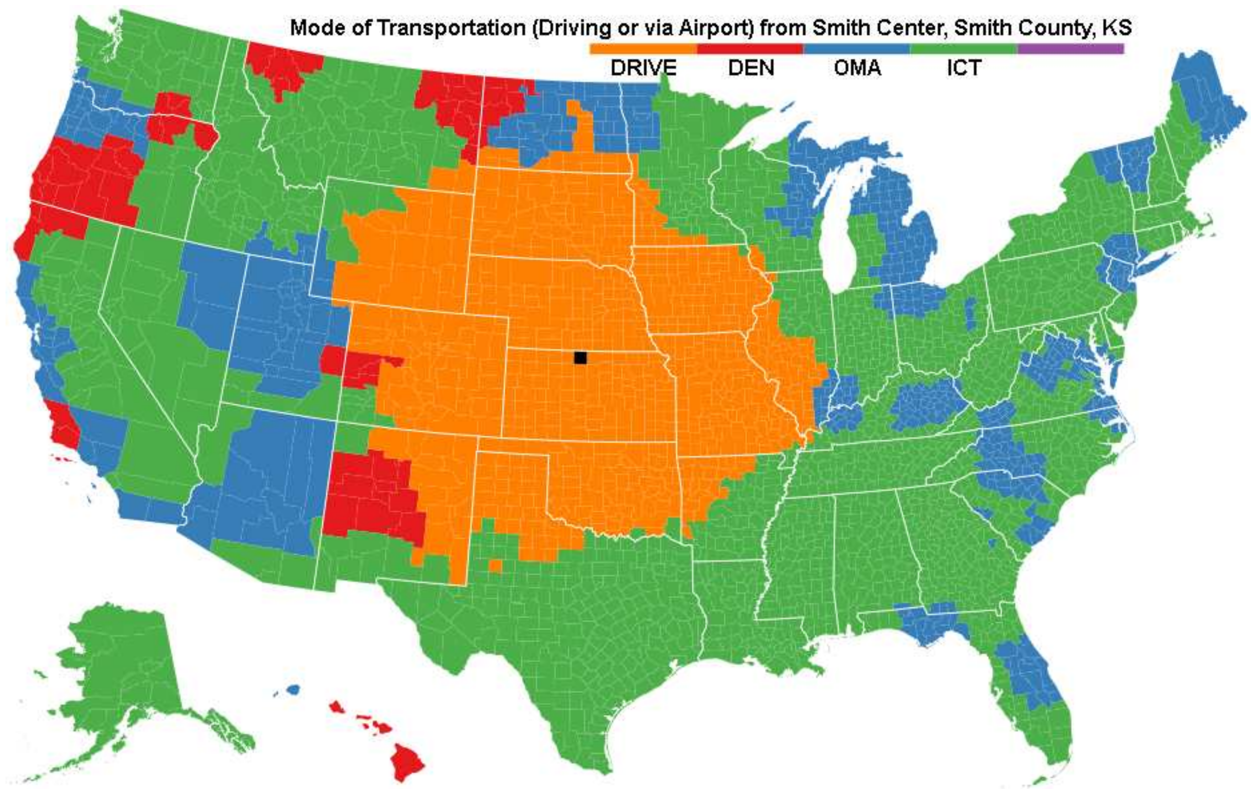

Figure 2: Mode of Transportation Map for Smith Center, Smith County, KS

3.2 Travel Time Maps

In conjunction with mode of transportation maps, we also constructed a travel time map for each of the counties in our dataset. The travel time map for Smith Center, Smith County, KS is shown in Figure 3 where again similar maps for all counties are accessible on the project website.

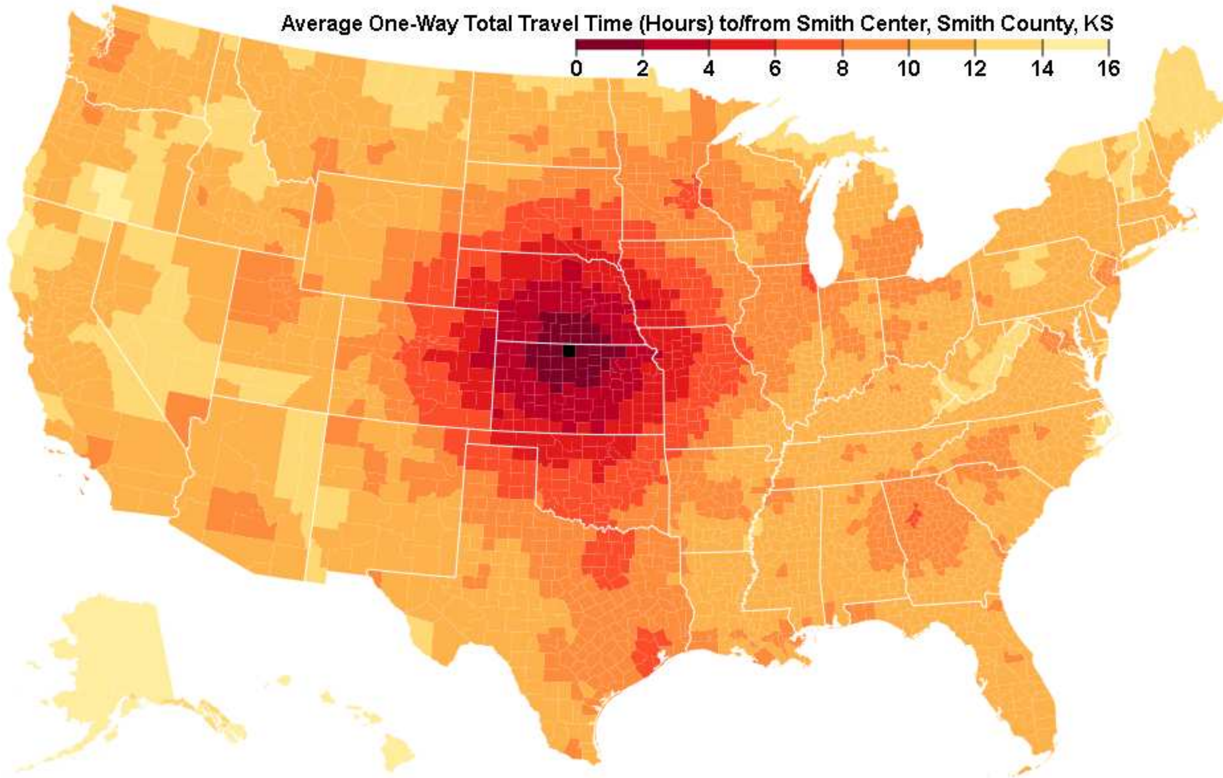

Figure 3: Travel Time Map for Smith Center, Smith County, KS

This map is shown with a gradient scale where those counties with the least travel time to be reached from Smith Center are darkest in color and those counties with the most travel time to be reached are lightest in color. Not surprisingly, the shortest-travel time counties surround Smith County (again shown in black) with other shorter-travel regions clustered around areas with major airports such as Minneapolis and Dallas.

The figure also shows that the plotted value is the "average one-way total travel time (hours) to/from Smith Center." The significance of the "to/from" is that any travel time involving a flight from a source to a destination is unlikely to be the same as from the destination back to the source. For example, we previously described how the travel time from Smith Center to Washington, DC is 8.63 hours. However, the return travel time from Washington to Smith Center is 9.26 hours—likely because of the prevailing west-to-east winds. As a result all one-way travel times used in this map as well as other maps and analysis are based on average one-way times to minimize the effect of the one-way differences.

3.3 Geographical Connectivity

Travel mode and travel time maps such as Figures 2 and 3 are useful and interesting to view, but soon lead to the obvious question of their significance. Fortunately, they collectively embody information that can be used to quantify the connectedness of all locations.

We use a straightforward analysis approach for each county in our dataset where the average one-way travel time from a source principal city to every other destination city is multiplied by the area of the destination county and accumulated. When we divide the accumulated sum by the total area we obtain an average one-way travel time to all areas within the U.S. The average one-way travel time from each county to all geographic area of the continental 48 states is shown in Figure 4. As a baseline, the average travel time across all 48 states is 9.06 hours.

