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A Handbook for Transportation-Efficient Growth in Small Communities and Rural Areas

Prepared for NCHRP Project No. 25-36 | Transportation Research Board of the National Academies

Brian J. Morton[1], Joseph Huegy[2], and John Poros[3]
[1] Center for Urban and Regional Studies, The University of North Carolina at Chapel Hill, Chapel Hill, NC
[2] Institute for Transportation Research and Education, North Carolina State University, Raleigh, NC
[3] Carl Small Town Center, College of Architecture, Art, and Design, Mississippi State University, Mississippi State, MS

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Brian J. Morton of the Center for Urban and Regional Studies at The University of North Carolina at Chapel Hill (UNC-CH) is the principal author of this report and the project's Principal Investigator. Prof. Yan Song of the UNC-CH Department of City and Regional Planning developed the typology of small communities and rural areas. These UNC-CH research assistants and research associates were immensely helpful to the project: Tom Dworetsky, Jun Huh, Prasanna R. Kusam, and Louis Merlin.

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Executive Summary

Many people in small communities and rural areas in the United States spend a considerable amount of time in their cars, crossing county lines daily as they drive back and forth between their homes and work, shopping, school, appointments, and more. New growth in such areas can add to an already high load of daily driving if land use decisions are not made with careful consideration and a regional perspective.

Increased driving has negative impacts on individuals (stress, time, fuel consumption, car maintenance); on communities (traffic jams, road maintenance, air pollutant emissions); and on the country and the world as a whole (cost, environment). For all these reasons, when planning for new growth, it makes sense to specifically consider how that growth might affect daily driving.

Hundreds of studies have investigated how land use affects daily driving in urban and suburban areas. The studies have provided a vocabulary for describing the specific land use characteristics that are most influential, such as: density, diversity of land uses, neighborhood layout, distance to employment centers, and distance to transit. In addition, the studies have shaped the public's discussion of important environmental issues, helping motivate interest in land use planning as a tool that local governments can use to accommodate employment and population growth while reducing growth in greenhouse gas emissions from residents' vehicles.

Very few of those studies have looked at small communities and rural areas. This handbook is intended to help fill that gap by providing insights into the relationship between a small/rural area's existing development patterns and changes in daily driving after hypothetical new growth.

The handbook offers a vocabulary of land use characteristics that are significant in small communities and rural areas. It also estimates the change in daily driving per person after hypothetical growth occurs according to different development visions or scenarios.

Three typical, actual small communities and rural areas that have substantially different population densities were investigated. The investigations were carried out using three computer models of travel patterns, one model for each small community and rural area. The computer models are integrated land use-transport models that were built specifically for this project. Their primary purpose is to predict how travel, specifically total vehicle-miles traveled and per person vehicle-miles traveled, might change in response to hypothetical changes in employment, population, and land use patterns.

The specific development strategies that were studied provide insight into the significance for travel behavior of differences in the location of employment and population growth, contrasting growth that is dispersed throughout a region, and growth that is concentrated. The analyses summarized here also assess the impact of land use, development patterns, and the associated economic activities on travel behavior in small communities and rural areas and identify those land use-related conditions that have the greatest impact on travel behavior. Although the report does not advocate any particular type of development pattern, it suggests the land-use-related conditions that are most important to consider when one of the goals of planning is minimizing the increase in vehicle-miles traveled and the consequent consumption of fossil fuels and vehicular emissions of air pollutants, including greenhouse gases.

While the results differ somewhat among the places, in general, daily driving per person decreases a little or does not increase much in either of these scenarios:

- New jobs and households are sited in a small area that already has a high amount of existing development, good access to the region's commercial developments, and a mix of jobs and households compared to other areas in the multi-county region.
- New jobs and households are spread out among several of the larger towns in the region, attempting to balance the new jobs and new households in each town.

However, siting new jobs and new households together in a small area that is relatively undeveloped and isolated can lead to a large increase in daily driving per person in the multi-county region.

The results of the computer models are summarized more fully in the Key Results chapter, and are explained in detail in the chapters on each study area. The project's results are applicable to many small communities and rural areas in the United States. The Project Overview chapter provides guidance on understanding the characteristics of the three types of small communities and rural areas that were studied, and the Checklists included with each study area chapter show how to apply the results to other small communities and rural areas that have similar characteristics.

In addition, the handbook includes dozens of streetscape visualizations of real towns in small communities and rural areas, showing ways in which noticeable levels of growth can be accommodated without losing the character and feel of the towns.

Introduction

The purpose of this handbook is to share insights about the relationship between patterns of regional economic development and the average resident's car usage in small communities and rural areas.

The insights were generated by computer models that were developed specifically for multi-county regions consisting of small communities and rural areas. The results are especially applicable to town and regional planning efforts. It is not necessary to have access to the computer models to understand or apply the results.

The computer models were applied to three multi-county study areas, each of which represents a larger group with similar characteristics. The study areas are as follows:

- a five-county area in North Carolina and Tennessee
- a six-county area in Ohio
- a three-county area in Washington state

The models use real information about where people live and work, collected from census records. The transportation network also is real, including freeways and major roads, but not all local roads.

The results of the computer modeling presented in this handbook will allow practitioners to choose strategies of development with a deeper understanding of how those strategies might impact vehicle miles traveled daily (VMT) by residents. For residents, more driving leads to spending more money on fuel and vehicle repairs, and may increase stress. For communities, more driving leads to traffic jams, air pollution, and more construction and repair. More driving also leads to the emission of larger volumes of carbon dioxide and other greenhouse gases, assuming the cars are burning fossil fuel or running on electricity generated by burning fossil fuels.

The handbook is intended for practitioners in the United States, including community or regional planners, transportation planners, town design consultants, real estate developers, civic leaders, and citizens engaged in planning efforts affecting a town, a county, several towns, or several counties.

Handbook Organization

The two Project Overview sections give some background on how the project was carried out—first in terms of defining and selecting the three study areas and then in terms of the computer models and the hypothetical development scenarios that the computer models accessed. Then key results are highlighted. Next, each study area is reviewed in its own chapter, including data from the results of multiple growth scenarios, a checklist for planners, and streetscape visualizations showing how some of the development scenarios might look in practice. The Appendix contains more in-depth information about some of the topics covered in the Project Overview sections.

A Note on the Streetscape Visualizations

In addition to quantitative results, this handbook presents streetscape visualizations and aerial perspectives of all three study areas to give a sense of what the towns look like now and what they could look like after experiencing growth in jobs and households similar to those called for in the computer scenarios. While there are many ways to increase density, these visualizations represent best practices for small towns that should allow them to accommodate growth with little or no increase in vehicle miles traveled per person, fuel consumption per person, or vehicular emissions per person. These best practices include 7-14 dwelling units per acre, connectivity of streets, pedestrian- and bike-friendly streets, and proximity to downtown. The visualizations illustrate that denser growth does not have to change the overall character of small towns. These visualizations are intended to illustrate general concepts, not to prescribe specific solutions.

