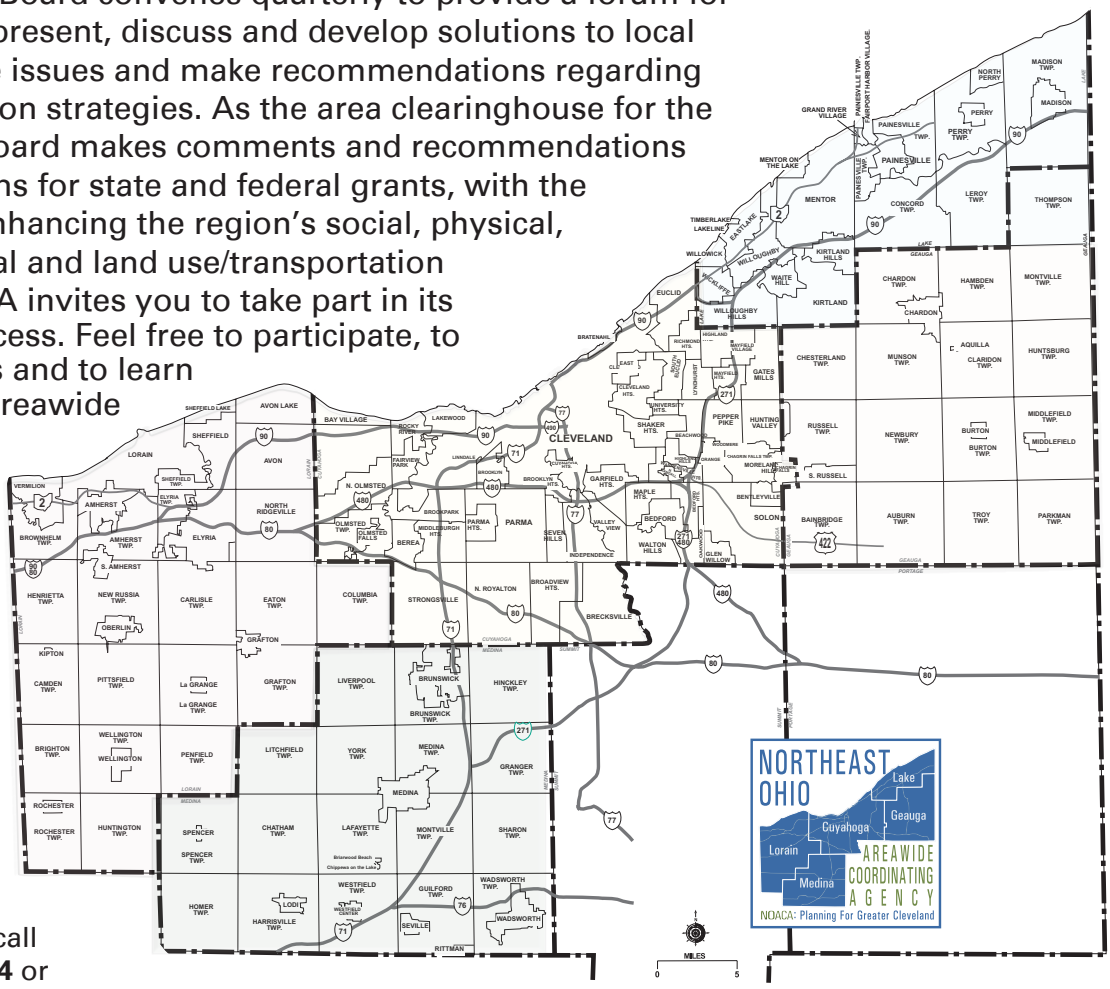
WORKFORCE ACCESSIBILITY AND MOBILITY

November 2019

The Northeast Ohio Areawide Coordinating Agency (NOACA) is a public organization serving the counties of and municipalities and townships within Cuyahoga, Geauga, Lake, Lorain and Medina (covering an area with 2.1 million people). NOACA is the agency designated or recognized to perform the following functions:

- Serve as the Metropolitan Planning Organization (MPO), with responsibility for comprehensive, cooperative and continuous planning for highways, public transit, and bikeways, as defined in the current transportation law.
- Perform continuous water quality, transportation-related air quality and other environmental planning functions.
- Administer the area clearinghouse function, which includes providing local government with the opportunity to review a wide variety of local or state applications for federal funds.
- Conduct transportation and environmental planning and related demographic, economic and land use research.
- Serve as an information center for transportation and environmental and related planning.
- As directed by the Board, provide transportation and environmental planning assistance to the 172 units of local, general purpose government.

NOACA's Board of Directors is composed of 45 local public officials. The Board convenes quarterly to provide a forum for members to present, discuss and develop solutions to local and areawide issues and make recommendations regarding implementation strategies. As the area clearinghouse for the region, the Board makes comments and recommendations on applications for state and federal grants, with the purpose of enhancing the region's social, physical, environmental and land use/transportation fabric. NOACA invites you to take part in its planning process. Feel free to participate, to ask questions and to learn more about areawide planning.



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12) Abstracts Transportation access for workers to jobs is important to the economic vitality of a region, as well as a social equity issue with regards to environmental justice populations. Considering resource scarcity and expanded cities, the prioritization of employment centers is an urban and transportation policy and planning challenge and this study offers a mathematical model to overcome these challenges. Most research and databases present one-dimensional workforce information such as number of available workers, jobs, etc. in administrative or community jurisdictions such as villages, cities, states, etc. This study offers a novel approach for adding transportation measures as the second dimension to workforce information. Transportation agencies have traditionally used average travel times and travel time savings to measure system performance and benefits of their investments. This study establishes the workforce information based on work commute time geographies rather than those political or administrative jurisdictions. The commute time during the morning peak period is the most important concern for workers and combining travel time measure with workforce information provides a powerful transportation planning tool. Finally, the study also presents annual benefits of travel time and congestion savings for each percent of the worker-employer mismatch reduction and recommends a number of transportation and land use solutions to alleviate the overall strain to the transportation system that these mismatches cause.	
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Workforce Accessibility and Mobility

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Executive Summary

Transportation access for workers to jobs is important to the economic vitality of a region, and is a social equity issue with regards to environmental justice populations. The greater the access to employment by all modes of transportation for the population of a region, the more economically competitive a region will be in the global economy. When jobs are easier to access for all workers and also lower income and minority populations, the entire region improves socially and economically.

Optimal infrastructure investments, site selection for a job hub or extending the current employment centers and workforce accessibility and mobility are highly dependent on the land use characteristics and accessibility to transportation facilities of the employment centers. Considering resource scarcity and expanded cities, the prioritization of employment centers is an urban and transportation policy and planning challenge and this study offers a mathematical model to overcome these challenges.

Most researches and databases present one-dimensional workforce information such as the number of available workers, jobs, etc. in administrative or community jurisdictions such as villages, cities, states, etc. This study offers a novel approach for adding modal travel time measures as the second dimension to workforce information.

In order to measure job accessibility in the NOACA region, a methodology was developed to measure the average travel time from a worker's home ZIP code to the major employment ZIP codes in the region. The major employment centers were identified using a research brief produced by NOACA, entitled "Major Employment Hubs in the Cleveland MSA." This study identified six major employment hubs in the region, and their associated ZIP codes were utilized for this particular accessibility and mobility analysis.

Travel time accessibility was measured using two modes of transportation: automobile and public transit. For each employment hub, travel time sheds were created using the commute time of workers living in neighborhoods throughout the region. The travel time data was mined from the NOACA travel forecasting model, and the average work trip AM peak period times for each home location ZIP code were calculated for both automobile and public transit travel. A series of maps and tables were created to show these travel time sheds in both geographic and tabular forms.

In addition to identifying the travel accessibility sheds, socioeconomic data of the workers, based on their home locations, was also collected and summarized for each major employment center's travel sheds. Socioeconomic breakdowns of age, income, job industry, race, ethnicity, educational attainment, and gender provide a more detailed look into what type of workers currently have greater access to each major employment center, and conversely, which types have less accessibility.

The implications of this analysis are far-reaching. This data could be used by employment placement agencies to help match job seekers to jobs within a reasonable commute time (via either automobile or public transit). By identifying the average travel times of home ZIP codes to major workplace ZIP codes, only the ZIP code of the prospective worker and the ZIP code of the business are needed to make this match, as opposed to the specific address of each and the need to look up a specific commute time for each case.

Economic development agencies can also benefit from this analysis in their business retention and attraction work. When a company is looking to expand or relocate to Northeast Ohio, the socioeconomic data that was collected for this analysis could be used to provide a "socioeconomic profile" of the workers residing in various travel sheds for a given employment center. Major employment centers throughout the region can quickly be compared to one another to help provide more information in the search for a business location.

On the workforce development side, the analysis and data could be used to identify undersupplies of worker types residing in areas with good accessibility to major employment centers. Targeted job training dollars could possibly be directed to residents where an undersupply of a particular type of worker is identified.

Finally, in order to reduce the worker and employer locations mismatch in this region, this study has recommended several transportation and land use solutions and policies. These solutions suggest more frequent transit services to the major job hubs, more park-and-ride locations throughout the region, implementation of low cost traffic engineering to remove arterial bottlenecks and more bike lanes to access major transit stations. Also, in terms of land use solutions, the study recommends implementing mix-use development around transit stations and major job hubs and support policies for housing development closer to job hubs.

Background

The fundamental tools, data, and geographies used for this study were:

NOACA Travel Forecasting Model

The NOACA travel forecasting model consists of the five counties of NOACA (Cuyahoga, Lake, Lorain, Medina and Geauga), and the two neighboring counties of Summit and Portage. The inclusion of Summit and Portage counties was necessary to improve upon the travel movements occurring between the Cleveland and Akron metro areas, as well as to accurately capture the through traffic that occurs in both areas.

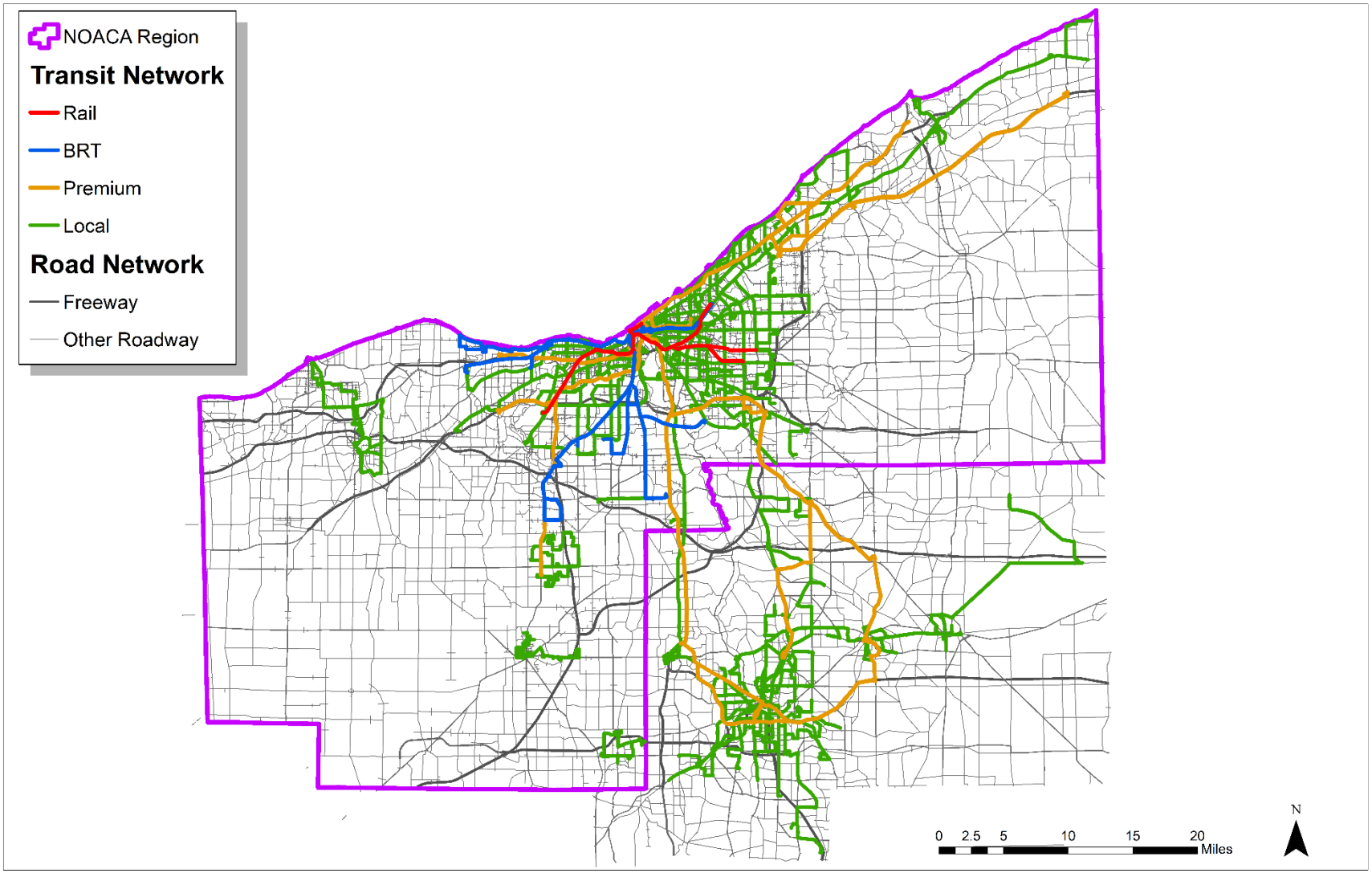
Traffic Analysis Zones (TAZ)

Every household in residential subdivisions, place of employment in commercial areas, shopping centers and other land use types produce and attract trips. For the purpose of connecting these land uses to the street network, the seven-county region is subdivided into approximately 6,000 small geographic areas such as neighborhoods. These small areas are called Traffic Analysis Zones (TAZs) and they are the primary unit of analysis in the travel modeling process since all trips are generated and attracted at the TAZ level. Travel throughout the model occurs between TAZs, with trips beginning and ending at specific TAZs.

Highway and Transit Networks

The NOACA travel forecasting model network is comprised of all road facility types of freeways, limited access highways such as expressways, major and minor arterials/collectors and local roads. The transit network of the NOACA model includes all transit services, such as rail, local bus, premium bus, and Bus Rapid Transit (BRT). Map 1 displays the NOACA travel forecasting model highway and transit networks.

Map 1: NOACA Travel Forecasting Model Highway and Transit Networks



AM Peak Period

The NOACA travel forecasting model is a "Time-of-day" type and includes five periods: Early morning period (3 A.M. – 6 A.M.), AM peak period (6 A.M. – 9 A.M.), Mid-day period (9 A.M. – 3 P.M.) , PM peak period (3 P.M. – 7 P.M.) and Night time period (7 P.M. – 3 A.M.).

This study attempts to locate workers' origins and destinations, identify their mode of travel and measure their commute time. The AM peak period is selected for this analysis, since the vast majority of work trips occur during this period.

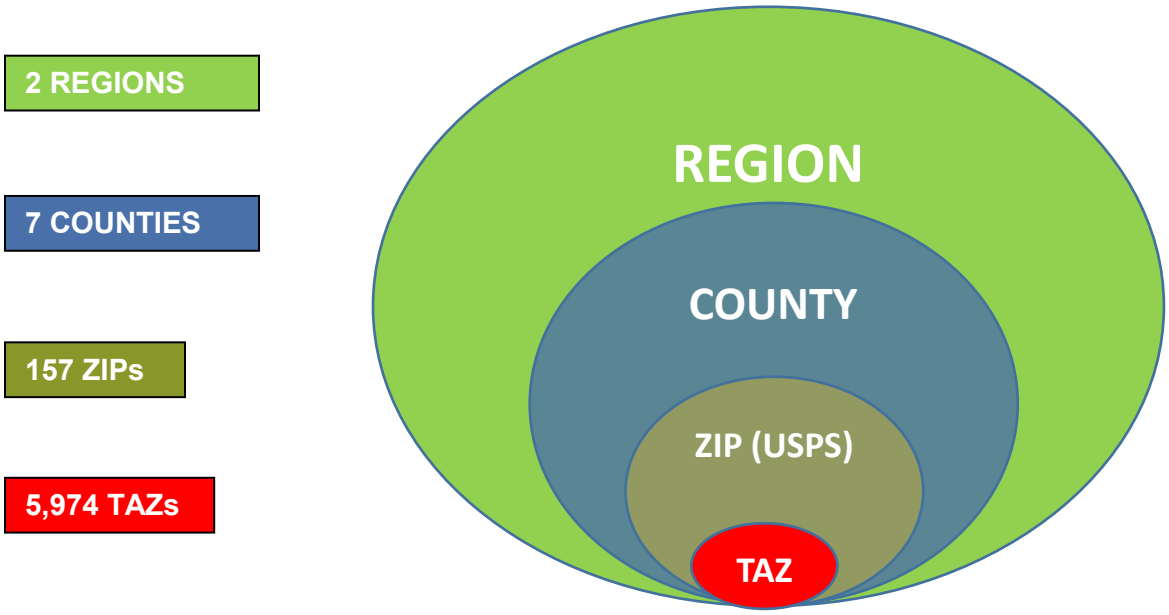
ZIP Code Geographies

The NOACA travel forecasting model produces many 6,000 by 6,000 detailed travel attribute matrices such as travel times, origin-destination volumes by mode of travel, etc. The TAZ-to-TAZ matrices were aggregated into another geography that could be more applicable to this study and a larger set of practitioners. The ZIP code was selected for the following reasons:

- ZIP codes are commonly known geographies to people of all disciplines.
- ZIP codes are also widely available to planning, economic development, and workforce development officials through address records, for both workers and businesses alike.
- ZIP codes are widely used and commonly understood geography, are very practical to the work of the planning and economic development community and have the potential to be applied in many different ways.