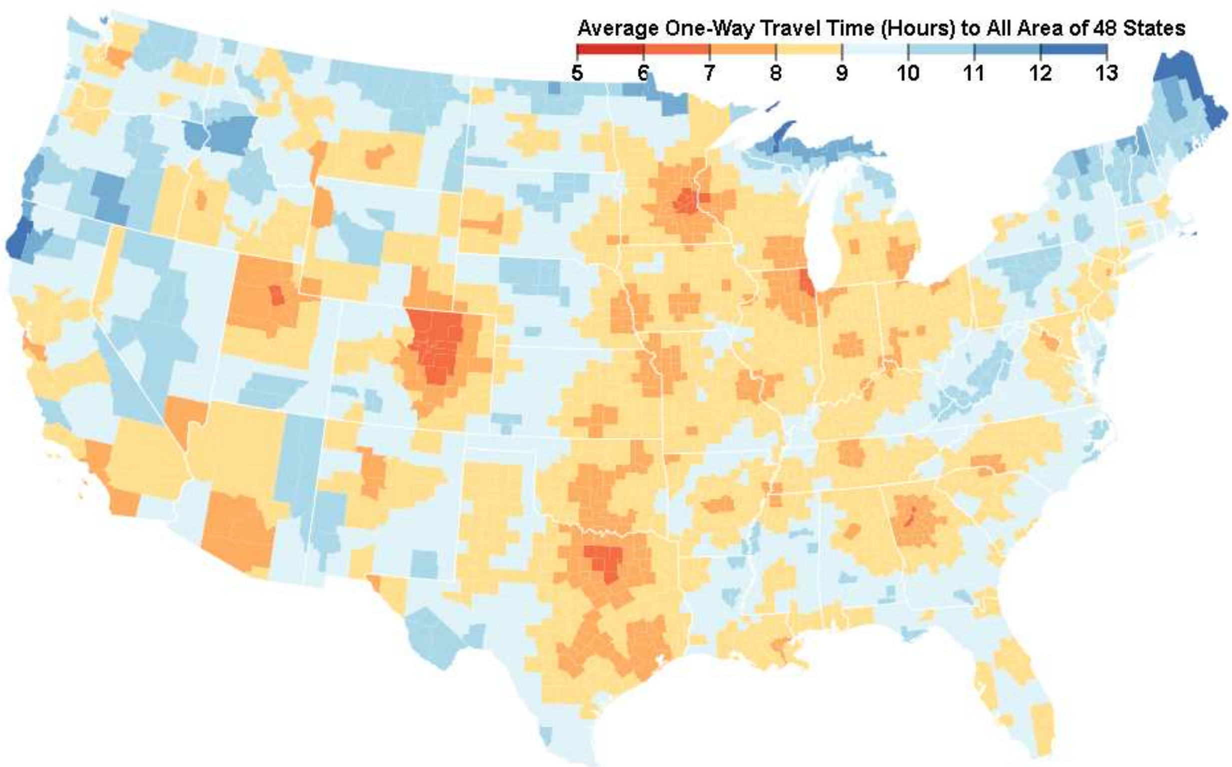

Figure 4: Average One-Way Travel Time to All Area of 48 States

A gradient is used with the counties having the smallest average one-way travel time (those that are most connected to all area) are shown in darker red. Locations with intermediate connectedness are shown in lighter hues with the least-connected counties having the highest average one-way travel time shown in darker blue colors.

As shown in the figure, regions near major airports in the central part of the country are shades of red while regions around the edge of the country, particularly those not near an airport, are shades of blue. As an aid in understanding connectivity, Table 1 shows the top-10 most-connected counties with the smallest average one-way travel time to all area in the 48 states. It shows that Adams County in Colorado is the most-connected county as it contains the DEN airport. Other counties in the top 10 are around this airport or the MSP airport in Minneapolis and DFW airport in

Dallas. These results indicate that residents of these three metropolitan areas are the most centrally located to all areas of the U.S. based on travel time, in contrast to the geographic center in Smith County, KS, which is the center based on distance.

Table 1: Top-10 Most-Connected Locations to/from All Area of 48 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Brighton, Adams County, CO	6.26
2.	Denver, Denver County, CO	6.36
3.	Broomfield, Broomfield County, CO	6.40
4.	Saint Paul, Ramsey County, MN	6.46
5.	Golden, Jefferson County, CO	6.49
6.	Dallas, Dallas County, TX	6.50
7.	Littleton, Arapahoe County, CO	6.51
8.	Minneapolis, Hennepin County, MN	6.51
9.	Castle Rock, Douglas County, CO	6.54
10.	Boulder, Boulder County, CO	6.59

At the other extreme, Table 2 shows the top-10 least-connected locations to all area of the 48 states. These results show that remote counties of the Upper Peninsula in Michigan, northern California, northern Maine, Nantucket Island in Massachusetts (which adds a ferry crossing to all drive times), southern Oregon and northern Minnesota have the worst connectivity in reaching all area of the continental 48 states.

Table 2: Top-10 Least-Connected Locations to/from All Area of 48 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Eagle River, Keweenaw County, MI	12.99
2.	Eureka, Humboldt County, CA	12.46
3.	Houghton, Houghton County, MI	12.32
4.	Machias, Washington County, ME	12.20
5.	Houlton, Aroostook County, ME	12.07
6.	Nantucket, Nantucket County, MA	12.05
7.	Lakeview, Lake County, OR	11.92
8.	Gold Beach, Curry County, OR	11.91
9.	Newberry, Luce County, MI	11.85
10.	Baudette, Lake of the Woods County, MN	11.78

Obviously the travel times for the least-connected locations would change if more airports were considered, and as previously described we did add six additional airports to our initial set. However, we controlled the total number of airports to keep data gathering at manageable levels. In addition, even if additional airports are considered, they are likely to have less scheduled air service and will still be less connected than larger airports.

For completeness, Figure 5 shows the average one-way travel time from each county to the geographic area of all 50 states. As expected, all counties show a worse connectivity because

Alaska is geographically large and both Alaska and Hawaii are remote relative to the other states. Conversely, the counties in Alaska and Hawaii are distant from the remainder of the U.S. The average one-way travel time across all counties in the 50 states is 10.16 hours, which is significantly higher than the 9.06 hours across the continental 48 states.