Project Overview: The Three Study Areas

This section explains how the nation's small communities and rural areas were characterized, and how the three study areas were chosen. In addition, there is more information in the Appendix about the process, including a gallery of maps and the sources of data used.

What are "Small Communities and Rural Areas"?

This project focused on non-urban areas, or "small communities and rural areas." As used in this project, the term refers to places that are outside Transportation Management Areas. A Transportation Management Area (TMA) is defined by the Federal Highway Administration as an urbanized area with a population of over 200,000. The U.S. Bureau of the Census designates urbanized areas, and they do so primarily on the basis of population density.

Multi-County Regions as a Focus: Commuting Zones

This project focuses on multi-county regions. In small communities and rural areas, people often drive between towns and counties for work and shopping. Therefore, for planning purposes, it makes sense to consider a group of counties rather than one small town at a time.

Planning on a multi-county scale will be familiar to the local officials developing short- and long-range transportation plans prepared under the auspices of regional transportation planning organizations, whether established according to federal transportation legislation (MAP-21) or state authority. Each such organization represents the interests of multiple contiguous counties. For example, North Carolina's Rural Regional Transportation Planning Organizations have jurisdictions encompassing 3 to 15 counties. Thirty-two states have formally established regional transportation planning organizations or have other multijurisdictional organizations continually engaged in transportation planning.[1]

This project began by looking at the multi-county regions called commuting zones, defined by the U.S. Department of Agriculture using 2000 census data, the most recent data available at the time of this project.[2] These commuting zones map local labor markets. Most trips from home to work are made entirely within a commuting zone, so commuting zones provide a natural way to organize data about people's daily travel and to look for patterns in those data.

Unfortunately, data about multi-county regions in which people travel for both shopping and personal business trips are not available for the entire United States. However, it is reasonable to expect that the most common destinations other than the workplace are not far from the route that connects home to work.

Identifying Commuting Zones in Small Communities and Rural Areas

Defining commuting zones containing counties that could be characterized as "small communities and rural areas" was a multi-step process. First, counties that lay entirely or partially outside Transportation Management Areas were identified as being small communities and rural areas (see Figure 1 below). All the remaining counties were identified as large-community/urban-area counties. (Note: The boundaries of urbanized areas—and hence TMAs—do not typically follow county lines, as the boundaries of commuting zones do.)

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1 "RPO States," National Association of Development Organizations/Rural Planning Organizations of America, http://www.ruraltransportation.org/about-rtpos/rtpo-states/.

2 http://www.ers.usda.gov/data-products/commuting-zones-and-labor-market-areas.aspx#.VAnJzGNkwnI.

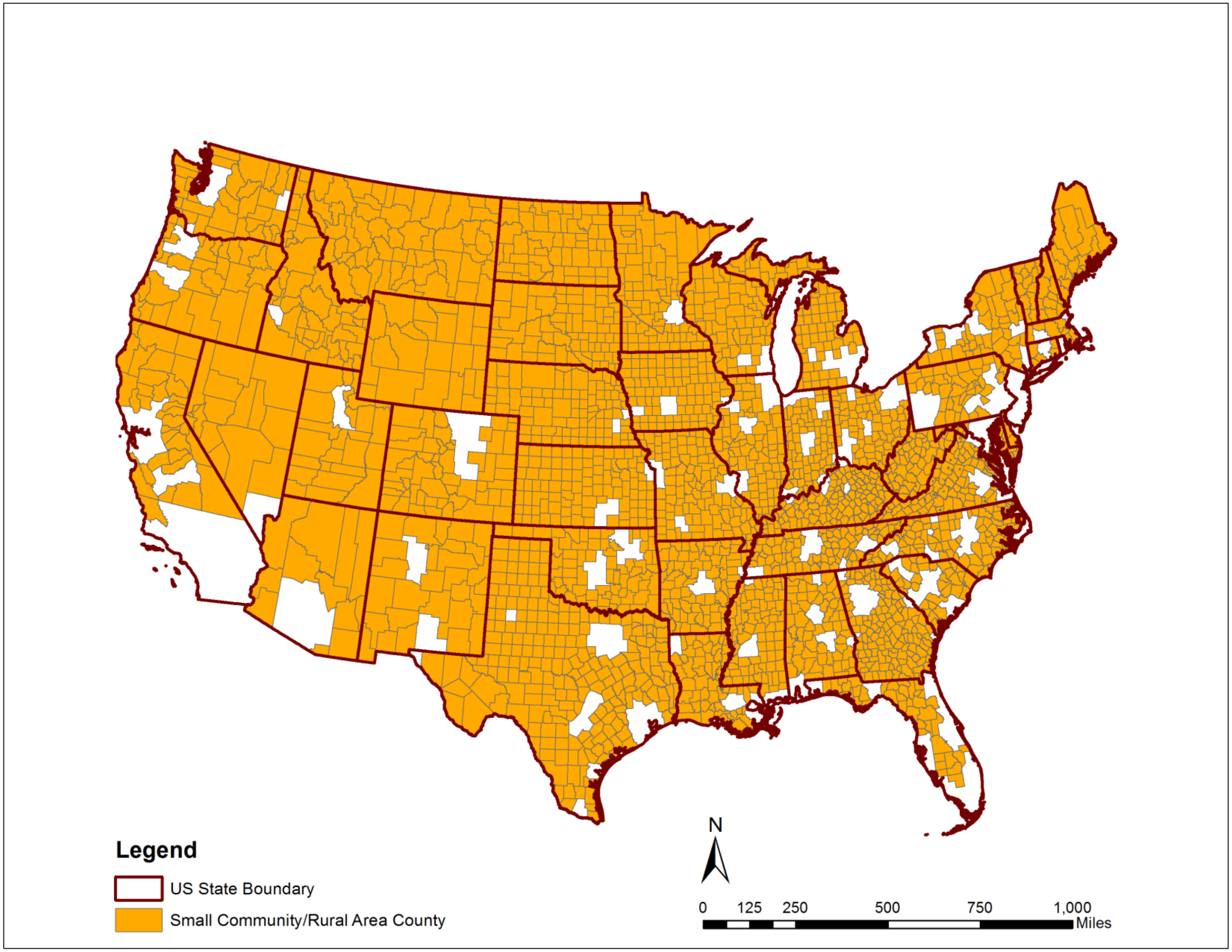


Figure 1. Counties entirely or partially outside Transportation Management Areas.