Figure 1 displays the geographical hierarchy used in this study.

Figure 1: Geographical Hierarchy



Travel Shed Groups

The average commute times were divided into the following five travel shed groups ranging from a short to long commute.

- 21 minutes or less
- 21 minutes to 31 minutes
- 31 minutes to 46 minutes
- 46 minutes to 61 minutes
- More than 61 minutes

These intervals were selected based on the average automobile and transit travel times in the NOACA region and for analysis purposes.

Socioeconomic Data

Socioeconomic data describing the population and economic activity are placed into a database organized by TAZs. Each record in this database represents a unique TAZ in the NOACA travel forecasting model and contains the socioeconomic data required by the model.

Using the U.S. Census Bureau's Longitudinal Employer Household Dynamics (LEHD) and Longitudinal Origin-Destination Employment Statistics (LODES) for 2015, socioeconomic data was collected and summarized for each employment hub ZIP and its commute travel shed groupings. The data focused on the total number of workers living in the various commute sheds of a given employment hub, as well as breakdowns of the workers into 7 various demographic and socioeconomic classifications. The socioeconomic classifications of the workers are as follows:

- Age
- Earnings/Income
- Industry
- Race
- Ethnicity
- Educational Attainment
- Gender

Major Regional Job Hubs

The major employment centers used in this analysis were adopted from a December 2016 NOACA research brief entitled “Major Employment Hubs in the Cleveland MSA.” This study identified employment areas within the 5-County Cleveland MSA that had the highest employment density compared to other areas in the region, as well as at least 1% of the MSA’s 2014 employment (approximately 10,000 jobs). The following six major employment hubs were identified in the report:

1. Downtown/Near East Side
2. University Circle, including Midtown between E. 105th Street and E. 83rd Street
3. Solon Cochran Corridor
4. Chagrin Highlands
5. I-77 and Rockside Road Area
6. Hopkins Airport Area

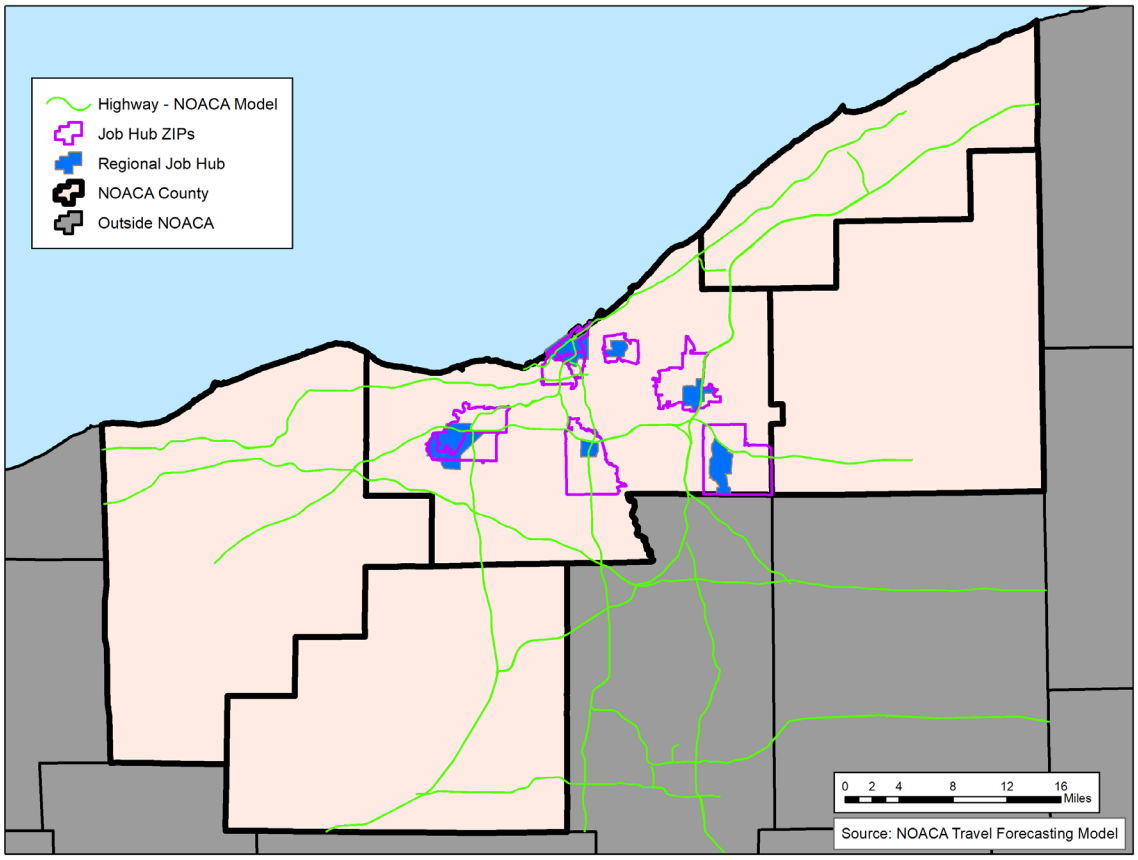
As expected, the boundaries of ZIP codes and the six major employment hubs do not match exactly, and in some cases can be quite different. Some of the ZIP codes, especially in the suburban areas, can be very large and thus contain an entire employment hub, as well as other surrounding neighborhoods and other land use types. Even with these other non-hub areas included in the ZIP code, the employment hub is still the most dominant employment area of that particular ZIP code, due to its size and regional nature. Therefore, these boundary discrepancies were not viewed as a large issue with regards to analyzing travel patterns to these ZIP codes. Other ZIP codes, like in urban areas, are much smaller, and thus a larger employment hub could contain multiple ZIP codes. Care was taken to select the most representative ZIP codes for each employment hub, disregarding any ZIP codes that overlapped very little with an employment hub.

The ZIP codes that were selected to represent the employment hubs are as follows:

1. 44113, 44114, 44115 (Downtown/Near East Side)
2. 44106 (University Circle, including Midtown between E. 105th Street and E. 83rd Street)
3. 44139 (Solon Cochran Corridor)
4. 44122 (Chagrin Highlands)
5. 44131 (I-77 and Rockside Road Area)
6. 44135, 44142 (Hopkins Airport Area)

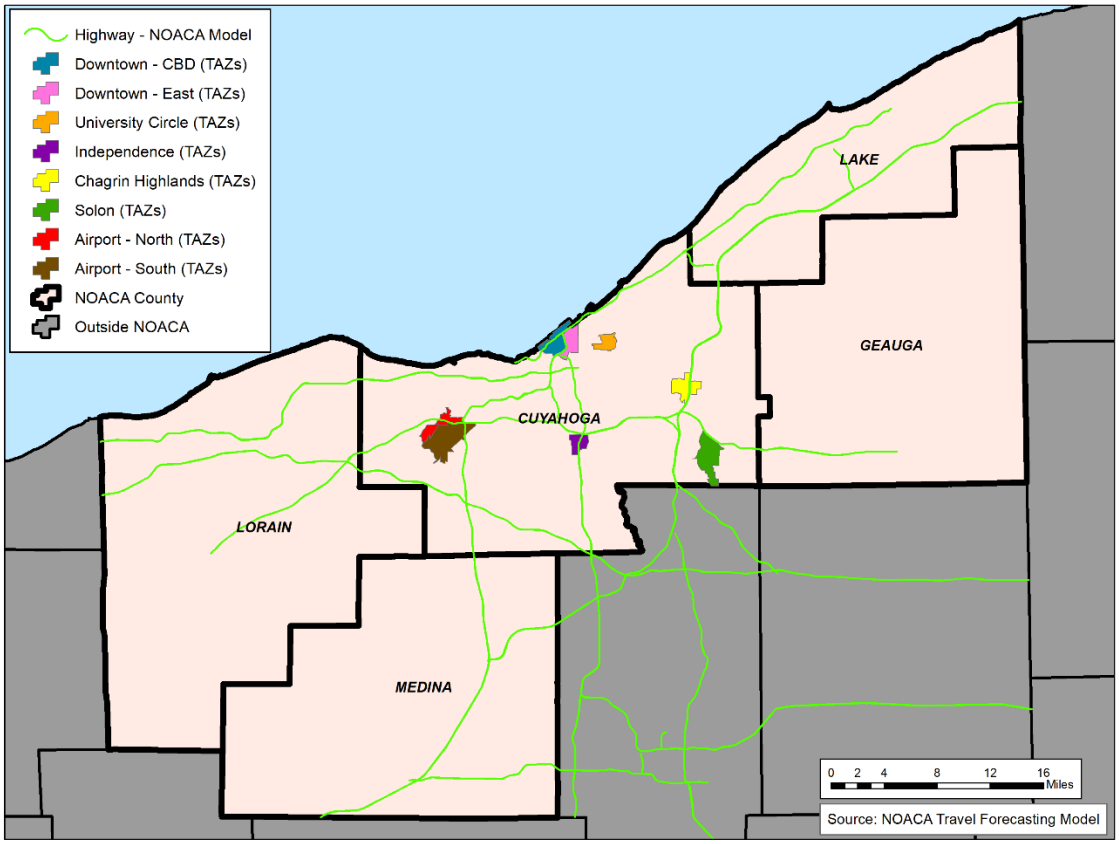
Map 2 displays the locations of major regional job hubs and their associated ZIP codes.

Map 2: Locations of the Major Regional Job Hubs



As indicated in Figure 1, the analyses in this study were implemented at three levels: County, ZIP code and TAZ. Due to the size and for the sake of accuracy, the Cleveland Downtown and Hopkins Airport job hubs have been split into two parts and each part was analyzed separately at the TAZ level. Map 3 shows the locations of the major regional job hub after this minor split.

Map 3: Locations of Eight Analyzed Regional Job Hubs



Selected Industry Sector for Regional Job Hubs

The industries with the highest proportion of overall employment of each job hub were identified and utilized. However, any industry could have been selected from any employment center and analyzed. It should be noted that this study does not attempt to recommend any particular industry to a specific job hub.
Table 1 shows the selected industry classes that have the highest percentage of employment in each job hub (highlighted in green).

Table 1: Industry Sector Percent for each Regional Job Hub

Job Hub	Manufacturing	Transportation & Warehousing	Professional & Scientific Services	Administrative, Support, & Waste Management	Health Care & Social Assistance	Public Administration	Other Industries Total
Airport (North)	1.8%	4.7%	19.2%	5.5%	0.8%	**42.0%**	26.1%
Airport (South)	18.5%	**37.1%**	2.7%	4.7%	1.6%	5.6%	29.8%
Chagrin Highlands	2.5%	1.3%	10.8%	13.1%	**16.4%**	0.8%	55.2%
Downtown (CBD)	0.4%	0.8%	**19.8%**	9.0%	3.8%	**17.4%**	48.8%
Downtown (East)	6.7%	9.6%	5.4%	9.0%	**22.2%**	3.6%	43.6%
Independence	0.8%	0.4%	13.2%	**29.2%**	6.8%	2.2%	47.5%
Solon	**36.8%**	1.4%	11.4%	6.2%	2.9%	0.0%	41.3%
University Circle	0.2%	0.0%	0.6%	0.1%	**72.8%**	2.3%	24.1%
Regional Median Yearly Wage ($2018)	$48,088	$41,192	$60,715	$26,481	$36,767	$52,856	
Regional Median Hourly Wage ($2018)	$23.12	$19.80	$29.19	$12.73	$17.68	$25.41	

Source: Census LODES 2015 and American Community Survey (ACS) 2017

Prioritization of Employment Centers

Work trips are the most frequent and mandatory journeys in an urbanized region and occur during the peak travel periods when traffic congestion is at its worst causing many negative impacts.

Optimal infrastructure investments, expansion of a job hub and workforce mobility are highly dependent on land use characteristics and accessibility to transportation facilities of the employment centers. Considering resource scarcity and expanded cities, the prioritization of employment centers is an urban and transportation policy and planning challenge. This section offers a mathematical model to overcome this challenge.

A Prioritization Model

In this study, a mathematical scoring model was developed to prioritize existing and future employments centers based on land use characteristics and accessibility to transportation facilities. For this study, the six major employment centers in the NOACA region were analyzed. This prioritization model could also be used to evaluate smaller employment centers to determine which ones might be candidates for expansion, or to evaluate multiple green-field development sites on their potential strength as new employment center locations.

This model utilizes socioeconomic data and accessibility to highway and transit facilities and its input data may be categorized as follow:

- Employment
- Population
- Highway accessibility
- Transit accessibility
- Area of employment center
- Area of employment center plus two miles of surrounding area

The model parameters are:

- Arterial traffic capacity
- Highway traffic capacity
- Average automobile occupancy
- Bus seating capacity
- Rail seating capacity

The model calculates the employment and household densities by using the following formulas:

$$Employment\ Density = \frac{Number\ of\ employees\ of\ Employment\ Center}{Area\ of\ Employment\ Center}$$

$$Household\ Density = \frac{Residential\ Population\ of\ Empoyment\ Center\ Plus\ two\ miles}{Area\ of\ Employment\ Center\ Plus\ two\ miles\ Surrounding\ Area}$$

The extra two miles in the above household density formula accounts for a possible maximum two miles walking distance from home to work.

The model is the following linear equation:

$$TS = ED + HD + \frac{(HL \times HC + AL \times AC) \times PC \times CO}{AREA} + \frac{BS \times BC + RS \times RC}{AREA}$$

Where;

TS: Total Score (Persons per Square Miles)
ED: Employment Density (Persons per Square Miles)
HD: Household Density (Persons per Square Miles)
AREA: Employment Center Area (Square Miles)
HL: Number of Highway lanes passing through or ending to the employment Center
HC: Highway Traffic Capacity (Vehicles per hour per lane)
AL: Number of Arterial Lanes passing through or ending to the Employment Center
AC: Arterial Traffic Capacity (Vehicles per hour per lane)
PC: AM Peak period Capacity Conversion Factor (Hours)
CO: Average Vehicle Occupancy during the AM peak period
BS: Number of Bus Services to the Employment Center during the AM Peak period
BC: Bus Seating Capacity,
RS: Number of Rail Services to the Employment Center during the AM Peak period
RC: Rail Seating Capacity

The model was applied to the six major regional job hubs using the 2018 data. Table 2 presents the parameter values of the calibrated prioritization model.

Table 2: Prioritization Model Parameter Values

Parameter	Unit	Value
Arterial Capacity	Vehicle/Hour/Lane	1,000
Highway Capacity	Vehicle/Hour/Lane	2,000
AM Peak Period Capacity Conversion factor	Hour	2.1
AM Peak Period Average Car Occupancy	Passenger	1.199
Bus Seating Capacity	Passenger	25
Rail Seating Capacity	Passenger	50

Table 3 displays the scoring results for the six major regional job hubs:

Table 3: Total Scoring Results for Major Regional Job Hubs

Major Job Hub	Density		Access		Total Score	Rank
	Employment	Population	Trip Capacity by Auto	Trip Capacity by Transit		
University Circle to E 83rd St	32,744	4,986	22,453	3,424	**63,606**	1
Downtown & Near Eastside	23,472	3,844	22,184	3,491	**52,991**	2
I-77 & Rockside	14,930	1,645	35,463	264	**52,302**	3
Chagrin Highlands	10,598	1,905	12,369	456	**25,327**	4
Solon- Cochran Corridor	5,769	1,448	8,517	63	**15,798**	5
Hopkins Airport Area	3,190	2,482	8,188	325	**14,186**	6

Note: All Numbers are Persons Per Square Miles.

Inter-County Work Trips

All six major regional job hubs and many other employment centers are located in Cuyahoga County and therefore attracts the majority of home-based work trips from its neighboring counties. The current highway system in the region accommodates most of the inter-county work trips and the transit system is utilized by a small portion of these trips. Tables 4 and 5 illustrate the current inter-county work trips by automobile, transit and non-motorized modes during a typical 2018 AM peak period and as the percentages of total work trips.

Table 4: Inter-County Work Trips by All Modes during a Typical 2018 AM Peak Period

		Destinations						
	County	Cuyahoga	Geauga	Lake	Lorain	Medina	Other Counties	**Total**
Origins	Cuyahoga	237,216	4,097	11,347	11,426	5,466	23,092	**292,644**
	Geauga	9,125	9,331	3,079	89	67	2,600	**24,292**
	Lake	25,541	3,724	30,518	309	129	3,323	**63,544**
	Lorain	30,482	210	634	36,747	2,752	4,657	**75,483**
	Medina	16,490	144	283	2,935	18,310	14,716	**52,879**
	Other Counties	44,599	4,618	2,952	2,977	9,730	141,599	**206,476**
	Total	**363,453**	**22,125**	**48,813**	**54,483**	**36,454**	**189,988**	**715,317**

Table 5: Inter-County Work Trip Percent by All Modes during a Typical 2018 AM Peak Period

		Destinations						
	County	Cuyahoga	Geauga	Lake	Lorain	Medina	Other Counties	**Total**
Origins	Cuyahoga	33.2%	0.6%	1.6%	1.6%	0.8%	3.2%	**40.9%**
	Geauga	1.3%	1.3%	0.4%	0.0%	0.0%	0.4%	**3.4%**
	Lake	3.6%	0.5%	4.3%	0.0%	0.0%	0.5%	**8.9%**
	Lorain	4.3%	0.0%	0.1%	5.1%	0.4%	0.7%	**10.6%**
	Medina	2.3%	0.0%	0.0%	0.4%	2.6%	2.1%	**7.4%**
	Other Counties	6.2%	0.6%	0.4%	0.4%	1.4%	19.8%	**28.9%**
	Total	**50.8%**	**3.1%**	**6.8%**	**7.6%**	**5.1%**	**26.6%**	**100.0%**

As shown in Table 4, about one fifth of work trips (origins and destinations) are outside the NOACA region. Considering the NOACA region only, the above percentages would change. Table 6 illustrates the inter-county work trip by all modes of the total work trips during a typical 2018 AM peak period in the NOACA region only.