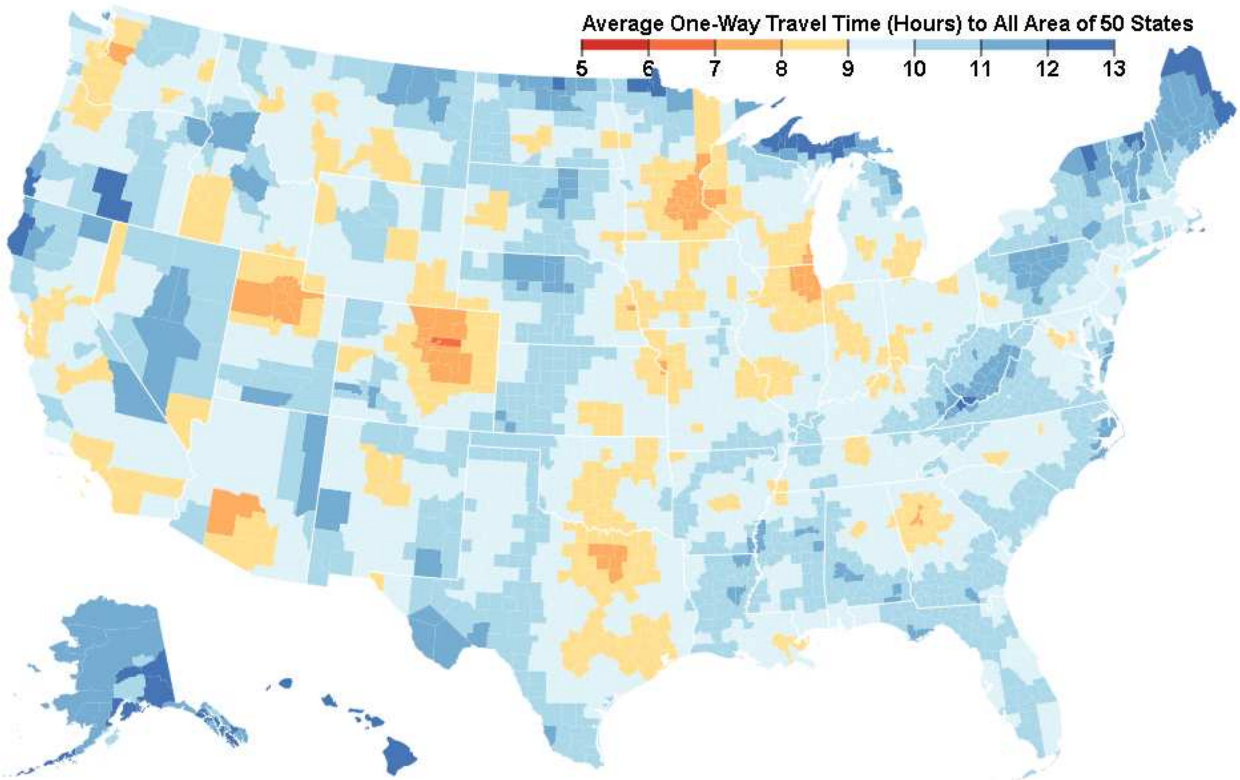

Figure 5: Average One-Way Travel Time to All Area of 50 States

Table 3 shows the top-10 most-connected locations when considering the area of all 50 states. The results in this table are similar to those in Table 1 with Adams County, CO, which contains the DEN airport, as the most-connected county. The Denver and Minneapolis metropolitan regions are again the most connected with the Salt Lake City, UT region replacing Dallas/Fort Worth in the top 10. These three metropolitan regions roughly surround the geographic center of the 50 U.S. states near Belle Fourche in Butte County, SD. As expected, counties in Alaska and Hawaii occupy most of the top-10 spots in the least-connected locations in the 50 U.S. states along with a county in northern Michigan and northern Maine. These counties are shown in Table 4.

Table 3: Top-10 Most-Connected Locations to/from All Area of 50 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Brighton, Adams County, CO	6.94
2.	Saint Paul, Ramsey County, MN	7.01
3.	Denver, Denver County, CO	7.04
4.	Minneapolis, Hennepin County, MN	7.06
5.	Broomfield, Broomfield County, CO	7.08
6.	Golden, Jefferson County, CO	7.17
7.	Littleton, Arapahoe County, CO	7.19
8.	Castle Rock, Douglas County, CO	7.23
9.	Salt Lake City, Salt Lake County, UT	7.23
10.	Shakopee, Scott County, MN	7.24

Table 4: Top-10 Least-Connected Locations to/from All Area of 50 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Valdez, Valdez-Cordova Census Area, AK	16.03
2.	Hilo, Hawaii County, HI	15.02
3.	Craig, Prince of Wales-Hyder Census Area, AK	14.36
4.	Hoonah, Hoonah-Angoon Census Area, AK	14.19
5.	Hooper Bay, Wade Hampton Census Area, AK	14.05
6.	Lihue, Kauai County, HI	14.04
7.	Eagle River, Keweenaw County, MI	13.70
8.	Wailuku, Maui County, HI	13.34
9.	Kalaupapa, Kalawao County, HI	13.16
10.	Machias, Washington County, ME	13.04

3.4 Population Connectivity

Results in Section 3.3 focus on connectivity based on geographic area. The availability of 2010 population for each of the counties also allows us to analyze connectivity based on population. This approach allows us to generate the average travel time to and from anywhere in the United States to every person in the U.S.

Figure 6 shows the average one-way travel to the population of the continental 48 states. It uses the same scale as Figure 4 and given that the averages for each county tend to be smaller (more red in color) indicates the average one-way travel time to population is less than to geographic area. This difference is confirmed where the average travel time from all area of the continental 48 states to the population of these states is 8.24 hours, which is less than the 9.06 hours average travel time to the area of the continental 48 states. The figure also shows that the eastern half of the U.S. tends to have better connectivity to all population than locations in the western U.S., which is not surprising given that the geometric median of the U.S. population is in southern Indiana.

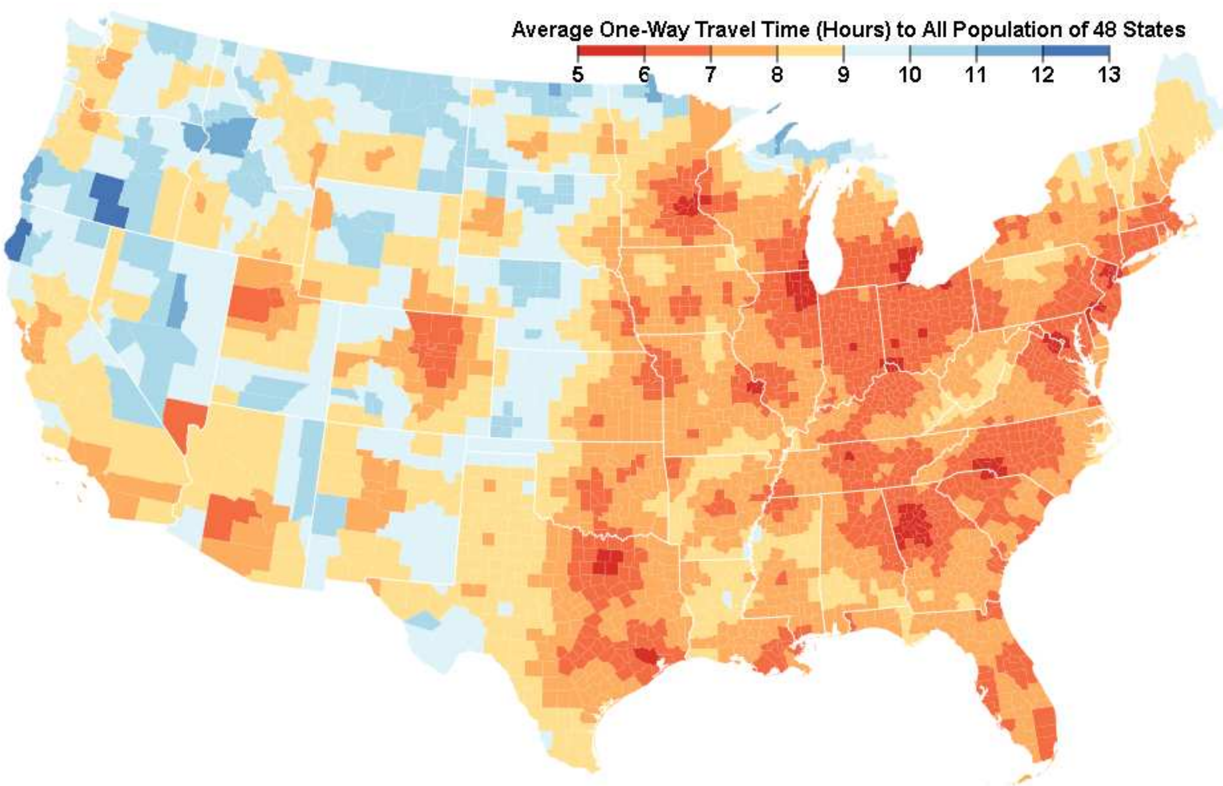

Figure 6: Average One-Way Travel Time to All Population of 48 States

Table 5 shows the top-10 best connected locations to all population of the continental 48 states. Compared with Table 1, the table shows Fulton County, which contains the ATL airport, and its surrounding counties having the best connectivity. Counties in and around Chicago also have top connectivity. In addition, Mecklenberg County containing the CLT airport in Charlotte and Washington, D.C with nearby access to DCA and IAD airports also have top-10 connectivity.