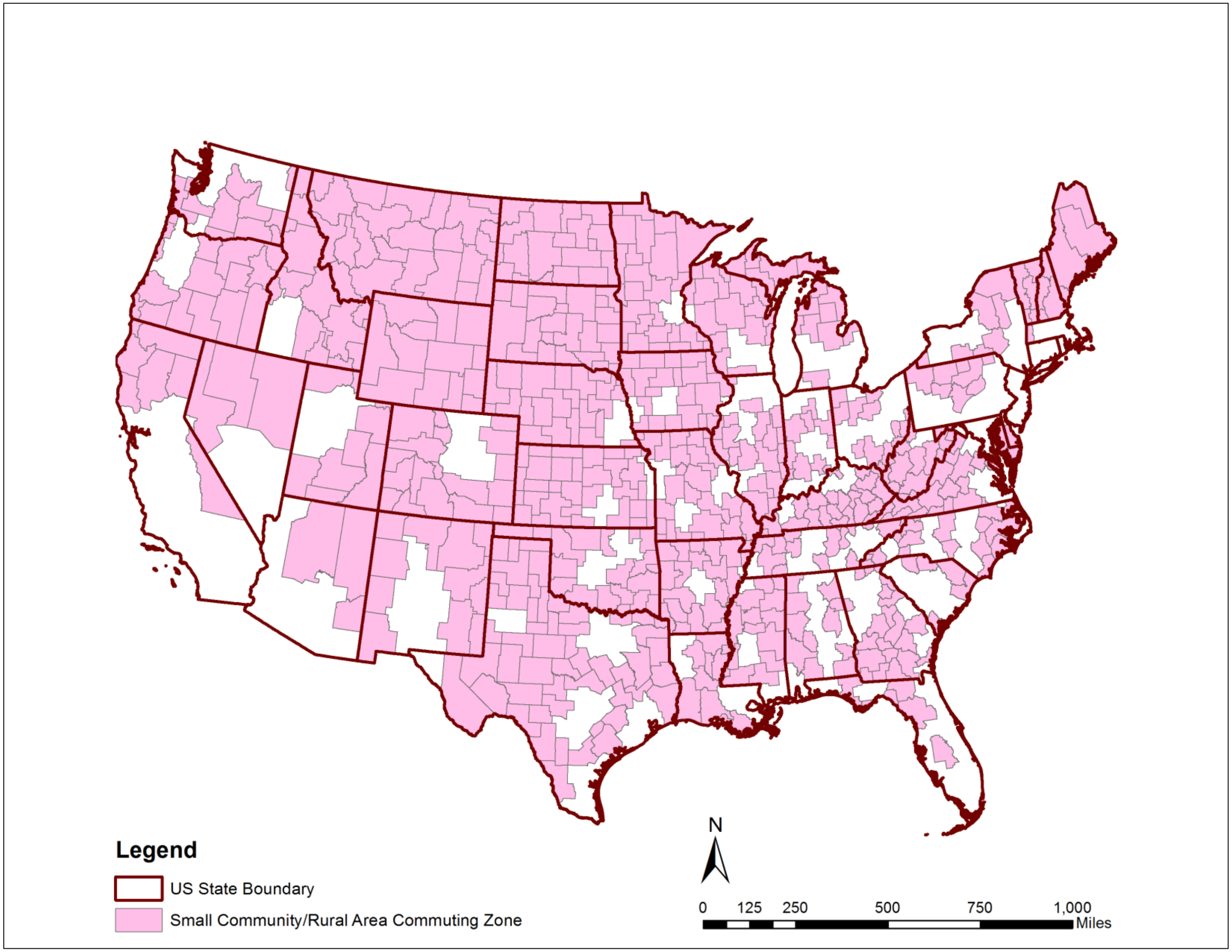


Figure 2. Small-community/rural-area commuting zones in the continental United States.

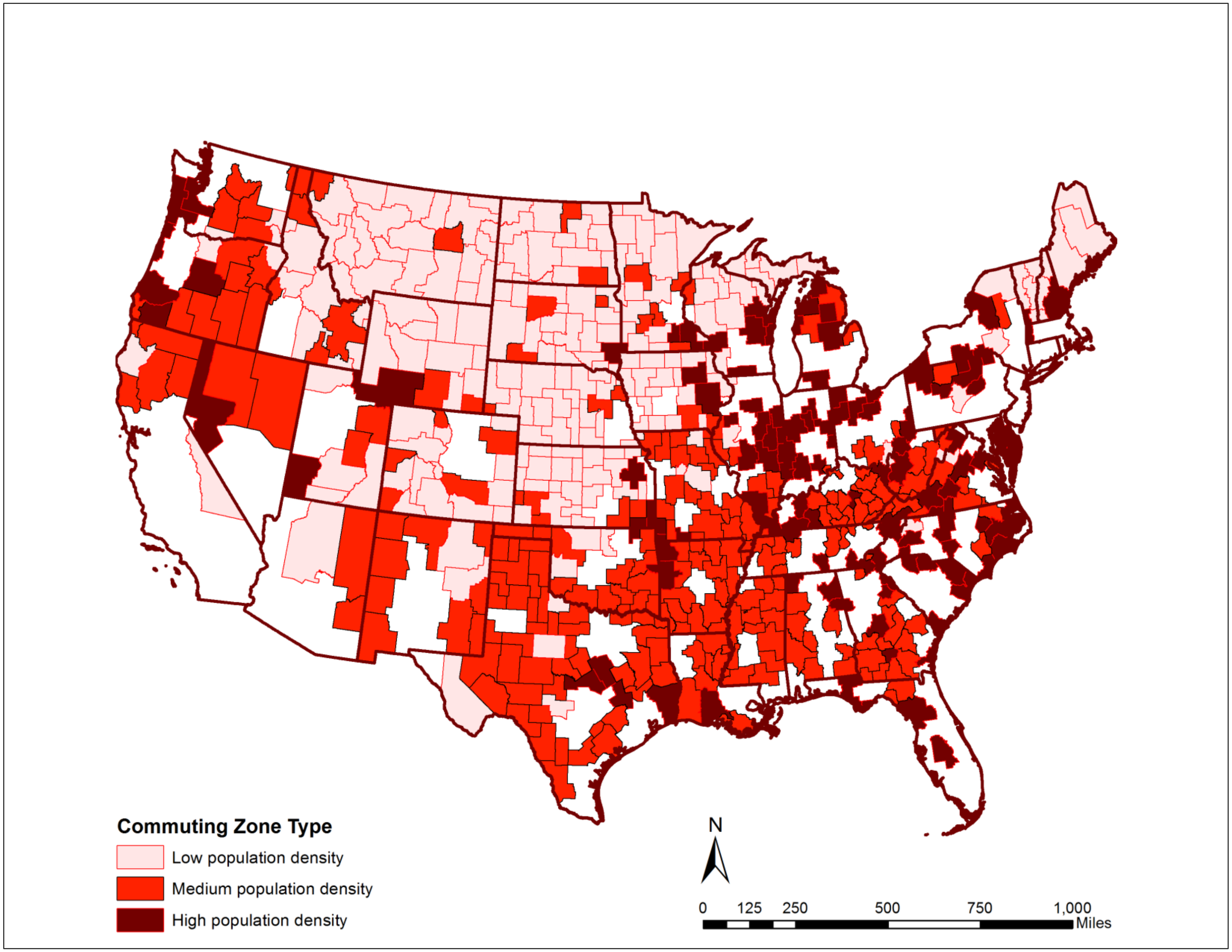


Figure 3. Small-community/rural-area commuting zones, by family.