The Inter-County work trip table illustrates the mismatch between workers' home and work locations at a high level. The highest percentage is associated with the internal Cuyahoga County work trips. As indicated in Table 5, Cuyahoga County attracts about half of the work trips and of those trips, two-thirds of the homes are in the county.

Table 6: Inter-County Work Trip Percent by All Modes during 2018 AM Peak Period NOACA Region Only

		Destinations						
	County	Cuyahoga	Geauga	Lake	Lorain	Medina	Other Counties	**Total**
Origins	Cuyahoga	41.3%	0.7%	2.0%	2.0%	1.0%	4.0%	**51.0%**
	Geauga	1.6%	1.6%	0.5%	0.0%	0.0%	0.5%	**4.2%**
	Lake	4.5%	0.6%	5.3%	0.1%	0.0%	0.6%	**11.1%**
	Lorain	5.3%	0.0%	0.1%	6.4%	0.5%	0.8%	**13.2%**
	Medina	2.9%	0.1%	0.0%	0.5%	3.2%	2.6%	**9.2%**
	Other Counties	7.8%	0.8%	0.5%	0.5%	1.7%		**11.3%**
	Total	**63.4%**	**3.8%**	**8.4%**	**9.5%**	**6.4%**	**8.5%**	**100.0%**

As shown in Table 6, about two thirds of destination work trips generated from the NOACA region are in the Cuyahoga County. Also, trips originating in and destined for Cuyahoga County account for almost half of all regional work trips.

When examining the work trips to just the job hubs in the region, the mismatch is apparent. Tables 7 and 8 show the number and percentages of work trips from counties to the major regional job hubs. As shown in Table 8 and as an example, over 40 percent of all regional work trips to the job hubs are destined to Downtown Cleveland. Out of that 40 percent, Cuyahoga residents account for approximately 30 percent and the remaining counties account for over 10 percent. Said another way, out of the 43,910 work trips heading to Downtown Cleveland, only 32,742 of those trips originate from Cuyahoga County, while the remaining 11,168 work trips come from other counties.

Table 7: Work Trips to Job Hubs by All Modes during a Typical 2018 AM Peak Period

Origins	Destinations							
		Downtown	University Circle	Independence	Chagrin Highlands	Solon	Airport	**Total**
	Cuyahoga	32,742	15,413	5,773	7,288	5,703	9,509	**76,428**
	Geauga	555	219	162	642	867	76	**2,522**
	Lake	3,312	1,271	253	1,329	747	207	**7,119**
	Lorain	2,656	569	439	220	246	1,961	**6,090**
	Medina	1,150	256	385	175	242	961	**3,168**
	Others	3,496	1,096	1,339	1,747	3,359	951	**11,987**
	Total	**43,910**	**18,824**	**8,351**	**11,401**	**11,164**	**13,665**	**107,315**

Table 8: Work Trip Percent to Job Hubs by All Modes during a Typical 2018 AM Peak Period

Origins	Destinations							
		Downtown	University Circle	Independence	Chagrin Highlands	Solon	Airport	**Total**
	Cuyahoga	30.5%	14.4%	5.4%	6.8%	5.3%	8.9%	**71.3%**
	Geauga	0.5%	0.2%	0.2%	0.6%	0.8%	0.1%	**2.4%**
	Lake	3.1%	1.2%	0.2%	1.2%	0.7%	0.2%	**6.6%**
	Lorain	2.5%	0.5%	0.4%	0.2%	0.2%	1.8%	**5.6%**
	Medina	1.1%	0.2%	0.4%	0.2%	0.2%	0.9%	**3.0%**
	Others	3.3%	1.0%	1.2%	1.6%	3.1%	0.9%	**11.1%**
	Total	**41.0%**	**17.5%**	**7.8%**	**10.6%**	**10.3%**	**12.8%**	**100.0%**

ZIP Code Level Analysis

The ZIP codes are TAZ aggregated geographies, which are below the county level as shown in Figure 1. TAZs are much smaller geographies than ZIP codes, so a ZIP code includes many TAZs. With regards to selection criteria, a TAZ was matched with a ZIP if its center point, also known as a centroid, was located within a particular ZIP. This was a one-to-one relationship, meaning that a TAZ could only be matched with one ZIP, as opposed to possibly being matched to more than one ZIP. One important note is that TAZ and ZIP code boundaries do not align exactly, so the boundaries of the TAZ sets and the matching ZIP are slightly different. These differences were not extreme so it was not viewed as an issue for obtaining and aggregating useful and reasonable outputs from the TAZ level.

Once the TAZ sets were established for all ZIP codes in the NOACA modeling region, the necessary modeling outputs were aggregated to the ZIP level. For instance, the average ZIP-to-ZIP automobile and public transit travel times were calculated for work commutes during the AM peak period. With these travel times being an average, it is important to remember that there can still be substantial accessibility differences within each ZIP code. ZIP codes are geographically large and often very diverse in terms of transportation and travel mode accessibility. Within a ZIP code, it is common to see areas that have faster connections to the interstate highway network, as well as areas that have much slower connections. Similarly, it is very common to see corridors within a ZIP code area with easy access to the public transit system, compared to corridors within the same ZIP that have little-to-no public transit options. In all the sections of this study, the average door-to-door travel time was calculated and analyzed. This analysis took into account the differences and attempted to provide a representative value for the entire ZIP code.

Major Regional Job Hubs and Time Sheds

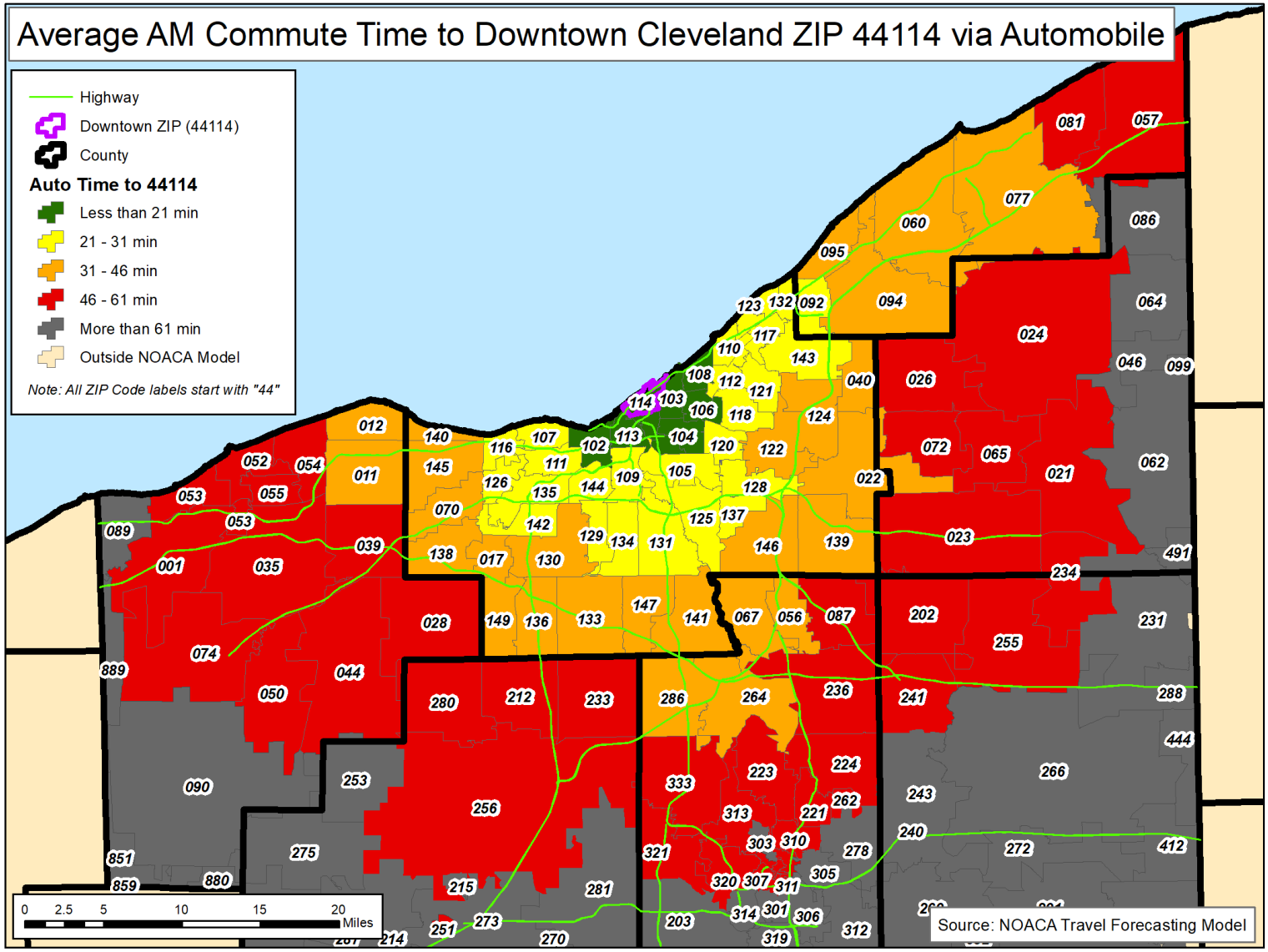
As discussed in previous sections, the major regional job hubs are destinations for a high number of work trips and the mismatch between workers' home and work locations is more demonstrative if work trip travel times to the major regional job hubs are analyzed.

Automobile and Transit Commute Times

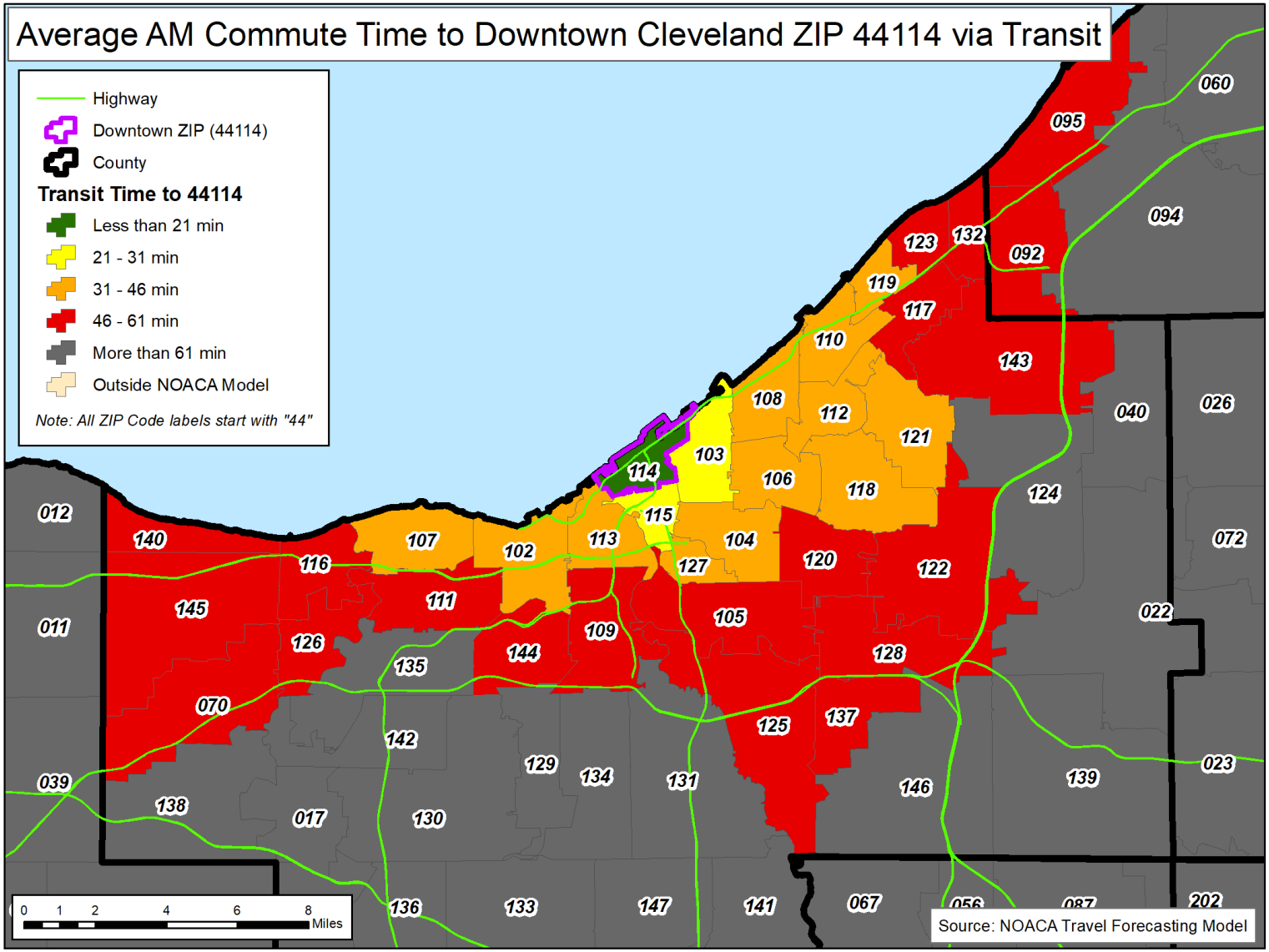
The 2018 AM peak period scenario of the NOACA travel forecasting model was utilized to estimate the TAZ-to-TAZ door to door travel time matrix. Then using the TAZ-to-ZIP code equivalency table, the travel time matrix was aggregated and averaged to the ZIP code level. It should be noted that the estimated travel times are outputs of the calibrated NOACA travel forecasting model and tend to be similar to the actual congested travel times that workers face during their morning commute.

Maps 4 and 5 display the auto and transit commute sheds of the Cleveland Downtown ZIP 44114 job hub. The appendix includes commute time maps for other major regional job hubs by automobile and transit.

Map 4: Automobile Commute Sheds of the Downtown Cleveland ZIP 44114 Job Hub



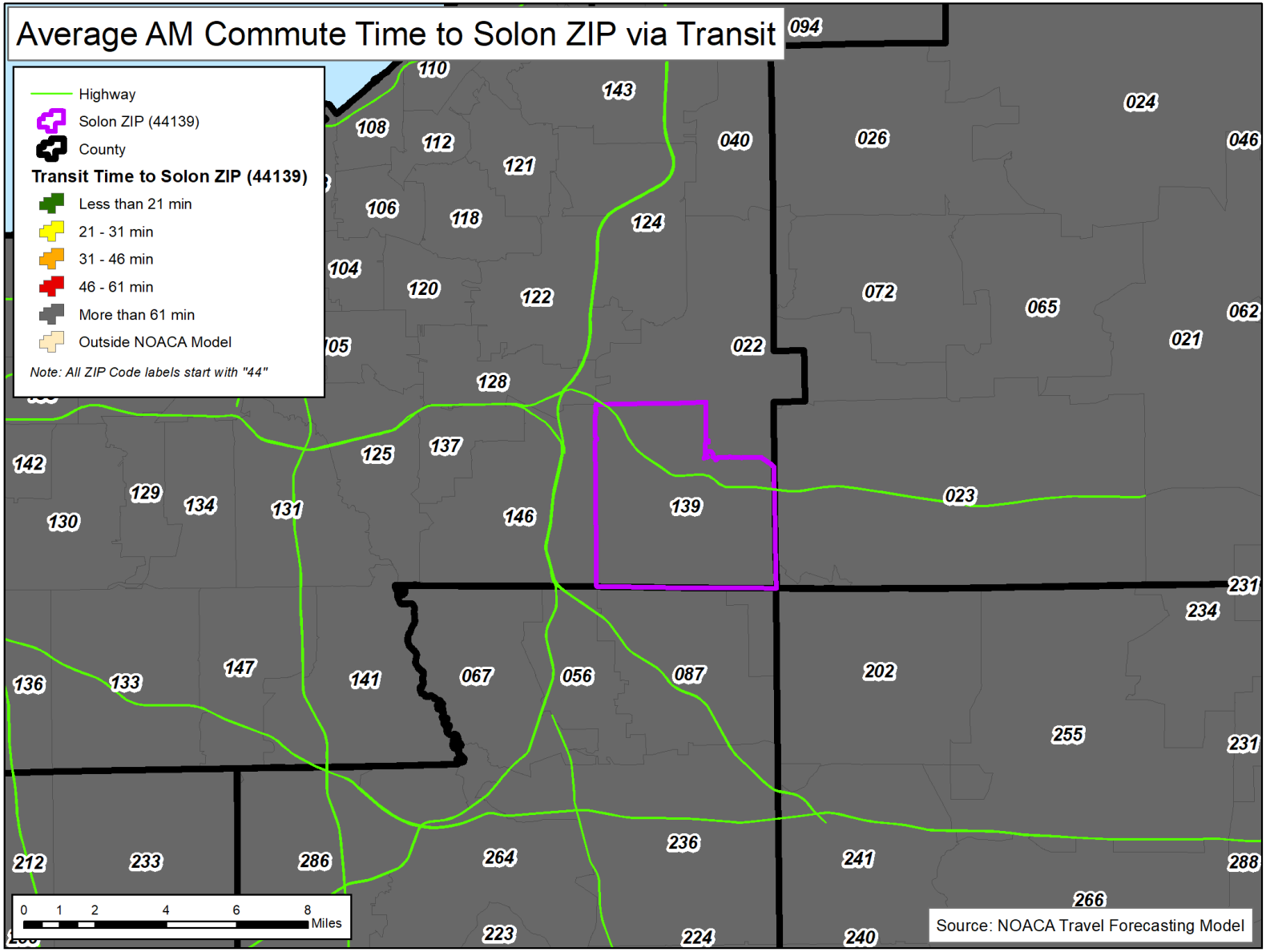
Map 5: Transit Commute Sheds of the Downtown Cleveland ZIP 44114 Job Hub



The averaging mechanism for the ZIP code level obfuscates the actual access times for some TAZs and as an example, Maps 6 and 7 show the ZIP-level and TAZ level analysis differences very starkly.