Table 6 again shows that many of the least-connected counties to area in Table 2 also have

Table 5: Top-10 Most-Connected Locations to/from All Population of 48 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Atlanta, Fulton County, GA	5.23
2.	Chicago, Cook County, IL	5.29
3.	Jonesboro, Clayton County, GA	5.34
4.	Decatur, DeKalb County, GA	5.41
5.	Charlotte, Mecklenburg County, NC	5.47
6.	Wheaton, DuPage County, IL	5.48
7.	Fayetteville, Fayette County, GA	5.50
8.	Washington, District of Columbia, DC	5.52
9.	Marietta, Cobb County, GA	5.54
10.	Douglasville, Douglas County, GA	5.55

relatively poor connectivity to population. Humboldt County in northern California is the least-connected county with other counties in remote locations of Oregon, Michigan, Idaho, Minnesota and North Dakota.

Table 6: Top-10 Least-Connected Locations to/from All Population of 48 States

Rank	City, County, State	Ave. One-Way Travel Time (Hr)
1.	Eureka, Humboldt County, CA	12.04
2.	Lakeview, Lake County, OR	12.00
3.	Eagle River, Keweenaw County, MI	11.91
4.	Gold Beach, Curry County, OR	11.70
5.	Enterprise, Wallowa County, OR	11.39
6.	Grangeville, Idaho County, ID	11.36
7.	Coquille, Coos County, OR	11.29
8.	Houghton, Houghton County, MI	11.23
9.	Baudette, Lake of the Woods County, MN	11.22
10.	Rolla, Rolette County, ND	11.14

As done for area with Figure 5, Figure 7 shows the travel time map for all 50 states with the inclusion of Alaska and Hawaii. The average travel time from all area of the 50 states to the population of all states is 9.05 hours. Again, counties in Alaska and Hawaii have poor connectivity to the U.S. population because of their remoteness and relatively little population themselves. The top-10 most-connected counties remain unchanged from Table 5 and are not shown. The top-10 least-connected counties to population are all in Alaska and Hawaii and not shown.

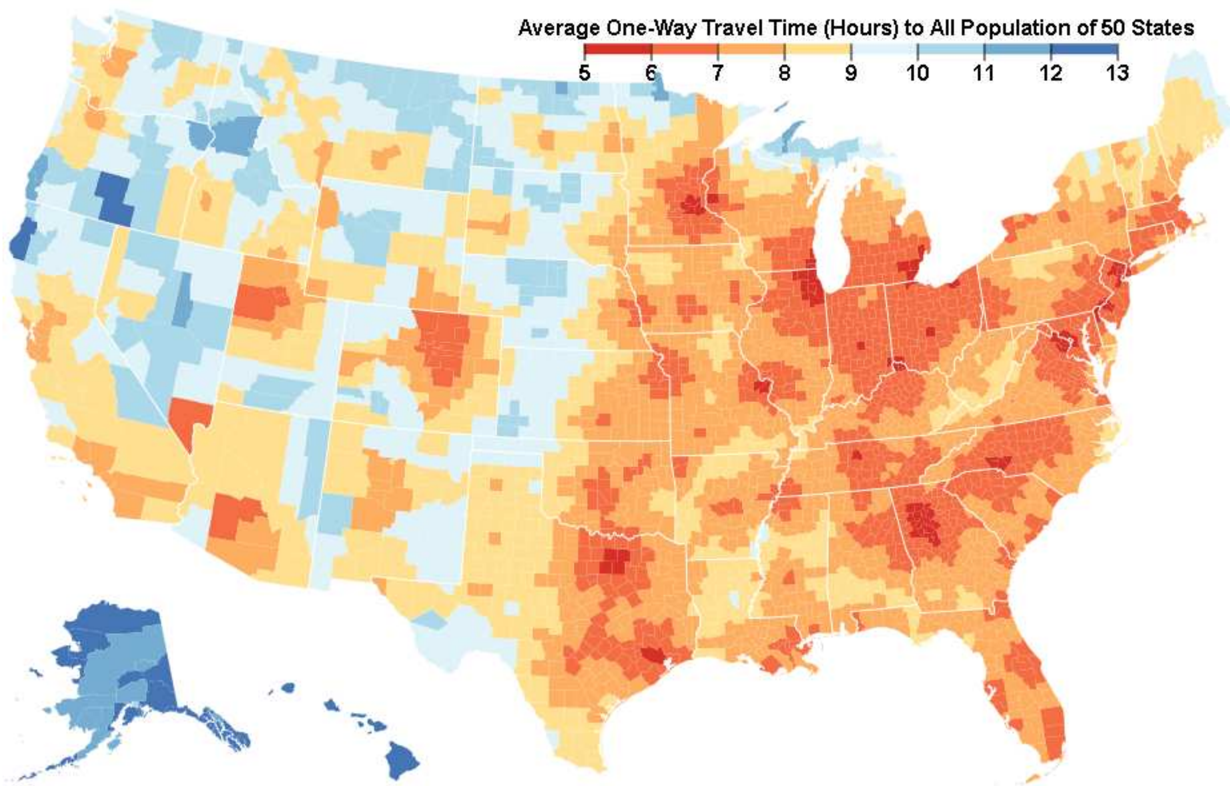

Figure 7: Average One-Way Travel Time to All Population of 50 States

3.5 Travel Time Relative to Distance

Our gathered data allows us to explore other measures related to connectivity, For example, it naturally happens that centrally-located counties have lower average travel times while counties on the edges of the U.S. borders tend to have higher average travel times. This observation leads to computing, for each county, how the average distance to all geographic area compares with average travel time. For this analysis we only consider the continental 48 states.

Table 7 shows the top-10 locations with the highest ratio of average distance to average travel time. These locations tend to be relatively far in distance from the area of the 48 states, but with relatively better travel time. As shown, Suffolk County, containing Boston, has the best ratio. Other nearby counties are included in the top 10. Other relatively well-connected locations compared to average distance are in southern Florida, around San Francisco and in northern New Jersey.

Table 7: Top-10 Most-Connected Locations Relative to Distance All Area of 48 States

Rank	City, County, State	Ave. Distance/Travel Time (Miles/Hr)
1.	Boston, Suffolk County, MA	179.93
2.	Miami, Miami-Dade County, FL	179.13
3.	Cambridge, Middlesex County, MA	175.99
4.	San Francisco, San Francisco County, CA	174.41
5.	Salem, Essex County, MA	174.01
6.	Fort Lauderdale, Broward County, FL	173.45
7.	Dedham, Norfolk County, MA	172.29
8.	Elizabeth, Union County, NJ	171.71
9.	Redwood City, San Mateo County, CA	171.61
10.	Newark, Essex County, NJ	171.59

In contrast, Table 8 shows the top-10 locations with the worst ratio of average distance to average travel time. These locations tend to be centrally located, but with not such good average travel time. All but one county is in Nebraska with the other in Kansas.

Table 8: Top-10 Least-Connected Locations Relative to Distance All Area of 48 States

Rank	City, County, State	Ave. Distance/Travel Time (Miles/Hr)
1.	Ainsworth, Brown County, NE	72.09
2.	Bassett, Rock County, NE	72.38
3.	Brewster, Blaine County, NE	72.82
4.	Taylor, Loup County, NE	73.35
5.	Springview, Keya Paha County, NE	74.08
6.	Johnson, Stanton County, KS	74.21
7.	Franklin, Franklin County, NE	74.34
8.	Mullen, Hooker County, NE	74.35
9.	Stockville, Frontier County, NE	74.59
10.	Burwell, Garfield County, NE	74.63

We next repeat the same analysis, but rather than consider average distance and travel time to geographic area, we do so for population. We again restrict our analysis to the continental 48 states. Table 9 shows the top-10 locations with the best ratio of average distance to average travel time to all population With the smallest average distance to the population in southern Indiana, the table shows the locations with the best ratios are near San Francisco, Seattle, Portland (OR) and Los Angeles.