In the next step, all counties in the continental United States were overlaid with the commuting zones. The commuting zones that contained the large-community/urban-area counties were deleted.

That left 546 commuting zones that were defined as small communities and rural areas (see Figure 2 above). Almost all of these commuting zones contain multiple counties, but a very few contain only one county.

Choosing the Three Study Areas

Next, the 546 small-community/rural-area commuting zones were analyzed to look for patterns in development and how the roads were laid out. The data analyzed included data about population density, variation in population density, road density, and diversity of land use. These data were chosen based on previous studies of the influence of the built environment on people's daily travel choices. (See the Appendix for more information on how the commuting zone families were characterized.)

This analysis identified three distinct families of commuting zones, which were assigned these descriptive labels (note that "low," "medium," and "high" are meant with respect to small communities and rural areas):

- Family 1: Low Population Density
- Family 2: Medium Population Density
- Family 3: High Population Density

Tables 1 and 2 show quantitative and qualitative characteristics of each family. Figure 3 (above) shows the commuting zones and identifies the family to which each commuting zone belongs.

Table 1. Quantitative defining characteristics of commuting zone families.

	Family 1 (n=194)	Family 2 (n=232)	Family 3 (n=120)
Population Density (persons per square mile)	Ave: 18.60	Ave: 35.43	Ave: 105.97
	Min-Max: 0.71 – 99.90	Min-Max: 0.31 – 96.60	Min-Max: 11.00 – 343.00
Variation in Population Density (coefficient of variation)	Ave: 1.89	Ave: 1.65	Ave: 1.38
	Min-Max: 0.00 – 7.27	Min-Max: 0.14 – 4.04	Min-Max: 0.79 – 2.14
Road Density (centerline miles per square mile)	Ave: 1.68	Ave: 2.14	Ave: 3.00
	Min-Max: 0.42 – 3.05	Min-Max: 0.45 – 3.80	Min-Max: 2.11 – 8.27
Diversity of Land Use (diversity index)	Ave: 0.15	Ave: 0.12	Ave: 0.13
	Min-Max: 0.12 – 0.22	Min-Max: 0.08 – 0.14	Min-Max: 0.10 – 0.18

Table 2. Qualitative defining characteristics of commuting zone families.

	Family 1	Family 2	Family 3
Population Density	Low	Moderate	High
Variation in Population Density	High	Moderate	Low
Road Density	Low	Moderate	High
Diversity of Land Use	High	Low	Moderate

A virtual flyover at an altitude of 10,000 meters gives the following subjective impression of the three families of commuting zones:

- Low population density commuting zones feature isolated settlements in open space (land that is unlikely to be developed because of the presence of protected areas such as parks and wilderness areas).
- Medium population density commuting zones feature small towns in a working landscape (land used for agriculture and forestry as well as landscapes that are the stage for new economic drivers such as tourism based on the aesthetics and sense of place).
- High population density commuting zones feature large towns in a working landscape (land used for agriculture and forestry as well as landscapes that are the stage for new economic drivers such as tourism based on the aesthetics and sense of place).

One commuting zone from each of the three families was chosen to be the study area representing that family. In order to have sufficient data for the computer model, each study area needed to contain at least several counties, at least several census tracts per county, at least several dozen census tracts and/or census block groups in total, and needed to have a complete tax parcel database that could be downloaded for at least one county.

The study areas are as follows:

- Family 1, low population density: a five-county area in North Carolina and Tennessee
- Family 2, medium population density: a six-county area in Ohio
- Family 3, high population density: a three-county area in Washington state

The handbook contains a chapter on each of these three study areas, including descriptive information, results of the computer simulations, and streetscape visualizations of different types of potential development. The results of each study area are most likely to be applicable to other small communities and rural areas in the same family.

An online, interactive map displays the commuting zones and their type, and the counties in each zone (see Figure 4 below). The URL for the map is http://go.ncsu.edu/scara-commuting-zones-map.

See the Appendix for informational maps illustrating characteristics from each of the three commuting zone families.