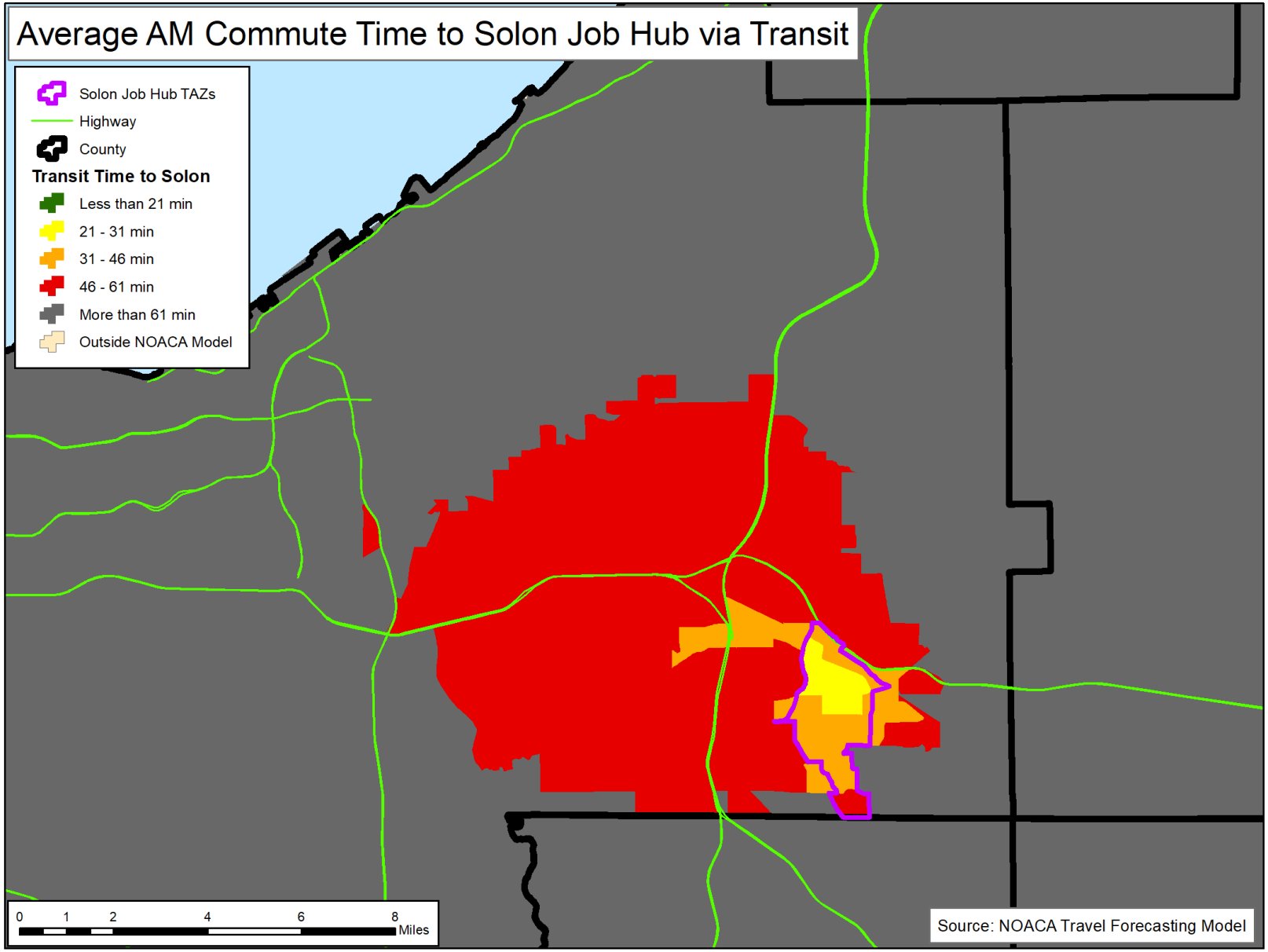
Map 6 shows the Solon job hub as the entire Solon ZIP code of 44139. Due to the averaging of the travel times between the other home ZIPs and the Solon ZIP (as discussed earlier in this report), the entire Solon ZIP has no transit under 61 minutes. Since the Solon ZIP is very large and the majority of the residential areas in Solon have no transit service, this drives up the average travel time to over 61 minutes between the Solon ZIP and the other home location ZIP codes.

Map 6: Transit Commute Sheds of the Solon ZIP 44139 Job Hub



Map 7 shows the TAZ boundary of just the Solon job hub, as opposed to the entire Solon ZIP of 44139. The TAZs are much smaller and allow for the job hub to be more precisely represented and analyzed. Since the corridor does have transit service through it, Map 7 therefore shows some limited transit accessibility into the surrounding areas. Since the TAZs more precisely represent the job hub and there is transit service to the hub, the calculated travel time averages are not driven up by areas that do not have transit service, which is the case when the entire Solon ZIP is analyzed. Therefore the study was replicated at the TAZ level for more precision and accuracy.

Map 7: Transit Commute Sheds of the Solon TAZ Job Hub



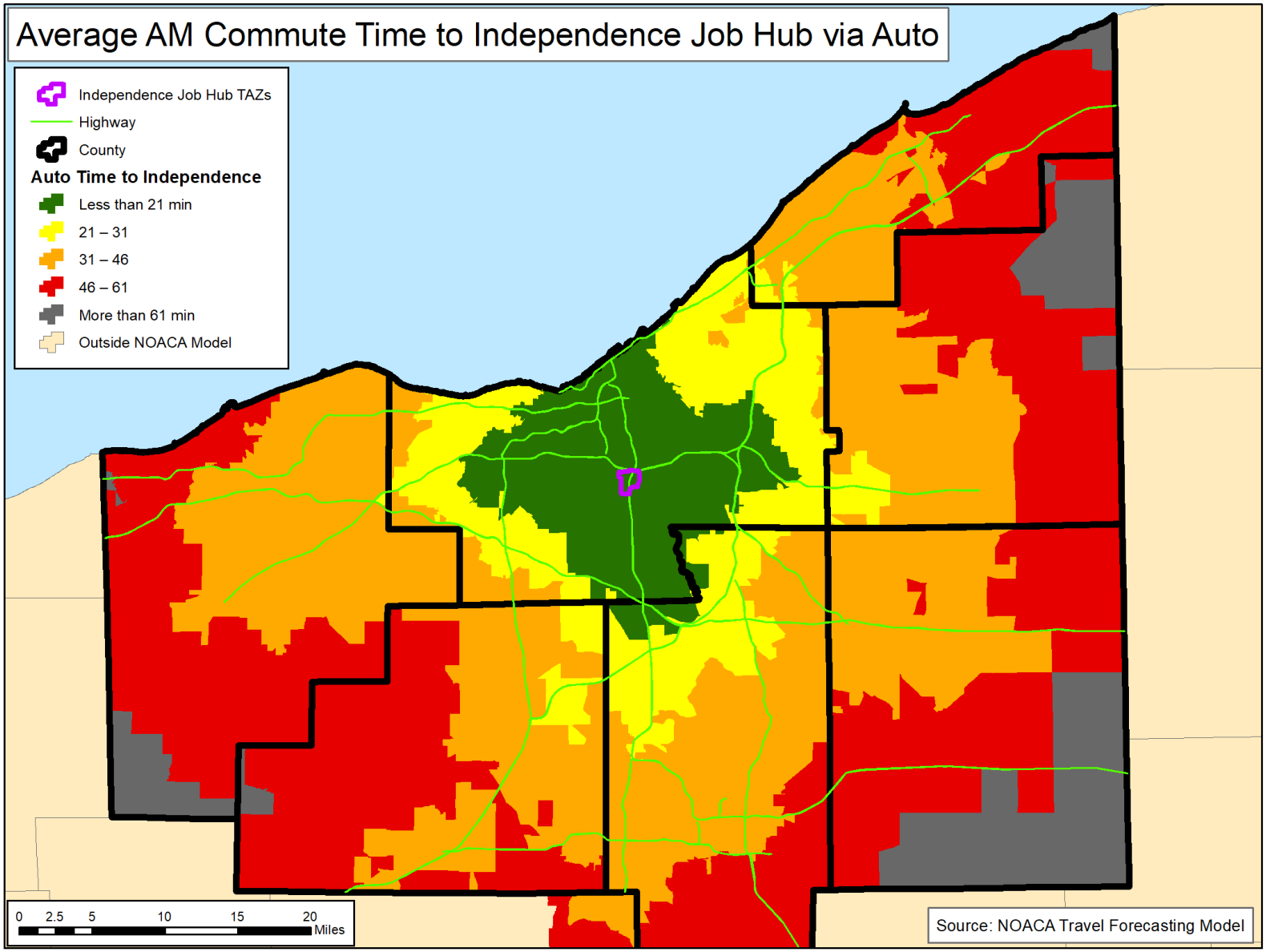
Living and Working Locations Mismatch

This section attempts to present the distance between employment centers and where people live at the TAZ level in the following three steps:

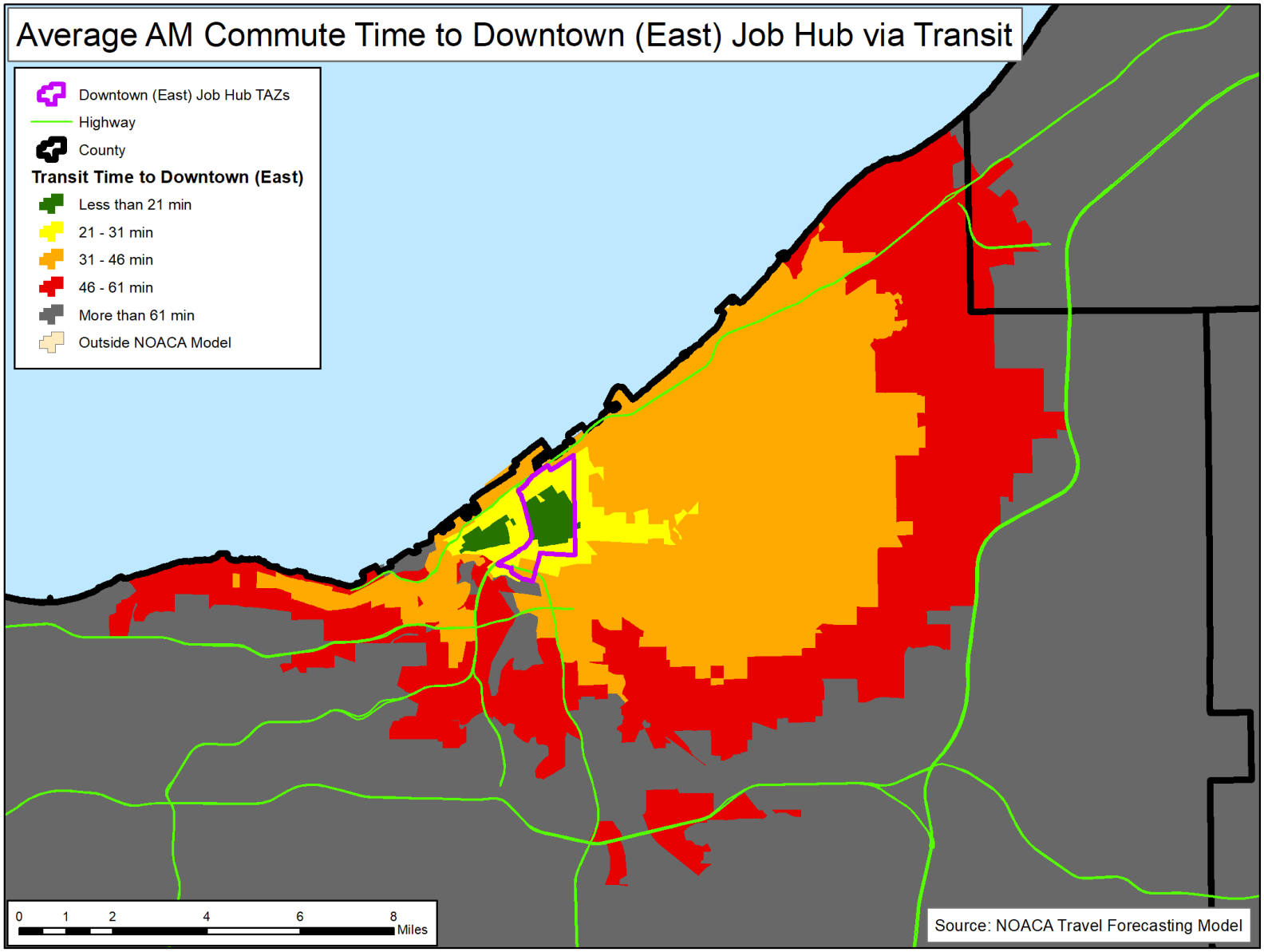
1. Automobile and transit commute times
2. Workers by industry living in the identified commute sheds
3. Origin–Destination for workers living in the identified commute sheds and job hubs

Similar to the ZIP code level analysis, Map 8 shows the auto commute sheds of the Independence job hub. Map 9 displays the transit commute sheds of the Downtown East job hub. The appendix includes commute time maps for the other major regional job hubs by automobile and transit at the TAZ level.