Table 9: Top-10 Most-Connected Locations Relative to Distance All Population of 48 States

Rank	City, County, State	Ave. Distance/Travel Time (Miles/Hr)
1.	San Francisco, San Francisco County, CA	239.01
2.	Redwood City, San Mateo County, CA	235.37
3.	Seattle, King County, WA	230.49
4.	Oakland, Alameda County, CA	228.91
5.	San Jose, Santa Clara County, CA	228.72
6.	Vancouver, Clark County, WA	227.98
7.	Portland, Multnomah County, OR	226.36
8.	Tacoma, Pierce County, WA	225.40
9.	Los Angeles, Los Angeles County, CA	224.70
10.	San Rafael, Marin County, CA	224.47

In contrast, Table 10 shows the top-10 locations with the worst ratio of average distance to average travel time. These locations are more varied with three counties in the Upper Peninsula of Michigan as well as in Mississippi, Missouri, Arkansas and Nebraska.

Table 10: Top-10 Least-Connected Locations Relative to Distance All Population of 48 States

Rank	City, County, State	Ave. Distance/Travel Time (Miles/Hr)
1.	Houghton, Houghton County, MI	88.67
2.	Rosedale, Bolivar County, MS	92.64
3.	Alton, Oregon County, MO	92.85
4.	Salem, Fulton County, AR	92.89
5.	Ontonagon, Ontonagon County, MI	93.45
6.	Marquette, Marquette County, MI	94.11
7.	Brewster, Blaine County, NE	94.47
8.	Mountain Home, Baxter County, AR	94.57
9.	L'Anse, Baraga County, MI	94.66
10.	Bassett, Rock County, NE	94.69

These results highlight locations that have relatively better or worse connectivity than would be predicted based solely on their location within the U.S. They provide another perspective on connectivity by seeking to factor out the relative distance to other locations in the travel time calculation.

3.6 Prevalence in Mode of Transportation

A final analysis approach we explore with our data is to examine the prevalence that each mode of transportation is taken. Conceptually, we assume that a random person in the United States wants to visit all other people in the U.S. with equal likelihood. For this analysis we consider all 50 states, but only focus on visiting the population (vs. area), and only consider mode of transportation *from* a location.

3.6.1 Prevalence of Driving

We first consider how often the shortest travel time for one person to visit another is done by driving from one location to the other. Across all locations in the U.S., driving as the only mode is used in 8.7% of the situations. For example, for Smith County, KS, shown in Figure 2, 9.1% of the U.S. population is best reached via driving. However, there is much variation across county locations in the prevalence that driving is used to reach the U.S. population. At one extreme, Table 11 show the top-10 locations where driving is most often used to minimize the travel time.

Table 11: Top-10 Locations Most Using Driving to Reach Population of 50 States

Rank	City, County, State	% Drive Mode
1.	Clearfield, Clearfield County, PA	27.50
2.	Brookville, Jefferson County, PA	25.99
3.	Ridgway, Elk County, PA	25.47
4.	Hollidaysburg, Blair County, PA	24.27
5.	Lock Haven, Clinton County, PA	24.11
6.	Bedford, Bedford County, PA	24.03
7.	Bellefonte, Centre County, PA	24.00
8.	Emporium, Cameron County, PA	23.60
9.	Huntingdon, Huntingdon County, PA	23.46
10.	McConnellsburg, Fulton County, PA	22.98

As shown, these are locations in central Pennsylvania that are relatively close to much population, but not as relatively close to an airport for air travel.

At the other extreme, most counties in Alaska and Hawaii require flying to reach other population. Ignoring counties in these two states, Table 12 show the top 10 locations where driving is least often used to travel. These are locations relatively far from most population, but relatively close to an airport for air travel. Departing from Key West, Florida travel time to virtually all locations is minimized by flying from the EYW airport. Other locations are in the western U.S. where the population within driving distance is small, but there is a relatively close airport to reach most of the U.S. population.

3.6.2 Transition From Driving to Flying

Another interesting question in terms of mode of transportation is how far from a location one must travel before the transition from driving to flying occurs. Obviously the answer to this question

Table 12: Top-10 Locations (Ignoring Alaska and Hawaii) Least Using Driving to Reach Population of 50 States

Rank	City, County, State	% Drive Mode
1.	Key West, Monroe County, FL	0.02
2.	Williston, Williams County, ND	0.69
3.	Grand Junction, Mesa County, CO	0.71
4.	Great Falls, Cascade County, MT	0.71
5.	Plentywood, Sheridan County, MT	0.71
6.	Conrad, Pondera County, MT	0.72
7.	Billings, Yellowstone County, MT	0.72
8.	Shelby, Toole County, MT	0.73
9.	Fort Benton, Chouteau County, MT	0.74
10.	Roundup, Musselshell County, MT	0.75

varies by location and even by direction of travel from a location. However to gain some insight into this transition we computed two values for each of the 3143 county locations in our dataset. The first value (MaxDrive) is the maximum travel time from the location to another location where the mode of transportation is driving. The second value (MinFly) is the minimum travel time from the location to another location where the mode of transportation is flying. We then sorted each of these sets of values and created a cumulative distribution function (CDF) for each value. Plots of the CDFs are shown in Figure 8.

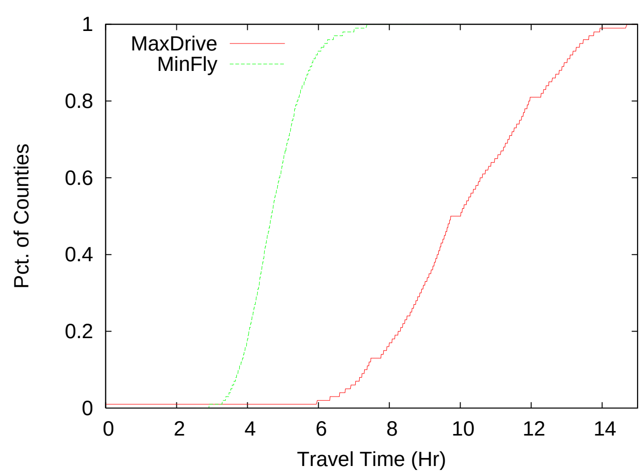

Figure 8: Cumulative Distribution Function for Transition From Driving to Flying By County

The 0.5-level on the y-axis in a CDF represents the median of the given value. Thus the figure shows the median for the minimum fly time value across all counties is 4.7 hours with 75% of minimum fly times between 4 and 6 hours. Similarly, the figure shows the median value for the maximum drive time across all counties is 9.9 hours with 65% of maximum drive times between 8 and 12 hours. These ranges provide rough insight on the transition where most travel less than 4 hours is done by driving and most over 12 hours is done by flying.

3.6.3 Flying as Mode of Transportation

With 8.7% of the population best reached by driving, that means 91.3% of the population is best reached by flying from an airport. Our data allow us to analyze which airports are most often used as this mode of transportation. The frequency that an airport is used depends on many factors such as size of the population served by the airport, the availability of other airports, the relative frequency that flying is needed, and the quality of the available flight connections. For example, again looking at the airports used for Smith County, KS in Figure 2 we find that 1.5% of the U.S. population is best reached via the DEN airport, 36.0% via OMA and 53.5% via the ICT airport. These results indicate the ICT airport is the primary airport for Smith County as it is used to reach the largest segment of the U.S. population.

Extending this analysis to each county, we determine the percentage of the U.S. population that is reached via each of the airports. Table 13 shows the top-20 airports for originating flights to the highest percentage of the U.S. population. As shown, ORD and LAX are the two airports serving the highest percentage of the U.S. population flying to reach other population.

Table 13: Top-20 Airports as Initial Mode of Transportation to Reach Population of 50 States

Origination			Boardings	
Rank	Airport	%	Rank	# (M)
1.	ORD	3.72	3	36.31
2.	LAX	3.70	2	36.35
3.	ATL	2.91	1	49.34
4.	DFW	2.57	4	31.59
5.	EWR	2.38	15	18.68
6.	DTW	2.38	18	16.26
7.	PHL	2.31	19	15.10
8.	BOS	2.27	17	16.29
9.	SFO	2.19	7	24.19
10.	CLT	1.87	8	21.91
11.	IAH	1.87	12	20.60
12.	MSP	1.87	16	17.63
13.	PHX	1.68	10	21.35
14.	JFK	1.66	5	27.78
15.	LGA	1.66	20	14.32
16.	SEA	1.58	13	20.15
17.	DEN	1.48	6	26.28
18.	MCO	1.40	14	18.76
19.	STL	1.36	32	6.24
20.	PIT	1.25	47	3.89

As comparison, Table 13 also shows the ranking and number of boardings for each airport from Appendix A. As shown, airports (e.g. EWR in Newark, DFW in Detroit, PHL in Philadelphia and

BOS in Boston) originate flight travel relatively more frequently than total number of boardings. In contrast, airports such as JFK in New York, DEN in Denver, LAS in Las Vegas (ranked 41st for originations, but 9th in boardings) and MIA in Miami (ranked 38th for originations, but 11th in boardings) have relatively more boardings than originations. Reasons for these differences could be airports with a relatively large number of transfers, such as DEN, travel destinations, such as LAS or MIA, and a higher proportion of international travel such as JFK and MIA.