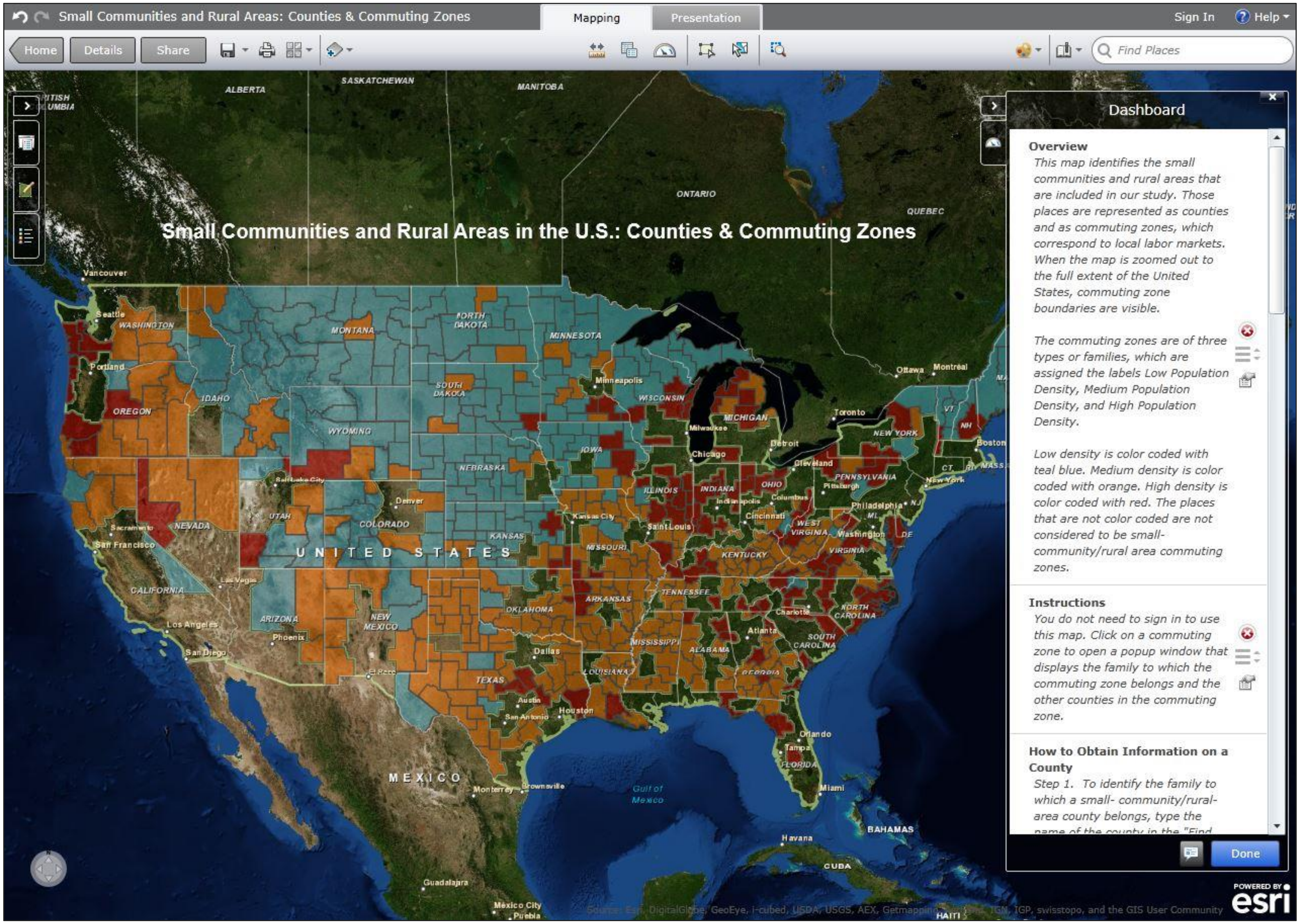


Figure 4. ArcGIS explorer map of small communities and rural areas. URL: http://go.ncsu.edu/scara-commuting-zones-map.

Project Overview: The Computer Models

The results presented in this handbook were generated by three computer models, one for each study area. The models are designed to illuminate ways in which different land use patterns affect travel in each study area in response to hypothetical, but realistic, economic growth.

This section briefly explains the computer models (including inputs, assumptions, and variables) and the different scenarios used in the models. For more detailed information, see the Appendix and the final report for NCHRP Project 25-36.

Background on the Computer Models

The primary tools that were used to investigate the influences of land use on travel were three integrated land use-transport models, one for each case-study area, that were built specifically for this project using the TRANUS modeling platform.[3] The computer models' primary purpose is to predict how travel, specifically total vehicle-miles traveled and per person vehicle-miles traveled, might change in response to hypothetical changes in employment, population, and land use patterns.

The computer models simulate the economy, population, and transportation system of each study area. In contrast to a physical model built with plywood and papier-mâché, these digital study areas are built with databases and mathematical formulas. The databases store information on jobs, households, residential buildings, roads, and bus routes. Some formulas describe the relationship between businesses and households: businesses are sources of jobs and of goods and services, and households are sources of employees and of consumers. Others describe the population's demands for the transportation services consumed on a daily (weekday) basis.

The digital study areas replicate travel within, to, and from each actual study area. Digital study area residents travel from home to work, shopping, doctors' offices, church or temple, friends, etc., and back home. Travel occurs via auto (including pickup truck, motorcycle, and van), walking, and, where available, public bus.

The power of integrated land use-transport models is that unlike their alternatives (i.e., stand-alone transportation models or stand-alone land use models), these models explicitly take into account interdependence in the causality between the land-use system and the transportation system. As land use patterns change, travel patterns change as residents patronize new businesses. The residents may also reduce the trips made to the existing businesses. Traffic congestion and travel times may also change, motivating travelers to change routes, time of day of travel, average number of trips made, and travel modes. As travel patterns change, the relative attractiveness of different places to existing and new businesses changes, motivating a gradual evolution in the land use patterns.

In contrast with integrated land use-transport models, transport-only models assume that the land use patterns are fixed. Likewise, land use-only models assume that the access to destinations provided by a transportation system is fixed. The integrated models allow changes in land use patterns to be reflected in travel patterns and changes in travel patterns to be reflected in land use patterns. The transportation and land use systems can evolve over time in a more realistic way in the integrated models.

[3] TRANUS was developed by Tómas de la Barra, Beatriz Perez, and Juancarlo Añez and is maintained by Modelistica (Caracas, Venezuela). Software, documentation, and users' guides are available from: http://www.tranus.com/tranus-english/download-install.

TRANUS based models go beyond the typical integrated land use-transport model because not only do they link land use and travel to each other, they also link travel to a study area's economy. Work commuting trips reflect businesses' demand for the labor provided by the study area's households. Shopping trips reflect households' demand for the goods and services provided by the study area's stores. Economic exchanges between businesses and households are mirrored in the trips made on the transportation network.

When a scenario involving employment growth is being studied with a TRANUS based model, the growing industry must be specified because businesses' demands for labor depend upon the industry to which the businesses belong. The model will accurately predict the induced growth in the household population: both the number of new households and the types of new households (households tend to vary with respect to the particular industry in which their members work). Consequently, employment growth and household growth are carefully and realistically coordinated.

Sources of Data Used to Build the Computer Models

The data on jobs, households, and residential buildings were obtained from U.S. Census Bureau surveys, primarily the 2000 decennial census. (It was not possible to use 2010 data because the needed data were not released in time for this project.)

To protect privacy, the census data about jobs and households are released to the public in aggregations according to geographical units known as census block groups and census tracts. A census block group contains 600 to 3,000 residents, and a census tract contains one or more census block groups. Census tracts do not cross county lines, and there are almost always more than one census tract per county. The total number of census tracts and census block groups in each of the three study areas ranges from 38 to 209.

Because the data in the computer model are aggregated in this way, jobs and households in the digital study areas are not located at exact street addresses, but in census block groups or census tracts. In general, that is a common practice in building computer simulations of a multi-county region's economy, population, and transportation system.

The computer simulations of the digital study areas predict the total volume of travel; total number of persons traveling by auto, walking, and bus; and the roads used. Total volume is measured by travel purpose in terms of persons, vehicles, and distance traveled. For example, the simulations count the number of commuters traveling from home to work and from work to home, and the simulations tally the distances commuters traverse via auto, walking, and bus. For all of the other trips included in the simulations, similar calculations are made.

The digital study areas allow one to predict the transportation consequences of changes in the economy, population, roads, and public transit. In this project, jobs and population were experimentally increased, while keeping roads and public transit the same.

Five D's

With that flexibility to design the future, the digital study areas provide answers to various "What if?" questions pertaining to how the built environment influences peoples' everyday transportation choices.

Typically in the context of metropolitan areas, the planners and researchers interested in these effects describe the built environment as having five specific characteristics, often termed the "five D's," which are listed in Table 3.

The computer models used in this project do not address *design* because the databases do not include data about sidewalks, shade, attractiveness of homes, etc., and furthermore, design features can vary quite a bit within a census block group or census tract. Similarly, the models don't address *distance to transit* because using aggregations of data from census block groups and census tracts makes it impossible to measure whether there are transit stops within a quarter- or half-mile of individual homes.

Density is expressed in the computer models not through persons per square mile or square acre, but through the total number of households and the total number of jobs in each census block group or census tract. Travel demand in the models is a function of the number of households and number of jobs, not a function of the density of households or jobs.

The computer models provide direct insight into the effects of *diversity of land use* and *destination accessibility*. Both of these factors are quantifiable and are at an appropriate scale for the computer models.