Map 8: Auto Commute Sheds of the Independence TAZ Job Hub



Map 9: Transit Commute Sheds of the Downtown (East) TAZ Job Hub

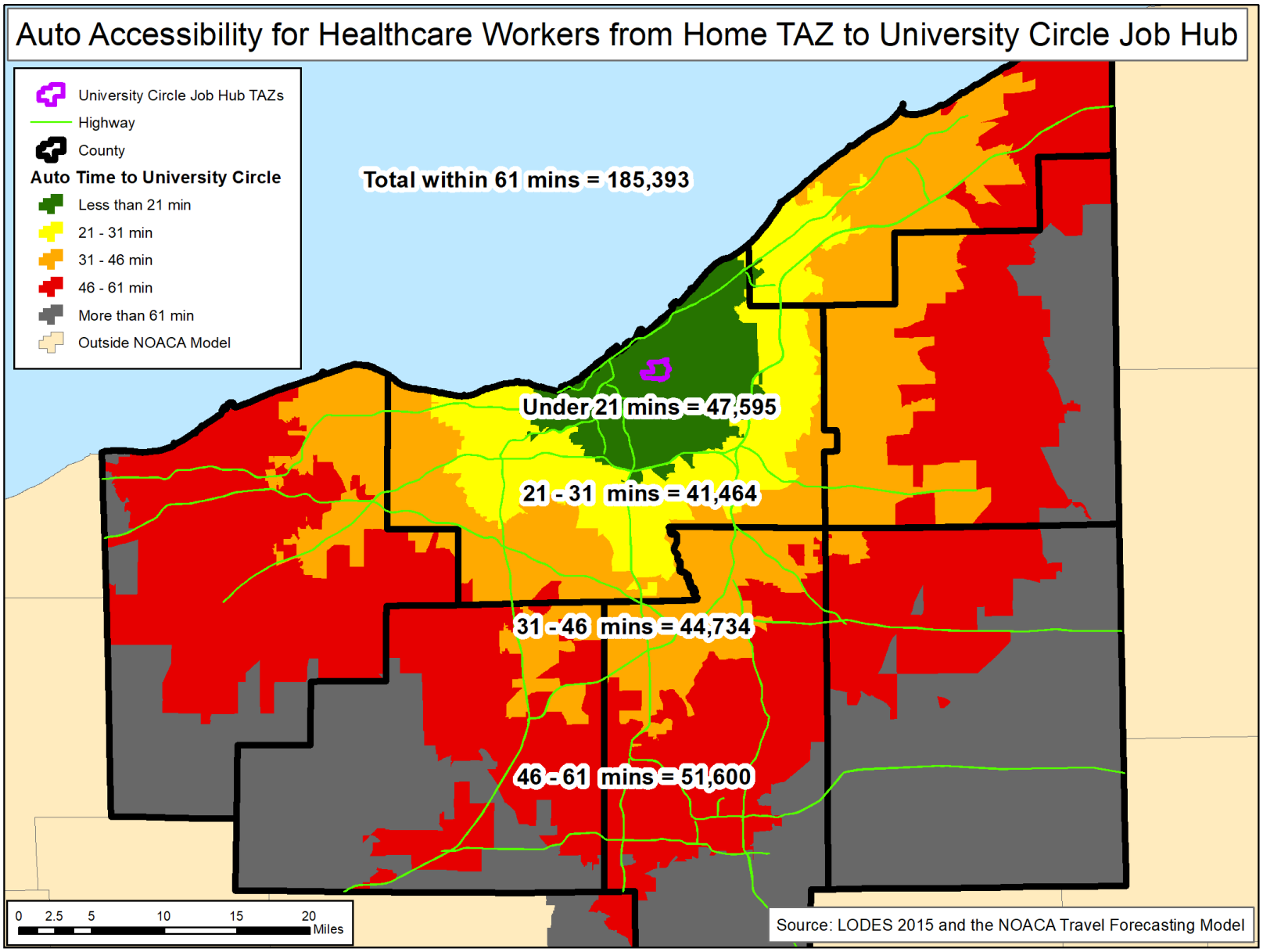


Workers by industry living in the identified commute sheds

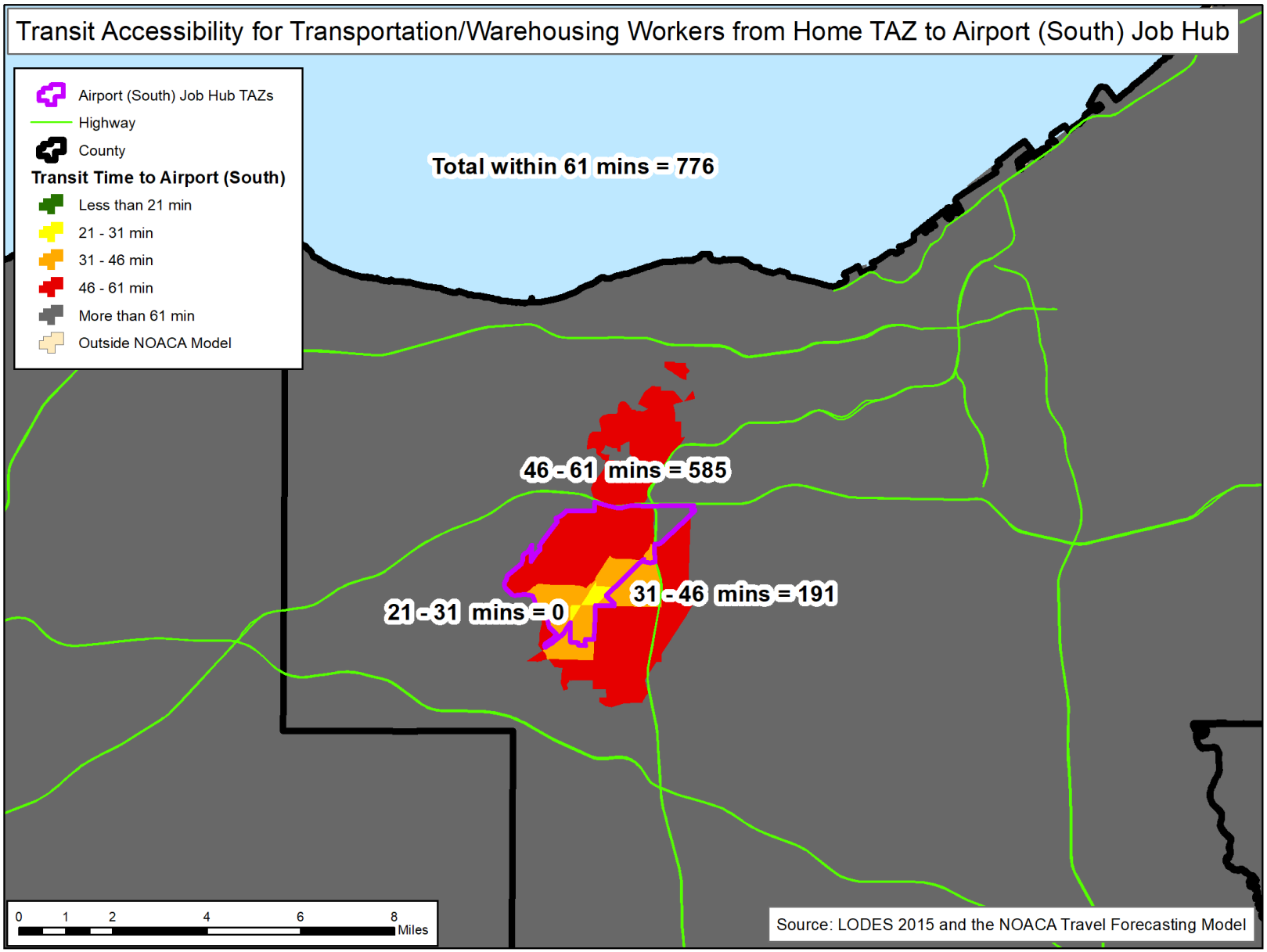
The total number of employed workers by industry, who live within the defined commute sheds of any major regional job hub, was collected. For instance, Maps 10 and 11 illustrate the number of healthcare and transportation/warehousing workers living in the identified auto and transit commute sheds of the University Circle and Airport (South) job hubs respectively. It should be noted that the number of workers shown on these maps may work at these job hubs or may work at other locations. These maps only represent the number of available workers living in the commuter shed areas.

The next section illustrates the mismatch between workers' home and work locations in more detail.

Map 10: Healthcare Workers Living in the University Circle TAZ Job Hub Automobile Commute Sheds



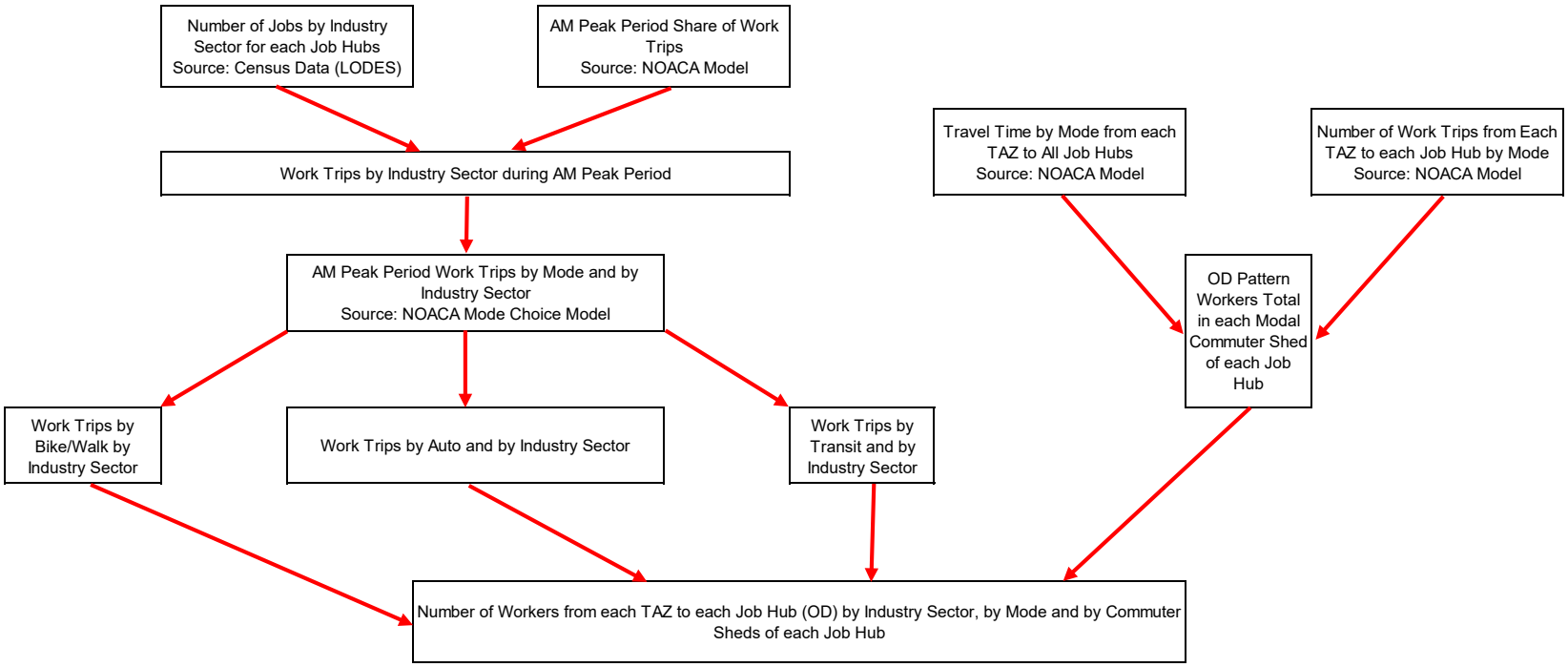
Map 11: Transportation/Warehousing Workers Living in the Airport (South) TAZ Job Hub Transit Commute Sheds



Home Location and Work Location

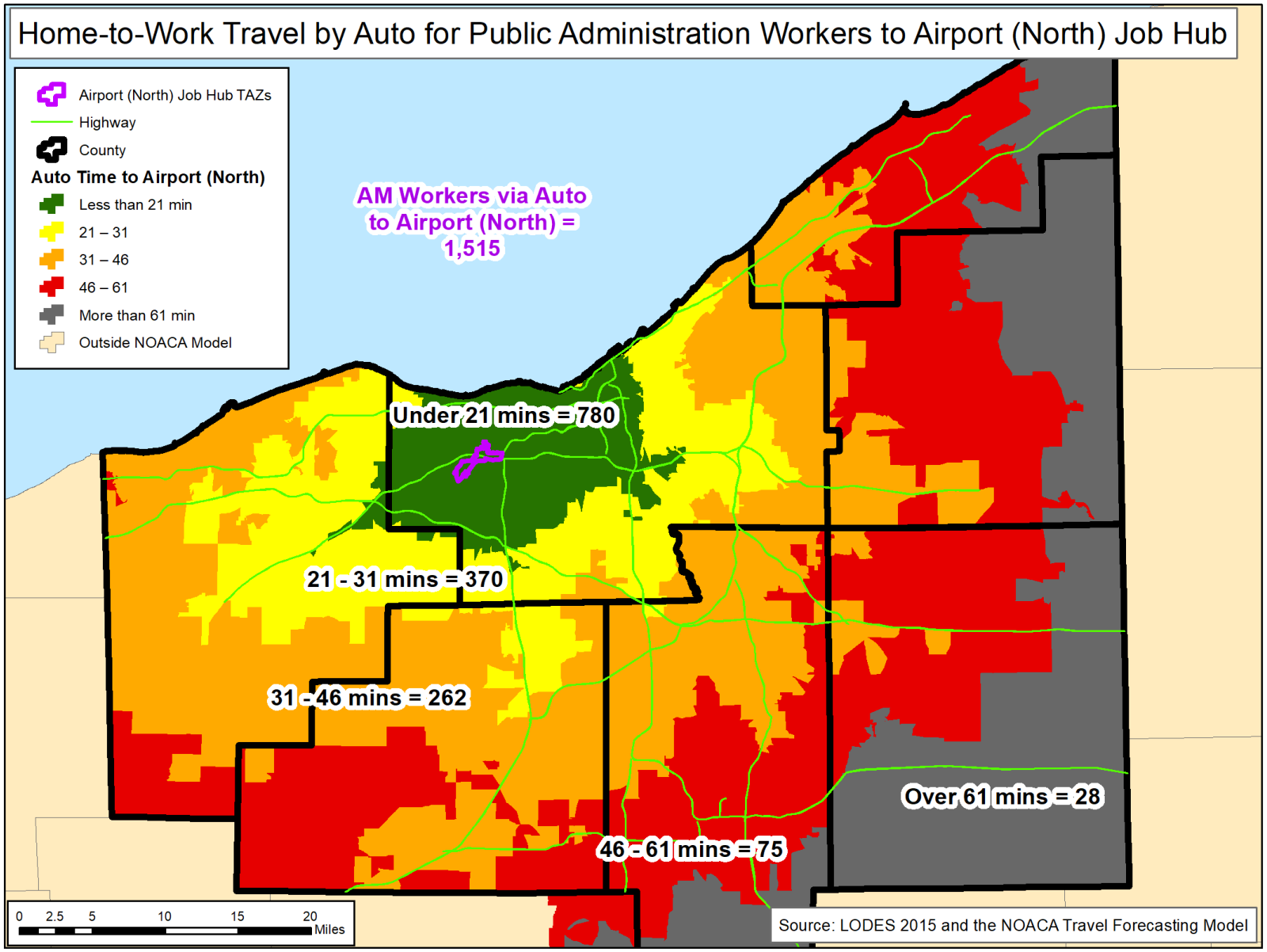
As stated in the previous section, workers who live in a job hub commute sheds may work at different locations. In order to illustrate the mismatch between workers' home and work locations, the NOACA travel forecasting model outputs were combined with Census LODES data. This calculation process is shown in the flow chart in Figure 2.

Figure 2: Origin-Destination Estimation Flow Chart

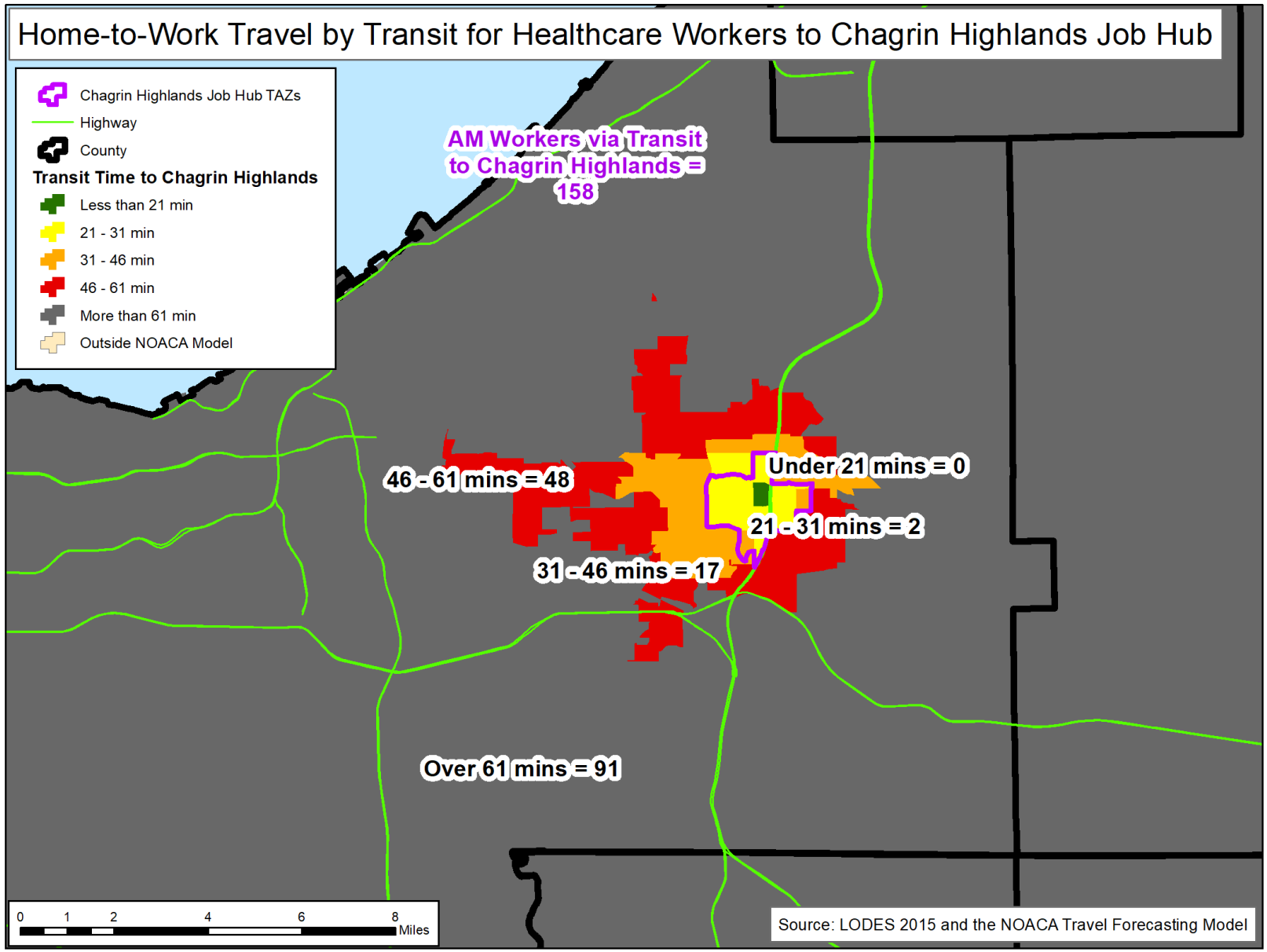


Map 12 shows public administration workers of the Airport (North) job hub living in its auto commute sheds and as another example and using the same procedure, Map 13 illustrates healthcare workers of the Chagrin Highlands job hub living in its transit auto commute sheds. The low numbers on these maps indicate the mismatch of living and working locations and the lack of transit services can be deduced from even a lower number of workers on the latter map.

Map 12: Public Administration Workers of the Airport (North) TAZ Job Hub Living in its Auto Commute Sheds



Map 13: Healthcare Workers of the Chagrin Highlands TAZ Job Hub Living in its Transit Commute Sheds



Tables 9, 10, 11, and 12 summarize the results of the home and work locations estimates for all job hubs by a selected industry and an all industries total. These tables distinguish the auto and transit commute shed time intervals and also display the ratios of the people currently working in each job hub and the available workers in the same commute sheds.

It is worth noting that the selected worker types and job hubs are only examples and should not imply any recommendation for a job hub with regards to which worker types are appropriate for a targeted increase at a particular job hub. This type of targeting should be decided at the local level through consensus with stakeholders. This analysis was designed to inform and guide those types of decisions. In order to reduce the mismatch between workers' and employers' locations, it is recommended to increase the ratios indicated by the green arrow and decrease ratios in the commute sheds indicated by the red arrows in the short term. The recommended auto and transit commute sheds are less than 30 and 45 minutes respectively.

By increasing shorter commutes and decreasing longer commutes for both auto and transit modes, this will provide residents with improved job access, make the job hubs more competitive from an employee attraction/retention standpoint, and reduce the overall strain on the regional transportation network by lowering regional vehicle miles traveled (VMT).