3.6.4 Airport Catchment Areas

The mode of transportation results also determine the primary airport for each county, which is the airport used to reach the largest segment of the U.S. population. Figure 9 shows the primary airport for each county where the collective results define the geographic region of influence for each airport.

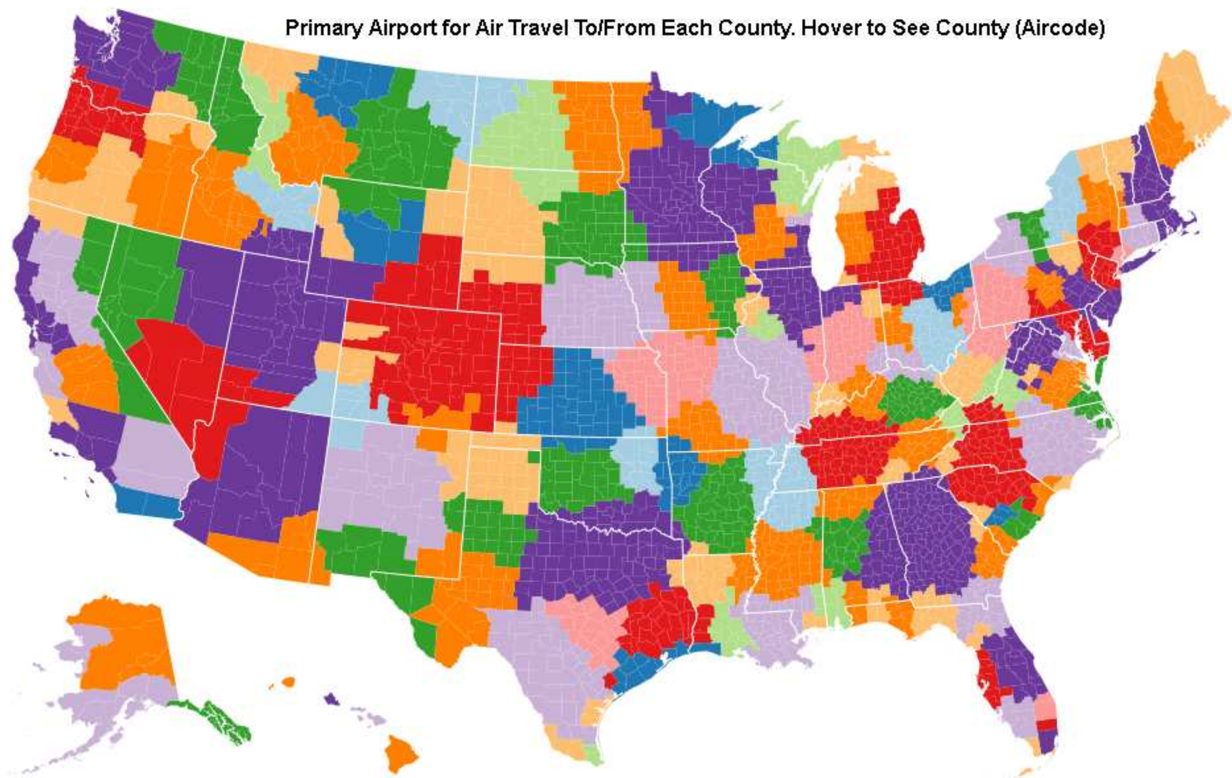

Figure 9: Catchment Area for Each Primary Commercial Airport

While not immediately evident in the figure because of the difference in scale, the ANC and FAI airports in Alaska serve the largest geographic areas for reaching the U.S. population. Within the continental U.S., the DEN, SLC, MSP, PHX and ABQ airports serve the largest geographic areas in the absence of nearby airports. The SLC and ABQ airports are notable in serving large geographic areas despite ranking 31st and 58th in total boardings. Metropolitan regions with multiple airports, such as New York or Miami, have a relatively small geographic "catch basin," although serve a relatively larger number of people.

The presence of an airport in a county also does not guarantee that the airport is designated as primary based upon our results. For example, Hillsborough County, NH is home of the MHT airport, but as shown in Figure 9 the primary airport for this county (and all counties in NH) is BOS with 61.2% of the U.S. population best reached by this airport versus 32.3% for MHT. Similarly, Milwaukee County, WI, containing MKE airport has ORD as the primary airport with 51.3% of the population best reached via it versus 41.0% for MKE. Interestingly, Manitowoc County, WI, which is a bit north of MKE shows it as primary with 36.5% of the population best reached via it, with 35.8% from ORD and 20.3% from GRB in Green Bay.

The region of influence results shown in Figure 9 reflect many factors including the frequency in which driving only is the best option, the number of available airports in a region and the quality of the available flight connections. The edges between airport regions are also not as sharp as indicated in the figure where each county is associated with a single airport. In reality, people in counties at the edges between regions use multiple airports because there is not a clear best choice for air travel to all locations and the flight may be include a long drive to/from the airport.

In all, Figure 9 divides the U.S. into 155 distinct regions based on the primary airport for each county. This result means that 27 of the 182 airports considered in our work do not serve as the primary airport for any county in the U.S. These 27 airports are the mode of transportation for some locations, but nearby larger and better-connected airports result in shorter travel time for more of locations.

4 Summary and Future Work

This work takes a comprehensive approach to compute, analyze and visualize multi-modal time travel maps from any location in the United States to any other. The comprehensive aspect of the work allows us to compute the relative connectivity, to either geographic area or population, for all locations in the U.S.

The results demonstrate that while concepts such as geographic and population centers are relatively easy to compute, they are based on the premise that it is equally easy to travel between any two points equidistant from each other. Our results show that for the U.S., and for any geographic region, locations are connected by land via a network of roads and by air via a network of airports and air routes.

Our work is unique in that we consider each of these transportation networks allowing interesting and enlightening analysis on the connectivity of the nation. Centralized regions near major airports such as Denver, Minneapolis/St. Paul and Dallas/Fort-Worth have the best connectivity to the geographic area of the continental 48 states with locations around the edges of the U.S. generally having the worst connectivity. Extending this analysis to all 50 states, shows the regions of Denver, Minneapolis/St. Paul and Salt Lake City with the best connectivity and locations in Alaska and Hawaii with the worst.

The best connectivity to the population of the continental 48 and all 50 states is in the Atlanta metropolitan region with the regions of Chicago, Charlotte and Washington, DC also having relatively shorter average travel times to the U.S. population.

The results also allow the mode of transportation to be determined with roughly 9% of the U.S. population reaching the remainder of the U.S. population in minimal travel time by driving. The remaining 91% of trips include an airline flight with ORD and LAX the most likely airports for origination of flights. networks allowing interesting and enlightening analysis on the connectivity of the nation. Centralized regions near major airports such as Denver, Minneapolis/St. Paul and Dallas/Fort-Worth have the best connectivity to the geographic area of the continental 48 states with locations around the edges of the U.S. generally having the worst connectivity. Extending this analysis to all 50 states, shows the regions of Denver, Minneapolis/St. Paul and Salt Lake City with the best connectivity and locations in Alaska and Hawaii with the worst.

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The results also allow the mode of transportation to be determined with roughly 9% of the U.S. population reaching the remainder of the U.S. population in minimal travel time by driving. The remaining 91% of trips include an airline flight with ORD (Chicago) and LAX (Los Angeles) the most likely airports for origination of flights. Determining the primary airport for each county, used to reach the largest segment of the U.S. population, allows us to divide the U.S. into catchment areas for each airport. In addition to being the basis for the best connectivity, DEN, SLC and MSP serve as the primary airport for the largest geographic areas within the continental U.S. due to the absence of nearby airports.