Table 3. Frequently investigated attributes of the built environment that influence people's daily transportation choices.†

Density	Population and employment by geographic unit (e.g., per square mile, per developed acre)
Diversity	Mix of land uses, typically residential and commercial development, and the degree to which they are balanced in an area (e.g., jobs-housing balance)
Design	Neighborhood layout and street characteristics, particularly connectivity, presence of sidewalks, and other design features (e.g., shade, scenery, presence of attractive homes and stores) that enhance the pedestrian- and bicycle-friendliness of an area
Destination accessibility	Ease or convenience of trip destinations from point of origin, often measured at the zonal level [such as a census block group] in terms of distance from the central business district or other major centers
Distance to transit	Ease of access to transit from home or work (e.g., bus or rail stop within ¼ to ½ mile of trip origin)

† Source: National Research Council (U.S.), Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions*, Special Report 298, Washington, D.C.: Transportation Research Board, 2009, p. 52 (modified Box 3-1).

Diversity of land use is measured by dividing a census tract or census block group's total number of jobs by its total number of households. Destination accessibility is measured in terms of three quantities: nearness/farness, number of households or number of commercial establishments, and economic factors. (See section titled Accessibility below for more information on this measurement.) Destination accessibility is central to the functioning of the computer simulations because of its strong influence on business owners' choices of the census tract or census block group in which to operate—they are attracted to areas where households (customers) will have good access to them.

A case could be made that destination accessibility is the most important attribute of the built environment. Badoe and Miller (2000) provide a compelling argument:[4]

> *Conceptually, accessibility is central to transportation planning–it is, very simply, what we are in the business of providing. The accessibility of people to workplaces and other activities, the accessibility of jobs to workers, of stores to their market must be of some relevance to the activity/travel process if this process is the least bit rational….Indeed, one of the reasons why the literature on the impact of factors such as residential density or neighborhood design is so mixed is that it tends to ignore the critical question of connectivity: it is of little use having a dense neighborhood which does not have good access to relevant activity destinations…." (pp. 251-252)*

[4] Badoe, D. A. and E. J. Miller. 2000. Transportation–land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research Part D*, vol. 5. pp. 235-263.

Definition of Scenario Terms

Scenario

A scenario describes a study area's economy, population, and car usage and travel choices, assuming a hypothetical amount of growth in jobs and households.

Analysis zone

For each of the counties in the study areas, the data used came from either census block groups or census tracts—whichever was the smallest unit for which there was good data available. Each of these units is called an "analysis zone" or simply "zone."

Growth target zone

When a scenario calls for economic growth in a particular analysis zone, that analysis zone is the "growth target zone."

Accessibility

Measures of accessibility play an important role in the computer model and in the scenarios. The phrase "access to households" refers to how near or far an analysis zone is from households in the entire study area, including information about how many households there are. "Access to commercial establishments" refers to how near or far that analysis zone is from commercial establishments in the study area. The number of commercial jobs approximates the size, number, and availability of commercial establishments. In both cases, higher measures indicate greater access. In addition, these measures of accessibility include economic factors. For more information about how accessibility measures were calculated for this project, see the Appendix.

VMT

In this guidebook, VMT means average vehicle miles traveled *per person per weekday* in private vehicles such as cars, vans, trucks, and motorcycles.

Background on Scenarios

For all scenarios in all three study areas, the number of manufacturing jobs were increased by 500. The following remained unchanged: jobs in the agricultural or natural resources industries, public transit routes, and roadway network (including vehicle capacity).

The increase in manufacturing employment increases the household population in the study area because local households are assumed to be the labor pool for expanding businesses. As the population increases, the demographics of the households remain the same, including age of householder, household size, marital status, and so forth.

The increased population stimulates an increased demand for the goods and services that are provided by the study area's commercial businesses. The number of commercial jobs increases in turn, as does the household population. For each study area, the number of new commercial jobs remains the same in all scenarios, as does the number of new households.

The new residents work, go shopping, visit friends, etc., and those new activities lead to new trips made via auto, walking, and, where available, public transit.

Some of the existing commercial businesses may move to get closer to the new households, which provide both consumers and employees.

Some of the existing residents may change place of employment and where they shop, eat out, etc. However, all existing households are assumed to stay where they were in the year 2000. Residential floor space increases only in the zone(s) targeted for household growth. The restriction on the increase in the supply of housing effectively precludes relocation of the existing households. Thus the scenarios reflect the assumption that the increase in manufacturing employment would not motivate the existing households to move.

The emergence of new manufacturing and commercial businesses and changes in the locations of existing commercial businesses may alter the lengths of the trips made by existing residents. Even if they continue to travel to the same destinations, they may change their routes to adapt to the changes in levels and locations of traffic congestion. Changes in travel mode may also occur.

With this approach to scenario design, the only causes of differences in travel patterns and hence differences in VMT are differences in the locations of new manufacturing jobs, new commercial jobs, new households, and existing commercial jobs.

The results of the scenarios show the average daily VMT per person in the study area after the growth as compared to the VMT in that study area in the year 2000.

Two Different Types of Scenarios: Single Zone and Largest Towns

In general terms, two different kinds of scenarios were simulated: the Single Zone scenario and the Largest Towns scenario.

In a Single Zone scenario, only one analysis zone in the study area is targeted for growth in jobs and in household population. For each study area, 8 to 10 Single Zone scenarios were simulated, with the growth sited in a different analysis zone to provide a variety of pre-growth conditions. For each scenario, the computer model has factors that represent each zone's attractiveness to commercial establishments. A growth target zone's attractiveness factor is adjusted in a trial-and-error process to ensure that the increase in households is accompanied by an increase in commercial jobs in that zone sufficient to provide the goods and services demanded by the new population. In each Single Zone scenario, growth is perfectly balanced: all new jobs and new households are sited in the same analysis zone.

In the Largest Towns scenario, the growth in manufacturing jobs is divided among the group of towns consisting of the largest town in each county. In this scenario, growth in each town is not perfectly balanced because of the difficulty of precisely controlling the locations of the commercial jobs and of the new households in the computer models. One Largest Towns scenario was simulated for each study area.

Key Results

Travel behavior in a region may be meaningfully summarized by daily vehicle miles traveled (VMT) per person. As the term VMT is used in this handbook, it means average weekday VMT per person, and refers only to privately owned cars, vans, trucks, and motorcycles, not buses or other public transportation. A change in VMT means that VMT increased or decreased when compared to the estimated VMT in the year 2000.

This handbook uses VMT per person as an indicator of transportation efficiency, which has to do with the expenditures of time and money that persons incur while traveling to and from work, school, stores, church or temple, healthcare appointments, to visit friends and family, and to participate in other activities of daily life. An increase in VMT per person indicates a decrease in transportation efficiency because travelers consume more resources to accomplish their daily routines, whereas a decrease in VMT per person indicates an increase in transportation efficiency. Similarly, decreased VMT per person will typically decrease fuel consumption per person and vehicular emissions per person, although the decreases may not be proportional to the change in VMT per person.