Table 9: Current and Available Workers Comparison by Job Hub and Auto AM Commute Times – Selected Industries

AUTO AM COMMUTES	JOB HUBS - INDUSTRY CLASS WITH THE HIGHEST PERCENT OF EMPLOYMENT TOTAL							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
	Professional, Scientific & Technical Services and Public Administration (37.2%)	Health Care (22.2%)	Public Administration (42%)	Transportation & Warehousing (37.1%)	Manufacturing (36.8%)	Health Care (72.8%)	Health Care (16.4%)	Administrative, Support & Waste Management Services (29.2%)
Under 21 min								
Currently Working There	9,481	1,552	780	1,361	2,276	15,771	1,062	2,888
Available Workers	25,235	62,076	9,809	10,213	12,746	47,595	44,855	20,431
Ratio	**37.6%**	**2.5%**	**8.0%**	**13.3%**	**17.9%**	**33.1%**	**2.4%**	**14.1%**
21-31 min								
Currently Working There	4,423	696	370	650	1,741	6,121	632	1,513
Available Workers	25,290	41,673	9,832	8,482	28,792	41,464	49,606	15,473
Ratio	**17.5%**	**1.7%**	**3.8%**	**7.7%**	**6.0%**	**14.8%**	**1.3%**	**9.8%**
31-46 min								
Currently Working There	3,716	622	262	559	1,785	5,112	401	1,497
Available Workers	30,080	49,177	11,510	11,091	51,932	44,734	48,598	26,698
Ratio	**12.4%**	**1.3%**	**2.3%**	**5.0%**	**3.4%**	**11.4%**	**0.8%**	**5.6%**
46-61 min								
Currently Working There	1,484	249	75	161	913	2,275	202	502
Available Workers	24,390	44,485	8,905	7,038	50,964	51,600	54,327	9,923
Ratio	**6.1%**	**0.6%**	**0.8%**	**2.3%**	**1.8%**	**4.4%**	**0.4%**	**5.1%**
Over 61 min								
Currently Working There	631	94	28	47	209	1,272	56	69
Available Workers	5,078	8,117	2,276	1,370	10,681	20,135	8,142	660
Ratio	**12.4%**	**1.16%**	**1.23%**	**3.43%**	**1.96%**	**6.3%**	**0.69%**	**10.45%**

Table 10: Current and Available Workers Comparison by Job Hub and Transit AM Commute Times – Selected Industries

	JOB HUBS - INDUSTRY CLASS WITH THE HIGHEST PERCENT OF EMPLOYMENT TOTAL							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
TRANSIT AM COMMUTES	Professional, Scientific & Technical Services and Public Administration (37.2%)	Health Care (22.2%)	Public Administration (42%)	Transportation & Warehousing (37.1%)	Manufacturing (36.8%)	Health Care (72.8%)	Health Care (16.4%)	Administrative, Support & Waste Management Services (29.2%)
Under 21 min								
Currently Working There	491	37	0	0	0	329	0	3
Available Workers	988	699	0	0	0	670	28	32
Ratio	**49.7%**	**5.3%**	**N/A**	**N/A**	**N/A**	**49.1%**	**0.0%**	**9.4%**
21-31 min								
Currently Working There	490	75	0	0	0	1,892	2	2
Available Workers	1,614	1,319	1	0	1	14,390	249	17
Ratio	**30.4%**	**5.7%**	**0.0%**	**N/A**	**0.0%**	**13.1%**	**0.8%**	**11.8%**
31-46 min								
Currently Working There	842	107	2	12	38	959	17	16
Available Workers	9,682	23,911	80	191	435	23,214	1,302	292
Ratio	**8.7%**	**0.4%**	**2.5%**	**6.3%**	**8.7%**	**4.1%**	**1.3%**	**5.5%**
46-61 min								
Currently Working There	646	18	9	16	127	165	48	66
Available Workers	32,133	20,131	281	585	6,895	11,696	6,053	1,125
Ratio	**2.0%**	**0.1%**	**3.2%**	**2.7%**	**1.8%**	**1.4%**	**0.8%**	**5.9%**
Over 61 min								
Currently Working There	123	21	20	164	70	452	91	245
Available Workers	65,656	159,468	41,970	37,418	147,784	155,558	197,896	71,719
Ratio	**0.2%**	**0.01%**	**0.05%**	**0.44%**	**0.05%**	**0.3%**	**0.05%**	**0.34%**

Table 11: Current and Available Workers Comparison by Job Hub and Auto AM Commute Times – All Industries

AUTO AM COMMUTES	JOB HUBS - ALL INDUSTRY CLASSES							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)
Under 21 min								
Currently Working There	28,667	5,961	2,234	3,619	5,214	19,416	5,438	6,614
Available Workers	272,538	303,153	262,014	280,669	116,386	208,296	199,789	266,688
Ratio	**10.5%**	**2.0%**	**0.9%**	**1.3%**	**4.5%**	**9.3%**	**2.7%**	**2.5%**
21-31 min								
Currently Working There	13,375	2,673	1,060	1,728	3,988	7,535	3,238	3,466
Available Workers	251,451	231,775	245,161	250,198	251,860	237,274	283,626	264,356
Ratio	**5.3%**	**1.2%**	**0.4%**	**0.7%**	**1.6%**	**3.2%**	**1.1%**	**1.3%**
31-46 min								
Currently Working There	11,237	2,388	752	1,485	4,088	6,294	2,053	3,428
Available Workers	309,985	315,117	339,926	387,410	402,270	278,316	307,361	456,334
Ratio	**3.6%**	**0.8%**	**0.2%**	**0.4%**	**1.0%**	**2.3%**	**0.7%**	**0.8%**
46-61 min								
Currently Working There	4,487	955	214	429	2,091	2,801	1,036	1,149
Available Workers	295,561	285,833	275,271	231,196	361,420	329,951	347,985	191,476
Ratio	**1.5%**	**0.3%**	**0.1%**	**0.2%**	**0.6%**	**0.8%**	**0.3%**	**0.6%**
Over 61 min								
Currently Working There	1,907	360	80	124	478	1,566	287	158
Available Workers	64,749	58,406	71,912	44,811	62,348	140,447	55,523	15,430
Ratio	**2.95%**	**0.62%**	**0.111%**	**0.277%**	**0.767%**	**1.115%**	**0.52%**	**1.024%**

Table 12: Current and Available Workers Comparison by Job Hub and Transit AM Commute Times – All Industries

	JOB HUBS - ALL INDUSTRY CLASSES							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
TRANSIT AM COMMUTES	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)
Under 21 min								
Currently Working There	1,484	143	0	0	0	405	0	7
Available Workers	5,585	3,492	0	0	0	2,325	107	393
Ratio	**26.6%**	**4.1%**	**N/A**	**N/A**	**N/A**	**17.4%**	**0.0%**	**1.8%**
21-31 min								
Currently Working There	1,482	286	0	0	0	2,330	8	5
Available Workers	16,981	6,072	2	0	9	55,376	1,208	244
Ratio	**8.7%**	**4.7%**	**0.0%**	**N/A**	**0.0%**	**4.2%**	**0.7%**	**2.0%**
31-46 min								
Currently Working There	2,545	412	5	33	87	1,181	86	36
Available Workers	111,084	94,808	1,489	3,760	3,539	96,344	5,031	4,426
Ratio	**2.3%**	**0.4%**	**0.3%**	**0.9%**	**2.5%**	**1.2%**	**1.7%**	**0.8%**
46-61 min								
Currently Working There	1,952	68	26	44	290	203	244	151
Available Workers	326,748	94,886	5,558	12,363	66,417	64,007	23,379	16,152
Ratio	**0.6%**	**0.1%**	**0.47%**	**0.4%**	**0.4%**	**0.3%**	**1.0%**	**0.9%**
Over 61 min								
Currently Working There	372	81	59	436	161	557	464	561
Available Workers	733,886	995,026	1,187,235	1,178,161	1,124,319	976,232	1,164,559	1,173,069
Ratio	**0.05%**	**0.01%**	**0.005%**	**0.037%**	**0.014%**	**0.057%**	**0.04%**	**0.048%**

Work Commute Time Reduction Benefits

Travel time is one of the largest costs of transportation, and travel time savings are often the primary justification for transportation infrastructure improvements. The previous sections demonstrated a vivid mismatch location between where workers live and work that results in longer work commutes for many workers. Shortening work travel time not only will benefit commuters, but will also mitigate traffic congestion severity, reduce VMT in the region, lessen stress and load on road pavements and lowers the overall burden on the transportation system. The study focus was work commute time; therefore, this section presents only the benefits of workers' travel time saving. Although the other benefits are important, they are outside the framework of this study.

Table 13 shows the percentage change of workers for the selected industries currently living in commuter sheds for all the job hubs and using their automobiles for their work commute. The ratios were changed based on the following two constraints that demonstrate a practically tangible work commute time saving:

- In order to estimate travel time reduction benefits, the ratios for each job hub, indicated in Table 9, were reduced for time intervals less or equal than 31 minutes and increased for the travel times greater than 31 minutes. The green and red arrows in the tables depict the decreased and increased ratios. For a fair comparison, the total number of people currently working in any job hub was not changed.

- The percentage change of living and working locations was kept at approximately one percent of the total work trips in the NOACA region.

Table 13: Current and Available Workers Ratios and Example of Ratio Changes by Auto AM Commutes – Selected Industries

	JOB HUBS - INDUSTRY CLASS WITH THE HIGHEST PERCENT OF EMPLOYMENT TOTAL							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
AUTO AM COMMUTES	Professional, Scientific & Technical Services and Public Administration (37.2%)	Health Care (22.2%)	Public Administration (42%)	Transportation & Warehousing (37.1%)	Manufacturing (36.8%)	Health Care (72.8%)	Health Care (16.4%)	Administrative, Support & Waste Management Services (29.2%)
Under 21 min								
Currently Working There	9,481	1,552	780	1,361	2,276	15,771	1,062	2,888
Available Workers	25,235	62,076	9,809	10,213	12,746	47,595	44,855	20,431
Ratio	**37.6%**	**2.5%**	**8.0%**	**13.3%**	**17.9%**	**33.1%**	**2.4%**	**14.1%**
Example of Increased Ratio	***39.0%***	***3.1%***	***9.00%***	***14.3%***	***19.00%***	***35.0%***	***3.00%***	***15.1%***
21-31 min								
Currently Working There	4,423	696	370	650	1,741	6,121	632	1,513
Available Workers	25,290	41,673	9,832	8,482	28,792	41,464	49,606	15,473
Ratio	**17.5%**	**1.7%**	**3.8%**	**7.7%**	**6.0%**	**14.8%**	**1.3%**	**9.8%**
Example of Increased Ratio	***19.5%***	***2.00%***	***4.50%***	***9.0%***	***7.75%***	***16.00%***	***1.44%***	***11.00%***
31-46 min								
Currently Working There	3,716	622	262	559	1,785	5,112	401	1,497
Available Workers	30,080	49,177	11,510	11,091	51,932	44,734	48,598	26,698
Ratio	**12.4%**	**1.3%**	**2.3%**	**5.0%**	**3.4%**	**11.4%**	**0.8%**	**5.6%**
Example of Decreased Ratio	***10.50%***	***0.50%***	***1.40%***	***4.00%***	***2.5%***	***10.00%***	***0.30%***	***4.64%***
46-61 min								
Currently Working There	1,484	249	75	161	913	2,275	202	502
Available Workers	24,390	44,485	8,905	7,038	50,964	51,600	54,327	9,923
Ratio	**6.1%**	**0.6%**	**0.8%**	**2.3%**	**1.8%**	**4.4%**	**0.4%**	**5.1%**
Example of Decreased Ratio	***5.20%***	***0.29%***	***0.30%***	***1.30%***	***1.70%***	***3.52%***	***0.26%***	***4.00%***
Over 61 min								
Currently Working There	631	94	28	47	209	1,272	56	69
Available Workers	5,078	8,117	2,276	1,370	10,681	20,135	8,142	660
Ratio	**12.4%**	**1.16%**	**1.23%**	**3.43%**	**1.96%**	**6.3%**	**0.69%**	**10.45%**
Example of Decreased Ratio	***10.54%***	***0.99%***	***0.08%***	***1.40%***	***0.994%***	***4.811%***	***0.073%***	***7.00%***

The total number of available workers for the selected industry classes is 582,095 and the total number of all workers of the selected industries currently working in the regional job hubs is 73,538. Examples of modified ratios are highlighted in red in Table 13.

The total number of changes in the Table 13 examples is 4,556, which is 0.78 percent of the total available workers for the selected industry classes.

Typical AM Peak Period and Selected Industry Classes

For the above selected industry and major job hubs, the following savings may be summarized for a typical AM peak period:

- Total work travel time is reduced by 2,032 hours.
- Total delay associated to work trips as a measure of congestion is reduced by 448 hours.

- Total work travel time cost is reduced by $24,331 (2018$).
- Total congestion cost is reduced by $5,346 (2018$).

- Total VMT is reduced by 92,614 miles.
- Total fuel consumption is reduced by 4,210 gallons.
- Total fuel cost is reduced by $10,609 (2018$).
- Total crash cost is reduced by $4,630,700 (2018$).
- Total air pollution emission cost is reduced by $2,778,420 (2018$).
- Total pavement maintenance cost is reduced by $185,228 (2018$).

Annual Savings for a Typical AM Peak period and Selected Industry Classes

Using the number of working day in a year, the above morning savings can be converted to the following annual reductions.

- Total annual work travel time is reduced by approximately 508,000 hours.
- Total annual delay associated to morning work trips is reduced by 112,000 hours.

- Total annual work travel time cost is reduced by $6,082,000 (2018$).
- Total annual congestion cost associated to morning work commutes is reduced by approximately $1,336,000 (2018$).

- Total annual VMT of morning work commutes is reduced by 23,153,000 miles.
- Total annual fuel consumption associated to morning work trips is reduced by 1,052,500 gallons.
- Total annual fuel cost associated to morning work trips is reduced by $2,652,250 (2018$).
- Total annual crash cost associated to morning work trips is reduced by $1,157,600,000 (2018$).
- Total annual air pollution emission cost associated to morning work trips is reduced by $694,600,000 (2018$).
- Total annual pavement maintenance cost associated to morning work trips is reduced by $46,300,000 (2018$).

Assumptions

It is worth noting that the cost savings are based on the following calculations:

- Travel time delays are calculated by comparing actual congested travel times with uncongested travel times.

- Travel time cost is calculated using the following equation:
  $Saved\ Travel\ Time\ Cost = Travel\ Time\ Reduction\ \times 60\%\ of\ average\ hourly\ wages$
  (Average hourly wage source: ACS 2017)

- Total fuel consumption assumes an average of 22 miles per gallon (Source: Bureau of Transportation Statistics 2016 and NOACA's Travel Forecasting Model 2018)

- Total fuel cost assumes an average of $2.52 per gallon of gas (2018$) (Source: ClevelandGasPrices.com 2018)

- Total crash cost assumes $50 per each VMT and was calculated using 2018 regional VMT, 2017 regional crashes, ODOT's 2016 comprehensive societal costs by crash type

- Total air pollution emission cost assumes $30 per each VMT and was calculated using recent corridor and sub-area studies within the NOACA region which analyzed emission savings using MOVES software

- Total pavement maintenance cost assumes $2 per each VMT and was calculated using 2018 regional VMT and NOACA's optimal maintenance and rehabilitation scenario from its 2018 regional pavement reports

- Annual estimates assume 250 workdays per year

Similar to Auto, Table 14 shows the percentage change of workers currently living in transit commuter sheds for all the job hubs and use public transport for their work commutes.

Table 14: Current and Available Workers Ratios and Example of Ratio Changes by Transit AM Commutes – Selected Industries

	JOB HUBS - INDUSTRY CLASS WITH THE HIGHEST PERCENT OF EMPLOYMENT TOTAL							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
TRANSIT AM COMMUTES	Professional, Scientific & Technical Services and Public Administration (37.2%)	Health Care (22.2%)	Public Administration (42%)	Transportation & Warehousing (37.1%)	Manufacturing (36.8%)	Health Care (72.8%)	Health Care (16.4%)	Administrative, Support & Waste Management Services (29.2%)
Under 21 min								
Currently Working There	491	37	0	0	0	329	0	3
Available Workers	988	699	0	0	0	670	28	32
Ratio	**49.7%**	**5.3%**	**N/A**	**N/A**	**N/A**	**49.1%**	**0.0%**	**9.4%**
Example of Increased Ratio	***51.0%***	***6.0%***				***51.0%***	***19.0%***	***15.0%***
21-31 min								
Currently Working There	490	75	0	0	0	1,892	2	2
Available Workers	1,614	1,319	1	0	1	14,390	249	17
Ratio	**30.4%**	**5.7%**	**0.0%**	**N/A**	**0.0%**	**13.1%**	**0.8%**	**11.8%**
Example of Increased Ratio	***32.0%***	***6.50%***	***100.0%***		***100.0%***	***14.00%***	***3.2%***	***25.00%***
31-46 min								
Currently Working There	842	107	2	12	38	959	17	16
Available Workers	9,682	23,911	80	191	435	23,214	1,302	292
Ratio	**8.7%**	**0.4%**	**2.5%**	**6.3%**	**8.7%**	**4.1%**	**1.3%**	**5.5%**
Example of Increased Ratio	***10.01%***	***0.55%***	***5.00%***	***12.00%***	***14.0%***	***4.50%***	***4.10%***	***8.30%***
46-61 min								
Currently Working There	646	18	9	16	127	165	48	66
Available Workers	32,133	20,131	281	585	6,895	11,696	6,053	1,125
Ratio	**2.0%**	**0.1%**	**3.2%**	**2.7%**	**1.8%**	**1.4%**	**0.8%**	**5.9%**
Example of Decreased Ratio	***1.67%***	***0.00%***	***3.20%***	***2.00%***	***1.66%***	***0.85%***	***0.20%***	***5.50%***
Over 61 min								
Currently Working There	123	21	20	164	70	452	91	245
Available Workers	65,656	159,468	41,970	37,418	147,784	155,558	197,896	71,719
Ratio	**0.2%**	**0.01%**	**0.05%**	**0.44%**	**0.05%**	**0.3%**	**0.05%**	**0.34%**
Example of Decreased Ratio	***0.10%***	***0.00%***	***0.04%***	***0.42%***	***0.04%***	***0.19%***	***0.04%***	***0.33%***

As mentioned previously, the total number of available workers for the selected industry classes is 582,095 and the total number of all workers of the selected classes currently working in regional job hubs and using transit for their work commutes is 7,595.