While the work is interesting and valuable for exploring real-life geographical relationships, there are additional considerations that could be taken into account. The trade-off between driving or flying to a location could be further examined. When flying we add in drive time on each end of the trip as well as a two-hour “wait” time. In the best case, this total time may be accurate, but not all flight-based trips will have this best time. These trips must also be taken on a schedule and often purchased in advance, where a driving-only trip is much more flexible. We could extend the analysis to consider cost by selecting the lowest cost airline option instead of the shortest duration.

The choice of airports to consider also influences the results, particularly for locations that are a significant driving distance from an airport. In some of these locations, the inclusion of smaller airports (based on number of passengers) would improve the relative connectivity of these locations, although the availability of flights from these smaller airports is still likely to be limited leading to larger travel times. We could also include airports across the border, particularly in Canada, although we would then need to account for expected time to cross the border via driving.

In addition to potential improvements, the results of this work also point to two directions for future work. The first is to examine virtual connectivity to determine regions that have relatively better or worse Internet connectivity. While likely not as varied as what we found for physical connectivity, not all areas have the same access to the Internet.

The second direction is to examine world-wide connectedness. Again this connectivity can be computed for both the physical and virtual world. It is likely to show more variation and even more important to understand on a global scale.

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A Commercial Airports

Tables 14-19 provide information on the 182 U.S. airports in the 50 U.S. states considered for air travel in this project. As described in the body of the report, the airports are divided into four categories based on number of boardings in 2015. There are 30 Large, 29 Medium, 69 Small and 54 Smaller airports.

Table 14: U.S. Large Category Commercial Airports

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
1	ATL	Hartsfield - Jackson Atlanta Int'l	Atlanta, GA	49.34
2	LAX	Los Angeles Int'l	Los Angeles, CA	36.35
3	ORD	Chicago O'Hare Int'l	Chicago, IL	36.31
4	DFW	Dallas-Fort Worth Int'l	Fort Worth, TX	31.59
5	JFK	John F Kennedy Int'l	New York, NY	27.78
6	DEN	Denver Int'l	Denver, CO	26.28
7	SFO	San Francisco Int'l	San Francisco, CA	24.19
8	CLT	Charlotte/Douglas Int'l	Charlotte, NC	21.91
9	LAS	McCarran Int'l	Las Vegas, NV	21.86
10	PHX	Phoenix Sky Harbor Int'l	Phoenix, AZ	21.35
11	MIA	Miami Int'l	Miami, FL	20.99
12	IAH	George Bush Inter'l/Houston	Houston, TX	20.60
13	SEA	Seattle-Tacoma Int'l	Seattle, WA	20.15
14	MCO	Orlando Int'l	Orlando, FL	18.76
15	EWR	Newark Liberty Int'l	Newark, NJ	18.68
16	MSP	Minn-StPaul Int'l/Wold-Chamberlain	Minneapolis, MN	17.63
17	BOS	Gen. Edward Lawrence Logan Int'l	Boston, MA	16.29
18	DTW	Detroit Metropolitan Wayne County	Detroit, MI	16.26
19	PHL	Philadelphia Int'l	Philadelphia, PA	15.10
20	LGA	Laguardia	New York, NY	14.32
21	FLL	Fort Lauderdale/Hollywood Int'l	Fort Lauderdale, FL	13.06
22	BWI	Balt./Wash. Int'l Thurgood Marshall	Glen Burnie, MD	11.74
23	DCA	Ronald Reagan Washington Nat'l	Arlington, VA	11.24
24	MDW	Chicago Midway Int'l	Chicago, IL	10.83
25	SLC	Salt Lake City Int'l	Salt Lake City, UT	10.63
26	IAD	Washington Dulles Int'l	Dulles, VA	10.36
27	SAN	San Diego Int'l	San Diego, CA	9.99
28	HNL	Honolulu Int'l	Honolulu, HI	9.48
29	TPA	Tampa Int'l	Tampa, FL	9.15
30	PDX	Portland Int'l	Portland, OR	8.34

Table 15: U.S. Medium Category Commerical Airports

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
31	DAL	Dallas Love Field	Dallas, TX	7.04
32	STL	Lambert-St Louis Int’l	St. Louis, MO	6.24
33	HOU	William P Hobby	Houston, TX	5.94
34	AUS	Austin-Bergstrom Int’l	Austin, TX	5.80
35	BNA	Nashville Int’l	Nashville, TN	5.72
36	OAK	Metropolitan Oakland Int’l	Oakland, CA	5.51
37	MSY	Louis Armstrong New Orleans Int’l	Metairie, LA	5.33
38	MCI	Kansas City Int’l	Kansas City, MO	5.14
39	RDU	Raleigh-Durham Int’l	Raleigh, NC	4.95
40	SNA	John Wayne Airport-Orange County	Santa Ana, CA	4.95
41	SJC	Norman Y Mineta San Jose Int’l	San Jose, CA	4.82
42	SMF	Sacramento Int’l	Sacramento, CA	4.71
44	RSW	Southwest Florida Int’l	Fort Myers, FL	4.16
45	SAT	San Antonio Int’l	San Antonio, TX	4.09
46	CLE	Cleveland-Hopkins Int’l	Cleveland, OH	3.92
47	PIT	Pittsburgh Int’l	Pittsburgh, PA	3.89
48	IND	Indianapolis Int’l	Indianapolis, IN	3.89
49	CMH	Port Columbus Int’l	Columbus, OH	3.31
50	MKE	General Mitchell Int’l	Milwaukee, WI	3.23
51	OGG	Kahului	Kahului, HI	3.22
52	PBI	Palm Beach Int’l	West Palm Beach, FL	3.11
53	CVG	Cincinnati/Northern Kentucky Int’l	Hebron, KY	3.05
54	BDL	Bradley Int’l	Windsor Locks, CT	2.93
55	JAX	Jacksonville Int’l	Jacksonville, FL	2.72
56	ANC	Ted Stevens Anchorage Int’l	Anchorage, AK	2.53
57	BUF	Buffalo Niagara Int’l	Buffalo, NY	2.34
58	ABQ	Albuquerque Int’l Sunport	Albuquerque, NM	2.32
59	ONT	Ontario Int’l	Ontario, CA	2.09
60	OMA	Eppley Airfield	Omaha, NE	2.05

Table 16: U.S. Small Category Commercial Airports (1 of 2)

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
61	BUR	Bob Hope	Burbank, CA	1.97
62	MEM	Memphis Int'l	Memphis, TN	1.87
63	OKC	Will Rogers World	Oklahoma City, OK	1.80
64	PVD	Theodore Francis Green State	Warwick, RI	1.76
65	RIC	Richmond Int'l	Highland Springs, VA	1.74
66	CHS	Charleston AFB/Int'l	Charleston, SC	1.67
67	RNO	Reno/Tahoe Int'l	Reno, NV	1.67
68	SDF	Louisville Int'l-Standiford Field	Louisville, KY	1.64
69	TUS	Tucson Int'l	Tucson, AZ	1.55
70	GEG	Spokane Int'l	Spokane, WA	1.52
71	ORF	Norfolk Int'l	Norfolk, VA	1.52
72	LIH	Lihue	Lihue, HI	1.49
73	BOI	Boise Air Terminal/Gowen Field	Boise, ID	1.49
74	KOA	Kona Int'l at Keahole	Kailua Kona, HI	1.49
76	ELP	El Paso Int'l	El Paso, TX	1.38
77	TUL	Tulsa Int'l	Tulsa, OK	1.36
78	BHM	Birmingham-Shuttlesworth Int'l	Birmingham, AL	1.33
79	GRR	Gerald R Ford Int'l	Grand Rapids, MI	1.28
80	ALB	Albany Int'l	Albany, NY	1.28
81	LGB	Long Beach /Daugherty Field/	Long Beach, CA	1.22
82	SFB	Orlando Sanford Int'l	Sanford, FL	1.21
83	ROC	Greater Rochester Int'l	Rochester, NY	1.18
84	DSM	Des Moines Int'l	Des Moines, IA	1.16
85	DAY	James M Cox Dayton Int'l	Dayton, OH	1.04
86	MHT	Manchester	Manchester, NH	1.03
87	SYR	Syracuse Hancock Int'l	Syracuse, NY	0.99
88	SAV	Savannah/Hilton Head Int'l	Savannah, GA	0.98
89	LIT	B&H Clinton National/Adams Field	Little Rock, AR	0.96
90	GSP	Greenville Spartanburg Int'l	Greer, SC	0.96
91	PSP	Palm Springs Int'l	Palm Springs, CA	0.95
92	MYR	Myrtle Beach Int'l	Myrtle Beach, SC	0.90
93	PWM	Portland Int'l Jetport	Portland, ME	0.86
94	TYS	McGhee Tyson	Alcoa, TN	0.85
95	GSO	Piedmont Triad Int'l	Greensboro, NC	0.85