The key results of this study are the following:

All Three Study Areas

In all three study areas, the Largest Towns scenario results in a negligible or very small increase in daily VMT. The increase ranges from 0.05 to 1.69 miles per person. In the Largest Towns scenario, one analysis zone in the largest town in each county receives a proportional share of the study area's total increase in new jobs and new households. In all cases, the growth in each analysis zone is somewhat, but not perfectly balanced. (Perfectly balanced growth would require each growth target zone's increase in households to be just enough to provide the workers for the zone's new manufacturing and commercial jobs, and the number of new commercial establishments to be just enough to provide the commercial goods and services demanded by the zone's new households.)

North Carolina-Tennessee Study Area: Low Population Density (Family 1)

When balanced growth of jobs and households is targeted for a single analysis zone in the study area, daily VMT increases. (Results are based on 10 Single Zone scenarios, each of which targeted a different analysis zone for growth. Different analysis zones were selected to provide a variety of pre-growth conditions.) For each of the following attributes of a growth target zone, higher values pre-growth are associated with smaller increases in VMT after growth:

- total number of jobs
- total number of households
- access to commercial establishments
- access to households

Diversity of land use in an analysis zone targeted for growth has essentially no impact on the predicted change in VMT.

In one Single Zone scenario, daily VMT increases 42% (18 miles per person). Relative to the analysis zone where simulated growth produced the smallest increase in daily VMT, this analysis zone has, before growth, a lower number of jobs, lower number of households, lower access to commercial establishments, and lower access to households. In other words, it is relatively undeveloped and relatively isolated compared to other analysis zones in the study area. (For a fuller explanation, see "Implications for Practice" in the next chapter.)

Ohio Study Area:
Medium Population Density (Family 2)

When balanced growth of jobs and households is targeted for a single analysis zone in the study area, daily VMT stays essentially the same—increasing or decreasing only slightly. (Results are based on nine Single Zone scenarios, each of which targeted a different analysis zone for growth. Different analysis zones were selected to provide a variety of pre-growth conditions.) When a growth target zone has high diversity of land use before growth, VMT increases less after growth.

Other attributes of the analysis zone have essentially no impact on the predicted change in daily VMT including total number of jobs, total number of households, access to commercial establishments, and access to households.

Washington Study Area:
High Population Density (Family 3)

In this study area, when balanced growth of jobs and households is targeted for a single analysis zone, daily VMT stays essentially the same—increasing or decreasing only slightly. (Results are based on eight Single Zone scenarios, each of which targeted a different analysis zone for growth. Different analysis zones were selected to provide a variety of pre-growth conditions.) For each of the following attributes of a growth target analysis zone, higher values pre-growth are associated with smaller increases in VMT after growth:

- diversity in land use
- total number of jobs
- access to commercial establishments
- access to households

Total number of households in an analysis zone targeted for growth has essentially no impact on the predicted change in daily VMT.

North Carolina-Tennessee Study Area: Low Population Density (Family 1)

Study Area Overview

The North Carolina-Tennessee (NC-TN) study area is a five-county commuting zone in the southern Appalachian Mountains, in the extreme northwestern corner of North Carolina and the extreme northeastern corner of Tennessee (Figure 5).

The study area is a member of the low population density family of small communities and rural areas, characterized by:

- low population density (per square mile of developed or developable land),
- low road density,
- high diversity of land use, and
- highly variable population density.

In this study area, census tracts were used as the analysis zones; there are 38 census tracts in the study area's five counties.

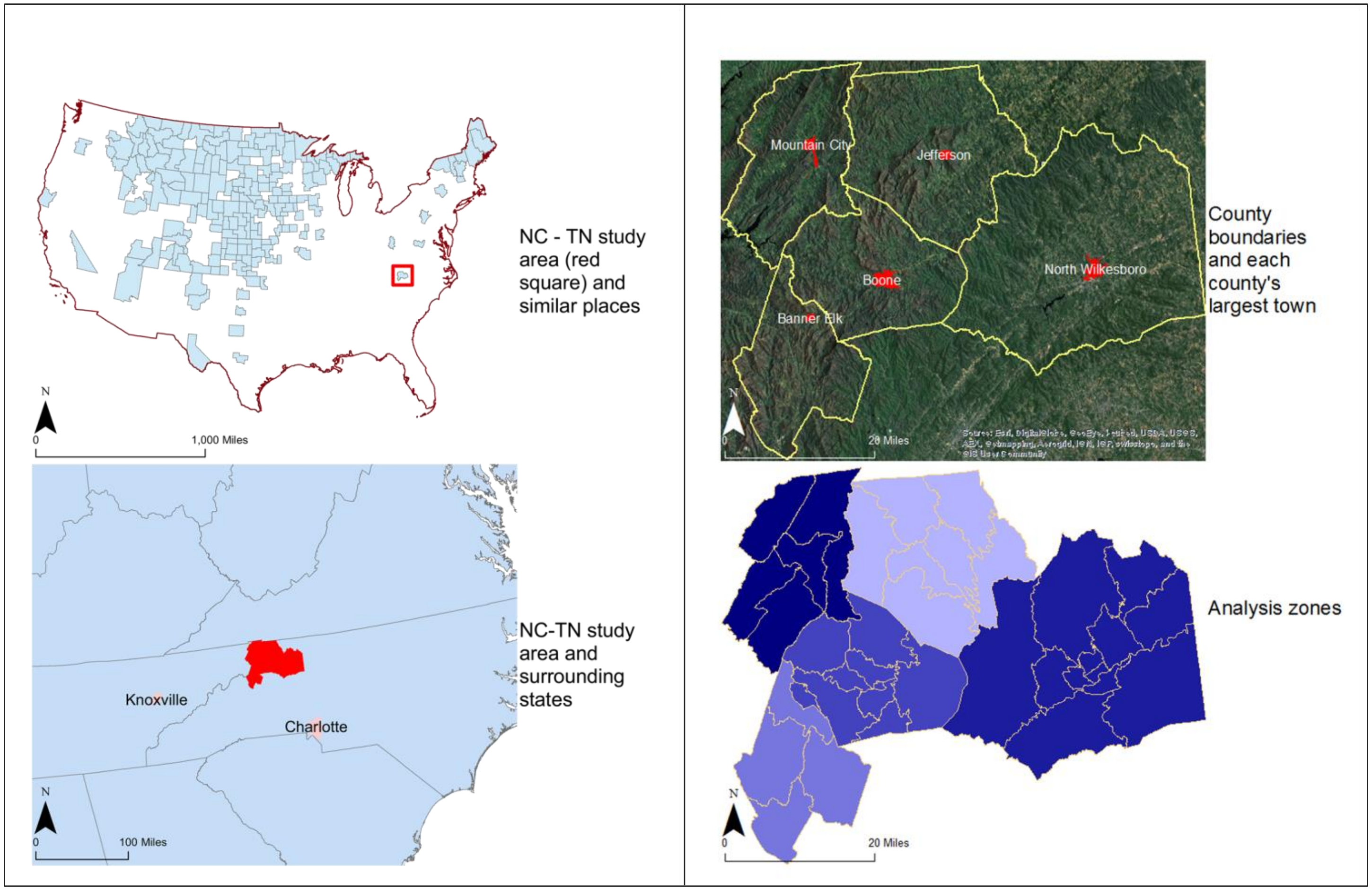


Figure 5. NC-TN study area: geographical context, counties, and analysis zones.