The total number of living or working location changes in Table 14 is 525, which is less than 0.1 percent of the total number of available workers for the selected industry classes. In this example, the annual travel time cost saving is over $0.84 million (2018$).

Tables 15 and 16 illustrate similar changed ratios for current and available workers of all industry classes in the regional job hubs commute sheds.

Table 15: Current and Available Workers Ratios and Example of Ratio Changes by Auto AM Commutes – All Industries

	JOB HUBS - ALL INDUSTRY CLASSES							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
AUTO AM COMMUTES	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)
Under 21 min								
Currently Working There	28,667	5,961	2,234	3,619	5,214	19,416	5,438	6,614
Available Workers	272,538	303,153	262,014	280,669	116,386	208,296	199,789	266,688
Ratio	**10.5%**	**2.0%**	**0.9%**	**1.3%**	**4.5%**	**9.3%**	**2.7%**	**2.5%**
Example of Increased Ratio	***12.0%***	***2.61%***	***1.052%***	***1.73%***	***5.00%***	***10.3%***	***3.21%***	***2.8%***
21-31 min								
Currently Working There	13,375	2,673	1,060	1,728	3,988	7,535	3,238	3,466
Available Workers	251,451	231,775	245,161	250,198	251,860	237,274	283,626	264,356
Ratio	**5.3%**	**1.2%**	**0.4%**	**0.7%**	**1.6%**	**3.2%**	**1.1%**	**1.3%**
Example of Increased Ratio	***6.1%***	***1.70%***	***0.6%***	***0.998%***	***2.002%***	***4.20%***	***1.672%***	***1.80%***
31-46 min								
Currently Working There	11,237	2,388	752	1,485	4,088	6,294	2,053	3,428
Available Workers	309,985	315,117	339,926	387,410	402,270	278,316	307,361	456,334
Ratio	**3.6%**	**0.8%**	**0.2%**	**0.4%**	**1.0%**	**2.3%**	**0.7%**	**0.8%**
Example of Decreased Ratio	***2.50%***	***0.10%***	***0.031%***	***0.006%***	***0.7%***	***1.50%***	***0.06%***	***0.525%***
46-61 min								
Currently Working There	4,487	955	214	429	2,091	2,801	1,036	1,149
Available Workers	295,561	285,833	275,271	231,196	361,420	329,951	347,985	191,476
Ratio	**1.5%**	**0.3%**	**0.1%**	**0.2%**	**0.6%**	**0.8%**	**0.3%**	**0.6%**
Example of Decreased Ratio	***1.00%***	***0.058%***	***0.001%***	***0.003%***	***0.50%***	***0.60%***	***0.20%***	***0.101%***
Over 61 min								
Currently Working There	1,907	360	80	124	478	1,566	287	158
Available Workers	64,749	58,406	71,912	44,811	62,348	140,447	55,523	15,430
Ratio	**2.95%**	**0.62%**	**0.111%**	**0.277%**	**0.767%**	**1.115%**	**0.52%**	**1.024%**
Example of Decreased Ratio	***1.428%***	***0.007%***	***0.006%***	***0.004%***	***0.600%***	***0.027%***	***0.03%***	***0.001%***

The total number of available workers for all the industry classes is 1,194,284 and the total number of all workers who currently work in the regional job hubs and use their automobile for their work commute is 164,073. The examples of modified ratios are highlighted in red in Table 15.

The total number of worker location changes in the Table 15 examples is 22,912 and that is 1.92% of the total available workers for all the industry classes.

Typical AM Peak Period and All Industry Classes

For all the industry and major job hubs, the following savings may be summarized for a typical AM peak period:

- Total work travel time is reduced by 10,328 hours.
- Total delay associated to work trips as a measure of congestion is reduced by 2,274 hours.

- Total work travel time cost is reduced by $112,164 (2018$).
- Total congestion cost is reduced by $24,695 (2018$).

- Total VMT is reduced by 478,420 miles.
- Total fuel consumption is reduced by 21,746 gallons.
- Total fuel cost is reduced by $54,800 (2018$).
- Total crash cost is reduced by $23,921,000 (2018$).
- Total air pollution emission cost is reduced by $14,352,600 (2018$).
- Total pavement maintenance cost is reduced by $956,840 (2018$).

Annual Savings for a Typical AM Peak period and All Industry Classes

Using the number of working day in a year, the above morning savings for all the workers can be converted to the following annual reductions.

- Total annual work travel time is reduced by approximately 2,582,000 hours.
- Total annual delay associated to work trips is reduced by 568,000 hours.

- Total annual work travel time cost is reduced by $28,040,000 (2018$).
- Total annual congestion cost associated to morning work commutes is reduced by approximately $6,173,000 (2018$).

- Total annual VMT of morning work commutes is reduced by 119,605,000 miles.
- Total annual fuel consumption associated to morning work trips is reduced by 5,436,500 gallons
- Total annual fuel cost associated to morning work trips is reduced by $13,700,000 (2018$).
- Total annual crash cost associated to morning work trips is reduced by $5,980,250,000 (2018$).
- Total annual air pollution emission cost associated to morning work trips is reduced by $3,588,150,000 (2018$).
- Total annual pavement maintenance cost associated to morning work trips is reduced by $239,210,000 (2018$).

Table 16 shows the summary comparison between the saving values of the selected and all industry classes.

Table 16: Comparison between Savings of the Selected and All Industry Classes

Industry Class	Modified Percent	Annual Travel time Cost Saving (2018$)	Annual Fuel Cost Saving (2018$)	Travel Time and Fuel Cost Savings (2018$)
Selected	0.78%	6,082,000	2,652,250	8,734,250
All	1.92%	28,040,000	13,700,000	41,740,000
Ratio	2.5	4.6	5.2	4.8

Table 16 indicates that the savings increase exponentially when more workers live closer to where they work.

Table 17: Current and Available Workers Ratios and Example of Ratio Changes by Transit AM Commutes – All Industries

	JOB HUBS - ALL INDUSTRY CLASSES							
	Downtown (CBD)	Downtown (East)	Airport (North)	Airport (South)	Solon	University Circle	Chagrin Highlands	Independence
TRANSIT AM COMMUTES	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)	Total Workers (100%)
Under 21 min								
Currently Working There	1,484	143	0	0	0	405	0	7
Available Workers	5,585	3,492	0	0	0	2,325	107	393
Ratio	**26.6%**	**4.1%**	**N/A**	**N/A**	**N/A**	**17.4%**	**0.0%**	**1.8%**
Example of Increased Ratio	***27.96%***	***4.93%***				***19.15%***	***10.0%***	***6.0%***
21-31 min								
Currently Working There	1,482	286	0	0	0	2,330	8	5
Available Workers	16,981	6,072	2	0	9	55,376	1,208	244
Ratio	**8.7%**	**4.7%**	**0.0%**	**N/A**	**0.0%**	**4.2%**	**0.7%**	**2.0%**
Example of Increased Ratio	***10.50%***	***5.50%***	***100.0%***		***100.0%***	***4.49%***	***6.0%***	***8.34%***
31-46 min								
Currently Working There	2,545	412	5	33	87	1,181	86	36
Available Workers	111,084	94,808	1,489	3,760	3,539	96,344	5,031	4,426
Ratio	**2.3%**	**0.4%**	**0.3%**	**0.9%**	**2.5%**	**1.2%**	**1.7%**	**0.8%**
Example of Increased Ratio	***3.05%***	***0.50%***	***3.50%***	***2.67%***	***4.80%***	***1.50%***	***6.00%***	***8.32%***
46-61 min								
Currently Working There	1,952	68	26	44	290	203	244	151
Available Workers	326,748	94,886	5,558	12,363	66,417	64,007	23,379	16,152
Ratio	**0.6%**	**0.1%**	**0.47%**	**0.4%**	**0.4%**	**0.3%**	**1.0%**	**0.9%**
Example of Decreased Ratio	***0.27%***	***0.01%***	***0.01%***	***0.10%***	***0.32%***	***0.01%***	***0.29%***	***0.70%***
Over 61 min								
Currently Working There	372	81	59	436	161	557	464	561
Available Workers	733,886	995,026	1,187,235	1,178,161	1,124,319	976,232	1,164,559	1,173,069
Ratio	**0.05%**	**0.01%**	**0.005%**	**0.037%**	**0.014%**	**0.057%**	**0.04%**	**0.048%**
Example of Decreased Ratio	***0.03%***	***0.00%***	***0.003%***	***0.034%***	***0.013%***	***0.030%***	***0.03%***	***0.02%***

As mentioned previously, the total number of available workers for all industry classes is 1,194,284 and the total number of all workers who currently work in regional job hubs and us public transportation for their work commutes is 16,204.

The total number of living or working location changes in Table 17 is 2,685, which is less than a quarter percent of the total number of available workers. In this example, the annual travel time cost saving is over $3.1 million (2018$).

Environmental Justice (EJ) Population

NOACA's Environmental Justice (EJ) policy states that environmental justice is a framework to ensure that the benefits and burdens of regional transportation investments are shared by all. EJ areas are identified based on socioeconomic and minority composition. NOACA develops specific programs for these areas to align with the principles and policies of the U.S. Department of Transportation, Title VI of the Civil Rights Act, and Presidential Executive Order 12898.

The EJ policy divides the TAZs in the NOACA region into EJ and Non-EJ areas based on the percentage of minority and/or low-income population. The selection of the TAZ system for the EJ procedure is due to the fact that the TAZ system is the information framework for most planning and analyses in the NOACA region. By definition, a TAZ is in an EJ area if its estimated population, based on American Community Survey data, satisfies one of the two following conditions:

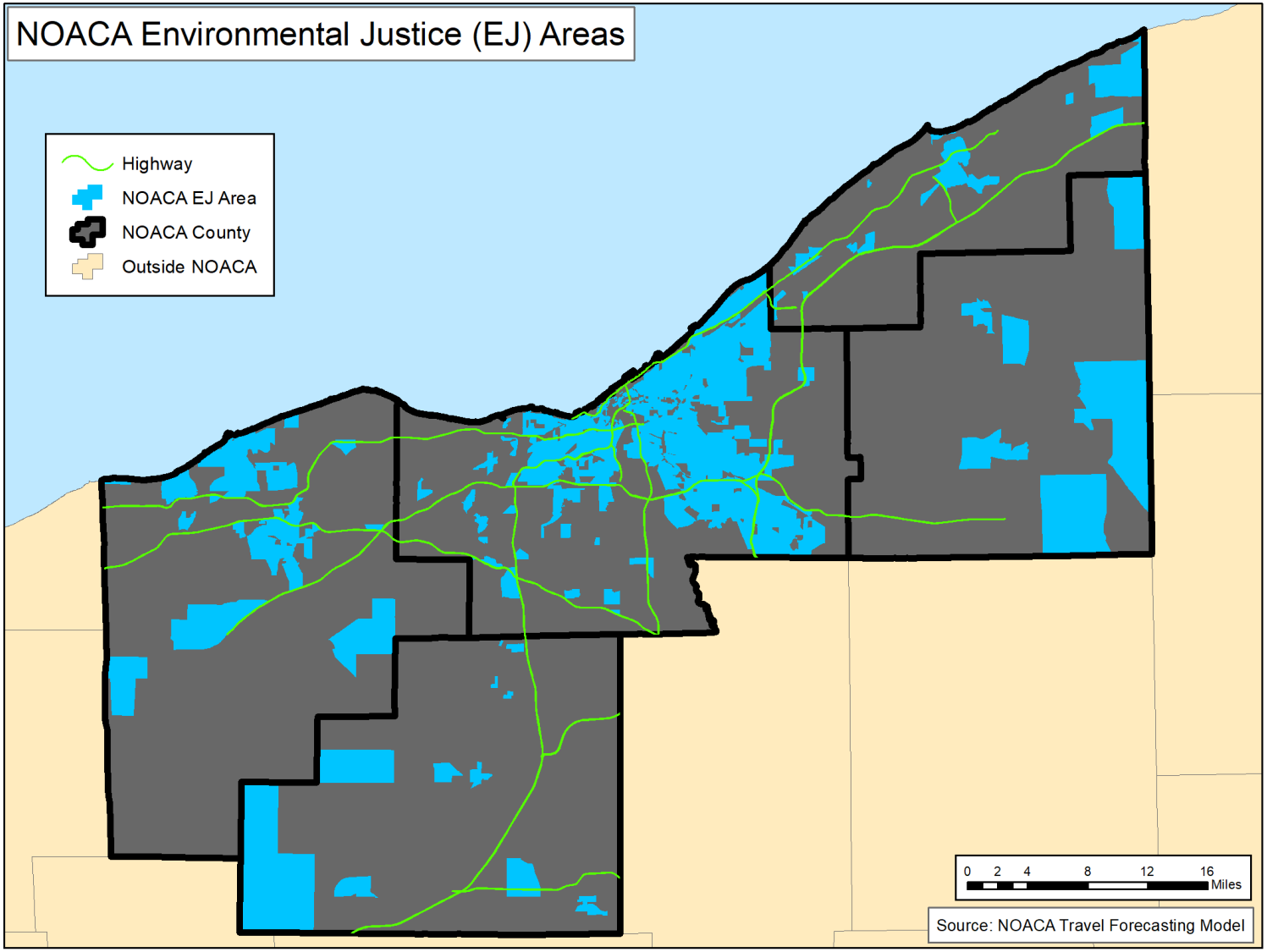
- The minority population is greater than 28.81%.
- The population below the poverty line is greater than 14.72%.

The selected thresholds are the lesser percentage of the national and regional averages.

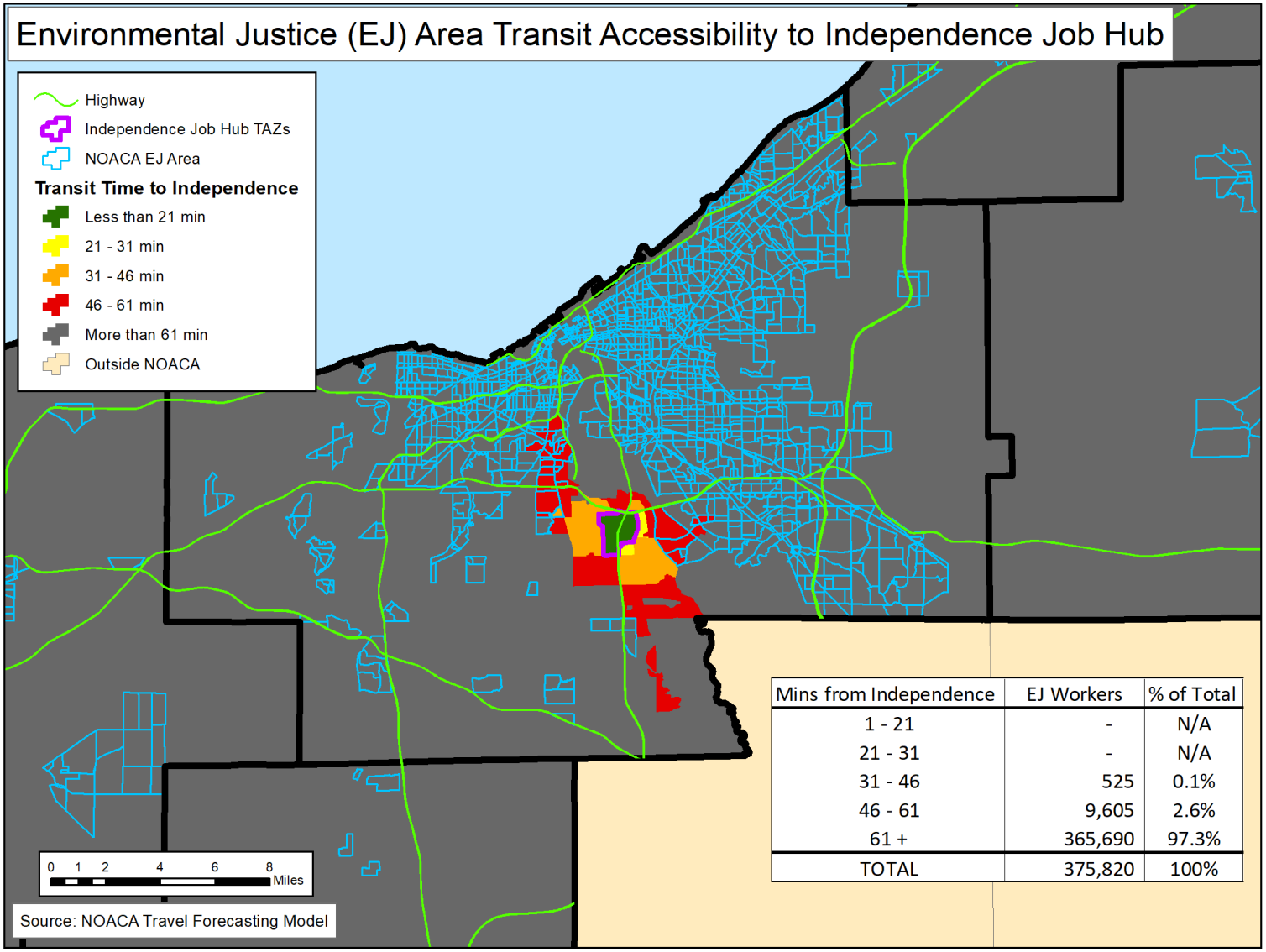
The EJ population is more dependent on transit service than other population sectors. Therefore, transit accessibility is critical for some of the EJ population for work-related journeys. In this section, only transit accessibility of the EJ area population is analyzed and the suggested long-term direction is shown in the following tables.