Table 17: More U.S. Small Category Commercial Airports (2 of 2)

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
96	MSN	Dane County Regional-Truax Field	Madison, WI	0.83
97	PIE	St Pete-Clearwater Int’l	Clearwater, FL	0.82
98	PNS	Pensacola Int’l	Pensacola, FL	0.79
99	ICT	Wichita D.D. Eisenhower Nat’l	Wichita, KS	0.77
100	CAK	Akron-Canton Regional	Akron, OH	0.76
101	HPN	Westchester County	White Plains, NY	0.76
103	FAT	Fresno Yosemite Int’l	Fresno, CA	0.70
104	IWA	Phoenix-Mesa Gateway	Mesa, AZ	0.67
105	XNA	Northwest Arkansas Regional	Bentonville, AR	0.63
106	ITO	Hilo Int’l	Hilo, HI	0.63
107	SRQ	Sarasota/Bradenton Int’l	Sarasota, FL	0.61
108	LEX	Blue Grass	Lexington, KY	0.61
109	ISP	Long Island MacArthur	Islip, NY	0.60
110	COS	City of Colorado Springs Municipal	Colorado Springs, CO	0.59
111	ACY	Atlantic City Int’l	Atlantic City, NJ	0.59
112	MDT	Harrisburg Int’l	Harrisburg, PA	0.59
113	BTV	Burlington Int’l	Burlington, VT	0.58
114	CID	The Eastern Iowa	Cedar Rapids, IA	0.56
115	CAE	Columbia Metropolitan	Columbia, SC	0.53
116	HSV	Huntsville Int’l-Carl T Jones Field	Huntsville, AL	0.52
117	MAF	Midland Int’l	Midland, TX	0.52
118	BZN	Bozeman Yellowstone Int’l	Bozeman, MT	0.51
119	JAN	Jackson-Medgar Wiley Evers Int’l	Jackson, MS	0.50
120	FSD	Joe Foss Field	Sioux Falls, SD	0.49
121	FAI	Fairbanks Int’l	Fairbanks, AK	0.49
123	SGF	Springfield-Branson National	Springfield, MO	0.45
124	EUG	Mahlon Sweet Field	Eugene, OR	0.45
125	BLI	Bellingham Int’l	Bellingham, WA	0.45
126	LBB	Lubbock Preston Smith Int’l	Lubbock, TX	0.44
127	FAR	Hector Int’l	Fargo, ND	0.44
128	ECP	Northwest Florida Beaches Int’l	Panama City, FL	0.43
129	PGD	Punta Gorda	Punta Gorda, FL	0.42
130	BIL	Billings Logan Int’l	Billings, MT	0.42
131	FNT	Bishop Int’l	Flint, MI	0.41
132	JNU	Juneau Int’l	Juneau, AK	0.40

Table 18: U.S. Smaller Category Commercial Airports (1 of 2)

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
133	CHA	Lovell Field	Chattanooga, TN	0.39
134	AVL	Asheville Regional	Asheville, NC	0.39
135	MFE	McAllen Miller Int'l	McAllen, TX	0.39
137	ILM	Wilmington Int'l	Wilmington, NC	0.39
138	VPS	Eglin AFB/Destin-Ft Walton Beach	Valparaiso, FL	0.37
139	MFR	Rogue Valley Int'l - Medford	Medford, OR	0.37
140	MLI	Quad City Int'l	Moline, IL	0.37
142	EYW	Key West Int'l	Key West, FL	0.36
143	FWA	Fort Wayne Int'l	Fort Wayne, IN	0.35
144	MSO	Missoula Int'l	Missoula, MT	0.35
145	PSC	Tri-Cities	Pasco, WA	0.35
146	AMA	Rick Husband Amarillo Int'l	Amarillo, TX	0.34
147	CRP	Corpus Christi Int'l	Corpus Christi, TX	0.34
148	TLH	Tallahassee Int'l	Tallahassee, FL	0.33
149	GCN	Grand Canyon National Park	Grand Canyon, AZ	0.33
150	ABE	Lehigh Valley Int'l	Allentown, PA	0.32
151	PIA	General Downing - Peoria Int'l	Peoria, IL	0.32
152	GPT	Gulfport-Biloxi Int'l	Gulfport, MS	0.32
153	SBA	Santa Barbara Municipal	Santa Barbara, CA	0.32
154	SBN	South Bend Int'l	South Bend, IN	0.32
155	JAC	Jackson Hole	Jackson, WY	0.31
156	DAB	Daytona Beach Int'l	Daytona Beach, FL	0.31
157	ROA	Roanoke-Blacksburg/Woodrum Field	Roanoke, VA	0.30
158	SHV	Shreveport Regional	Shreveport, LA	0.30

Table 19: More U.S. Smaller Category Commercial Airports (2 of 2)

Rank	Airport	Airport Name	City, ST	2015 Boardings (M)
159	GRB	Green Bay-Austin Straubel Int’l	Green Bay, WI	0.30
160	RDM	Roberts Field	Redmond, OR	0.28
161	MOB	Mobile Regional	Mobile, AL	0.28
162	CHO	Charlottesville-Albemarle	Charlottesville, VA	0.27
163	BGR	Bangor Int’l	Bangor, ME	0.27
164	AGS	Augusta Regional at Bush Field	Augusta, GA	0.27
165	RAP	Rapid City Regional	Rapid City, SD	0.26
166	BIS	Bismarck Municipal	Bismarck, ND	0.26
167	HRL	Valley Int’l	Harlingen, TX	0.26
168	ATW	Appleton Int’l	Appleton, WI	0.26
169	LFT	Lafayette Reg/Paul Fournet Field	Lafayette, LA	0.24
170	FCA	Glacier Park Int’l	Kalispell, MT	0.24
171	BVU	Boulder City Municipal	Boulder City, NV	0.23
172	ASE	Aspen-Pitkin County/Sardy Field	Aspen, CO	0.23
173	CRW	Yeager	Charleston, WV	0.23
174	MLB	Melbourne Int’l	Melbourne, FL	0.22
175	FAY	Fayetteville Regional/Grannis Field	Fayetteville, NC	0.22
176	AVP	Wilkes-Barre/Scranton Int’l	Avoca, PA	0.22
177	TRI	Tri-Cities Regional TN/VA	Blountville, TN	0.22
178	GJT	Grand Junction Regional	Grand Junction, CO	0.21
179	GNV	Gainesville Regional	Gainesville, FL	0.21
180	TVC	Cherry Capital	Traverse City, MI	0.21
181	EVV	Evansville Regional	Evansville, IN	0.20
183	PHF	Newport News/Williamsburg Int’l	Newport News, VA	0.20
184	DRO	Durango-La Plata County	Durango, CO	0.19
186	GTF	Great Falls Int’l	Great Falls, MT	0.18
201	IDA	Idaho Falls Regional	Idaho Falls, ID	0.15
209	DLH	Duluth I’l	Duluth, MN	0.13
223	CPR	Casper/Natrona County Int’l	Casper, WY	0.10
225	ISN	Sloulin Field Int’l	Williston, ND	0.10