Map 14 shows the EJ areas in the NOACA region. As an example, Map 15 illustrates the current transit commute sheds of the Independence job hub and EJ areas. As indicated, the work transit commutes are more than 60 minutes for the majority of EJ area workers who travel to the independence job hub.

Map 14: NOACA Environmental Justice Areas



Map 15: Transit Commute Sheds of the Independence Job Hub & Environmental Justice Areas – Status Quo



Mins from Independence	EJ Workers	% of Total
1 - 21	-	N/A
21 - 31	-	N/A
31 - 46	525	0.1%
46 - 61	9,605	2.6%
61 +	365,690	97.3%
TOTAL	375,820	100%

Tables 18 and 19 show the EJ areas' transit accessibility to the regional job hubs by the number and percentage of EJ workers living in the commute sheds of the regional job hubs. As indicated by the green arrows, the regional goal would be to increase the EJ areas' accessibility percentages for the shorter commute sheds to all of the job hubs.

Table 18: Number of EJ Workers Living in Transit Commute Sheds of Regional Job hubs

Job Hub	1 - 21 min	21 - 31 min	31 - 46 min	46 - 61 min	61+ min	TOTAL
Downtown (CBD)	12,529	17,131	104,813	138,168	103,179	375,820
Downtown (East)	6,112	10,681	93,647	68,945	196,435	375,820
University Circle	5,169	60,045	77,093	56,411	177,102	375,820
Airport (North)	-	-	153	1,831	373,836	375,820
Airport (South)	-	-	1,743	1,364	372,713	375,820
Chagrin Highlands	1	545	4,777	18,822	351,675	375,820
Solon	-	8	3,346	58,605	313,861	375,820
Independence	-	-	525	9,605	365,690	375,820
AVERAGE	2,976	11,051	35,762	44,219	281,811	

Long-Term Objective

Table 19: Percentage of EJ Workers Living in Transit Commute Sheds of Regional Job hubs

Job Hub	1 - 21 min %	21 - 31 min %	31 - 46 min %	46 - 61 min %	61+ min %	TOTAL %
Downtown (CBD)	3.3%	4.6%	27.9%	36.8%	27.5%	100%
Downtown (East)	1.6%	2.8%	24.9%	18.3%	52.3%	100%
University Circle	1.4%	16.0%	20.5%	15.0%	47.1%	100%
Airport (North)	0.0%	0.0%	0.0%	0.5%	99.5%	100%
Airport (South)	0.0%	0.0%	0.5%	0.4%	99.2%	100%
Chagrin Highlands	0.0%	0.1%	1.3%	5.0%	93.6%	100%
Solon	0.0%	0.0%	0.9%	15.6%	83.5%	100%
Independence	0.0%	0.0%	0.1%	2.6%	97.3%	100%
AVERAGE OF ALL JOB HUBS	0.8%	2.9%	9.5%	11.8%	75.0%	100%

Long-Term Objective

Transit Enhancement

Transit travel time is comprised of the following:

- Access/egress times
- Wait time
- In-vehicle travel time

The above time components depend on the following transit system characteristics:

- Access/egress times depend on the transit network coverage. Riders must walk longer distances to the nearest transit stop if the transit system coverage is low. Adding more routes to the transit network reduces the access/egress time.

- The average wait time mainly depends on frequencies (headways) of transit services. Adding more services on existing transit routes, would reduce riders' wait time at stations and consequently the total travel time by transit.

- In-vehicle travel time to a large extent depends on traffic congestion, existence of dedicated bus lanes, number of stops, etc. Therefore, in-vehicle travel time reduction is a traffic engineering issue and involves other vehicles and travel modes in the transportation system.

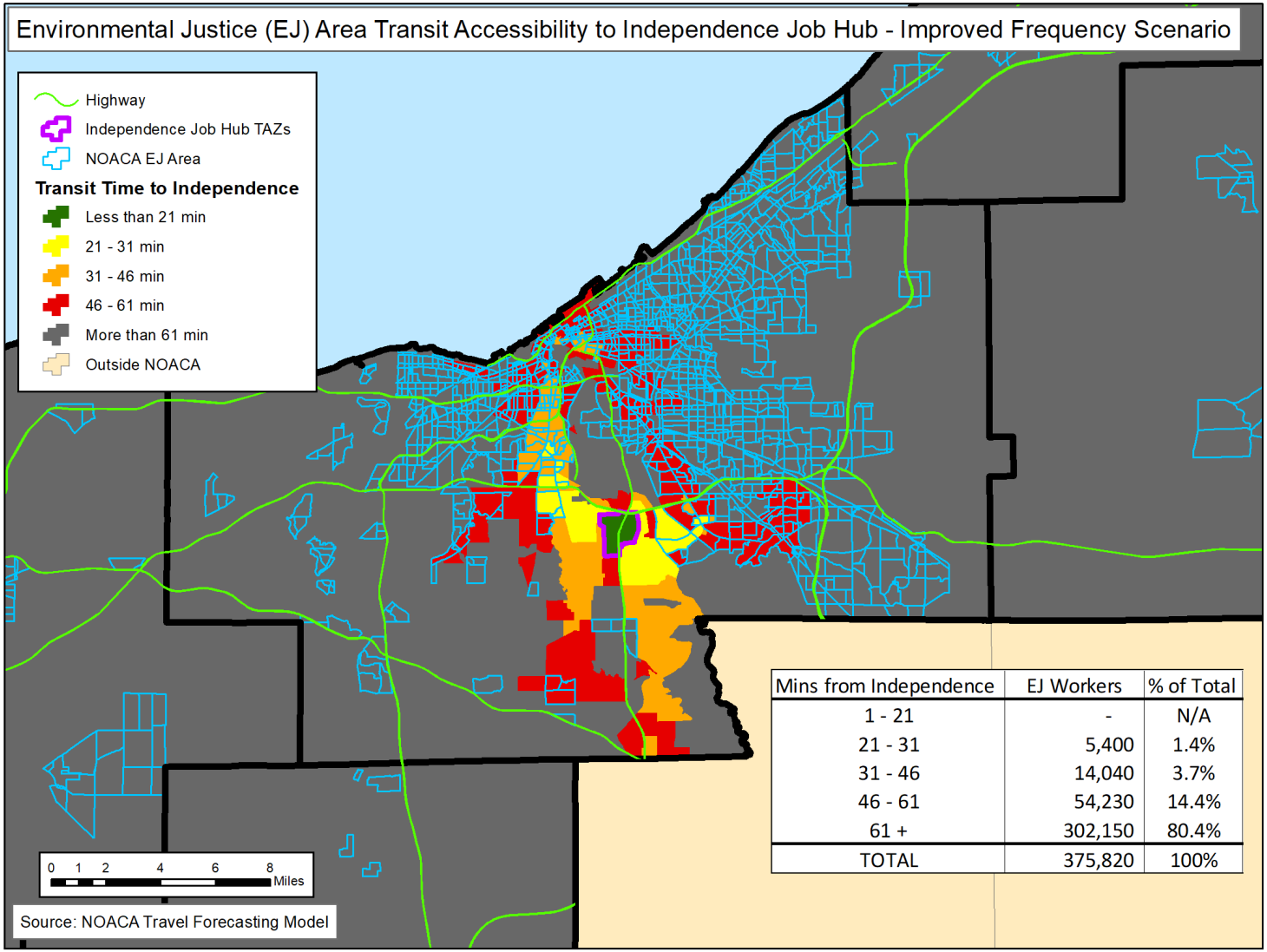
This study examined impacts of the increasing service frequencies for the existing routes of the NOACA transit system only. Modifying service frequencies is the least costly policy compared to adding new routes or transit infrastructure. Despite being the least costly improvement, it should be noted that this option might still be cost prohibitive for the transit agencies in the region.

As the first step of this exercise, transit routes serving the major regional job hubs were identified and then their service frequencies of the identified routes were set to 15 minutes or less during the AM peak period. Some routes currently have service headways of less than 15 minutes and those were not modified.

As expected, the average wait time for transit riders on the modified routes was reduced and resulted in shorter travel time. However, the access/egress time and in-vehicle time were not reduced in this modified scenario.

As an example of the impact of the improved transit services, Map 16 shows the transit time sheds of the Independence job hub and the EJ areas. Comparing this map to Map 15 vividly shows the impacts of the improved transit services.

Map 16: Transit Commuter Sheds of the Independence Job Hub & Environmental Justice Areas – Improved Frequency Scenario



Mins from Independence	EJ Workers	% of Total
1 - 21	-	N/A
21 - 31	5,400	1.4%
31 - 46	14,040	3.7%
46 - 61	54,230	14.4%
61 +	302,150	80.4%
TOTAL	375,820	100%

Table 20 presents the number of additional EJ workers of the improved frequency scenario who use transit services for their work trips compared with the current transit services to regional job hubs. In the table below, the number of decreased EJ workers is shown in red.

Table 20: EJ Workers Using Transit:
Status Quo versus Improved Frequency Services Scenario

Job Hub	1 - 21 min	21 - 31 min	31 - 46 min	46 - 61 min	61+ min	TOTAL
Downtown (CBD)	1,220	3,751	7,520	(10,460)	(2,031)	-
Downtown (East)	1,269	2,663	11,221	8,125	(23,278)	-
University Circle	420	1,114	2,921	12,385	(16,840)	-
Airport (North)	-	-	-	8,881	(8,881)	-
Airport (South)	-	-	2,535	25,339	(27,874)	-
Chagrin Highlands	-	1,617	12,334	80,757	(94,708)	-
Solon	-	186	14,240	7,661	(22,087)	-
Independence	-	5,400	13,515	44,625	(63,540)	-
AVERAGE	**364**	**1,841**	**8,036**	**22,164**	**(32,405)**	

It should be noted that the increased and decreased number of EJ workers are in the same direction as the recommended transit accessibility long-term objectives, indicated in the previous tables.

User Guide

This study combines the existing workforce database with work commute times during the AM peak period in the NOACA region to provide abundant information for practitioners, transportation and urban planners and decision makers. The resulting data may be utilized at several levels of geography as shown in Figure 1. Also, the maps depicting data could be either downloaded or interactively accessed from the NOACA website.

Data Download

The appendix of this report includes over 120 maps. The maps show data related to the following eight analyzed regional job hub sections:

1) Airport (North)
2) Airport (South)
3) Chagrin Highlands
4) Downtown (CBD)
5) Downtown (East)
6) Independence
7) Solon
8) University Circle

Each job hub section includes the following maps:

ZIP Code Level

- Average AM peak period commute time from ZIP codes to the regional job hub ZIP code by automobile in five travel shed groups
- Average AM peak period commute time from ZIP codes to the regional job hub ZIP code by transit in five travel shed groups

TAZ Level & Auto

- AM peak period auto drive time isochrones to the regional job hub TAZs
- Number of available workers in the auto commute time sheds of the regional job hub TAZs by selected industry sector
- Total number of available workers in the auto commute time sheds of the regional job hub TAZs regardless of industry
- Number of employees of the regional job hub TAZs living in its auto commute sheds by selected industry sector
- Total number of employees of the regional job hub TAZs living in its auto commute sheds regardless of industry

TAZ Level & Transit

- AM peak period transit time isochrones to the regional job hub TAZs
- Number of available workers in the transit commute time sheds of the regional job hub TAZs by selected industry sector
- Total number of available workers in the transit commute time sheds of the regional job hub TAZs regardless of industry

- Number of employees of the regional job hub TAZs living in its transit commute sheds by selected industry sector
- Total number of employees of the regional job hub TAZs living in its transit commute sheds regardless of industry

TAZ & Environmental Justice (EJ) Areas

- Number of available EJ workers in the AM transit commute time sheds of the regional job hub TAZs
- AM peak period transit time isochrones to the regional job hub TAZs based on the improved frequency scenario
- AM peak period transit time isochrones to the regional job hub TAZs and NOACA EJ areas number of EJ workers based on the improved frequency scenario

In addition to the regional major job hubs, the methodology discussed in the previous sections may be applied to the sub area or county level employment centers. As a pilot study, the appendix includes the maps of four Medina County employment centers.

Interactive Database

An interactive user-friendly database system is being developed for retrieving data from the NOACA Workforce Accessibility & Mobility system. This system will have three levels: County, ZIP code, and TAZ. The following paragraphs provide a short description of each level of the database system. A detailed user guide is also being developed and will be available to all users of the system.

County Level

As stated previously, the major regional job hubs attracted work trips from other counties and are located in Cuyahoga County and therefore Section 4 discussed the inter-county work trip in relation to this county. However, there are other job hubs in other counties of the NOACA region and the user of the NOACA Workforce Accessibility & Mobility system may retrieve the relevant information from the developed database.

ZIP Code Level

For any given ZIP code, the user of the NOACA Workforce Accessibility & Mobility system is able to create time shed maps similar to the discussed ZIP codes of the regional major job hubs. The NOACA Workforce Accessibility & Mobility system identifies the ZIP code destinations located in the discussed time intervals of any ZIP code origin. Alternatively the user may request the ZIP code origins for any ZIP code destinations. The system produces a table of the resulting ZIP codes and a map for visualization purposes.

TAZ Level

Similar to the ZIP code level, the NOACA Workforce Accessibility & Mobility system may interactively be utilized at the TAZ level. For any selected TAZ, as origin or destination of work trips, the system provides various maps, such as transit accessibility, number of available workers in various categories, etc.

Conclusions & Recommendations

A mathematical scoring model was developed to prioritize the extension of existing and possible future employment centers. One of the applications in this model compares green fields and ranks them for potential development into an employment center. Infrastructure investment for connecting origins and destinations of work trips is another application of the model.

The model was developed based on socioeconomic data and accessibility to transportation facilities. There are several model parameters such as road capacity, average car occupancy, and transit vehicle seating capacity. The model utilizes the input data and parameter values to estimate a score for any existing or future employment center. All variable and parameter units were converted to a single unit of “Persons per square Miles” and consequently, the scoring results are also measured using this unit.

The model was calibrated for the AM peak period using the six regional major job hubs. The results of the calibrated model indicated that the University Circle job hub has the highest score among the six major job hubs. The highest employment and residential density in a small area is the main factor to gain the highest score, although the Downtown Cleveland job hub has higher road connections and more transit services.

Most researches and databases present one-dimensional workforce information such as the number of available workers, jobs, etc. in administrative or community jurisdictions, such as villages, cities, states, etc. This study offers a novel approach for adding transportation measures as the second dimension to workforce information. Transportation agencies have traditionally used average travel times and travel time savings to measure system performance and benefits of improvement investments. This study establishes the workforce information based on work commute time geographies rather than those political or administrative jurisdictions. The commute time during the morning peak period is the most important concern for workers. Combining the travel time measure with workforce information provides a powerful transportation planning tool.

The current workers’ accessibility and mobility in the NOACA region were analyzed during the AM peak period in relation to the six major job hubs. As expected, the results indicate that the number of workers riding buses or trains for their work trips are much smaller than workers driving their cars to work. As Tables 9 to 12 show, the available workers in the commute sheds of any major job hub is higher than the number of workers currently living in that commute shed. These discrepancies illustrate the mismatch between where workers live and work. This study recommends to increase the worker ratios for auto commute sheds of less than 30 minutes and decrease these ratios for the commute sheds higher than 30 minutes. It should be noted that the average work journey time in this region falls in the interval of 20 to 30 minutes.

Tables 18 and 19 indicate that a small portion of EJ area workers live in the reasonable transit commute sheds of the regional major job hubs. The majority of EJ area workers should currently spend more than an hour traveling from home to reach their employment location at five of the major job hubs during the AM peak period. This study recommends to increase the number EJ area workers in the lower commute sheds by providing more frequent transit services to the EJ areas. The green arrow in Tables 18 and 19 schematically depicts this recommendation.

In order to reduce the workers and employers locations mismatch and implement the discussed recommendations, the following transportation and land use solutions are recommended:

Transit Solutions

- More frequent express and local buses to major regional job hubs
- Implement low cost traffic engineering solutions at identified arterial bottleneck locations on transit routes
- Extend the transit network to/from major regional job hubs and inter-county transit services
- Adding more park-and-ride locations throughout the region
- Dedicate highway lanes to express buses and car pooling
- Develop more bike lanes to access major transit stations

Land use Solutions

- Mixed-use development along existing major transit corridors
- Mixed-use development around job hubs
- Support policies for housing development closer to job hubs
- Encourage businesses to locate near existing transit services, particularly rail and BRT

NOACA Policies

Regarding the above recommended solutions, the potential planning policies currently under discussion at NOACA's policy committee are:

- Support and prioritize transportation funding, especially transit expansion and enhancements around major regional job hubs
- Support and prioritize funding for multimodal accessibility to job hubs and connections to transit services
- Support regionalized transit system – inter county transit routes and expansion of park-and-ride system
- Encourage efficient mixed-use development
- Implement mobility-accessibility study for any current and potential employment centers

In conclusion, this study intends to encourage the business community and government organizations to consider shorter work commutes during the planning and decision making process. Business site selection and housing incentive programs should attempt to match the industry sectors of existing employment centers with workers of a required skill-set who reside within a shorter commuting shed. Such planning and policies will save commute time, alleviate traffic congestion, reduce accidents, and mitigate pollution in order to improve quality of life.

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