Data from 2000 census:

- Households: 66,960
- Persons: 157,420
- Total number of civilian jobs: 70,935 (including 5,270 workers whose residence was located in a 50-mile buffer drawn around the five counties)
    - Agricultural and natural resource jobs: 2,421
    - Commercial jobs (retail, professional services, social services, public administration, etc.): 45,039
    - Construction and manufacturing jobs: 23,475

Figure 6 shows each census tract's number of jobs and number of households in the year 2000.

In the year 2000, the VMT for this study area was almost 43 miles a day. The average refers to weekday travel, and accounts for all residents, including non-drivers, living in households. For the inbound commuters (who did not live in the study area), only the mileage associated with their commuting trips is included in the average.

Implications for Practice

When balanced growth of jobs and households is targeted for a single analysis zone in the study area, daily VMT increases, and the increase may be substantial. (Results are based on 10 Single Zone scenarios, each of which targeted a different analysis zone for growth.) For each of the following attributes of a growth target zone, higher values pre-growth are associated with smaller increases in VMT after growth:

- total number of jobs
- total number of households
- access to commercial establishments
- access to households

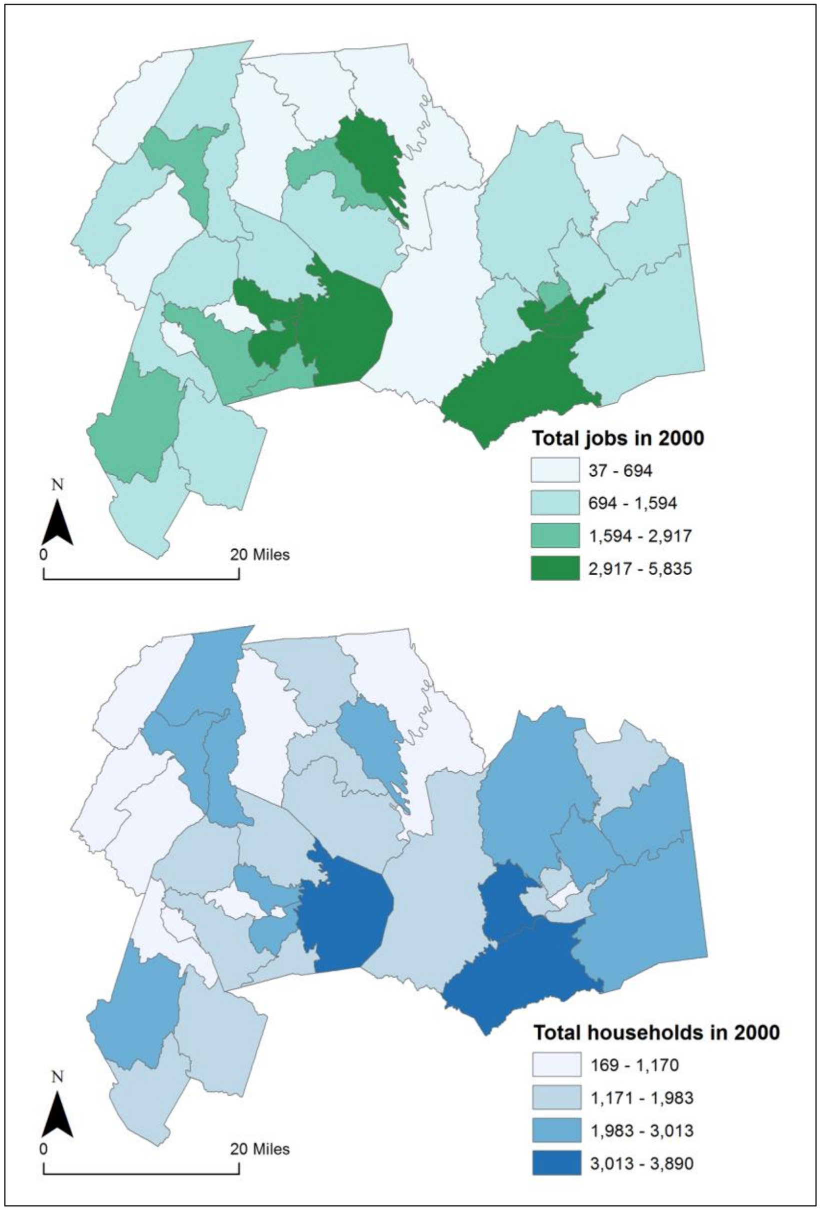


Figure 6. NC-TN study area: total civilian jobs (resident jobs) and total households in the year 2000.

Diversity of land use in an analysis zone targeted for growth has essentially no impact on the predicted change in VMT.

In one Single Zone scenario, daily VMT increases 42% (18 miles per person). Relative to the analysis zone where simulated growth produced the smallest increase in daily VMT, this analysis zone has, before growth, a lower number of jobs, lower number of households, lower access to commercial establishments, and lower access to households. In other words, it is relatively undeveloped and relatively isolated compared to other analysis zones in the study area. Even when new jobs and new households are located in the same growth target zone, some of the zone's new residents will drive outside the zone for work, shopping, etc. Some of the new jobs (including the new commercial jobs) will be filled by the residents of the other zones. Consequently, average weekday VMT per person increases more when growth occurs in this analysis zone (4009) than when growth occurs in the more developed and less isolated analysis zone 4006.

In the Largest Towns scenario, growth results in a very small increase in VMT.

Increases and decreases in VMT have implications for driving-related fuel consumption and emissions. Increases in VMT per person will typically increase fuel consumption per person and vehicular emissions per person; decreases will typically lead to the reverse. It is important to note that the increases and decreases in fuel consumption and emissions may not be proportional to the changes in VMT.

Single Zone Scenarios

There are 10 Single Zone (SZ) scenarios, each of which increases jobs and households (balanced growth) in a different analysis zone (see Table 4 and Figure 7 below). Daily VMT increases in all the scenarios. The increases range from a low of 1.69 miles per person to a high of 18.11 miles per person.

Table 4. NC-TN study area: key results of 10 Single Zone scenarios.

Scenario	Manufacturing Growth Target Zone	Commercial Growth Target Zone	Household Growth Target Zone	Change in VMT Per Person†
SZ-4006	4006			1.69
SZ-5009	5009			1.87
SZ-5002	5002			2.80
SZ-6003	6003			2.85
SZ-3002	3002			2.94
SZ-5008	5008			3.44
SZ-5010	5010			3.97
SZ-3001	3001			6.00
SZ-5001	5001			6.46
SZ-4009	4009			18.11

† Change in VMT per person compared to year 2000. Scenarios are listed in ascending order of change in VMT.

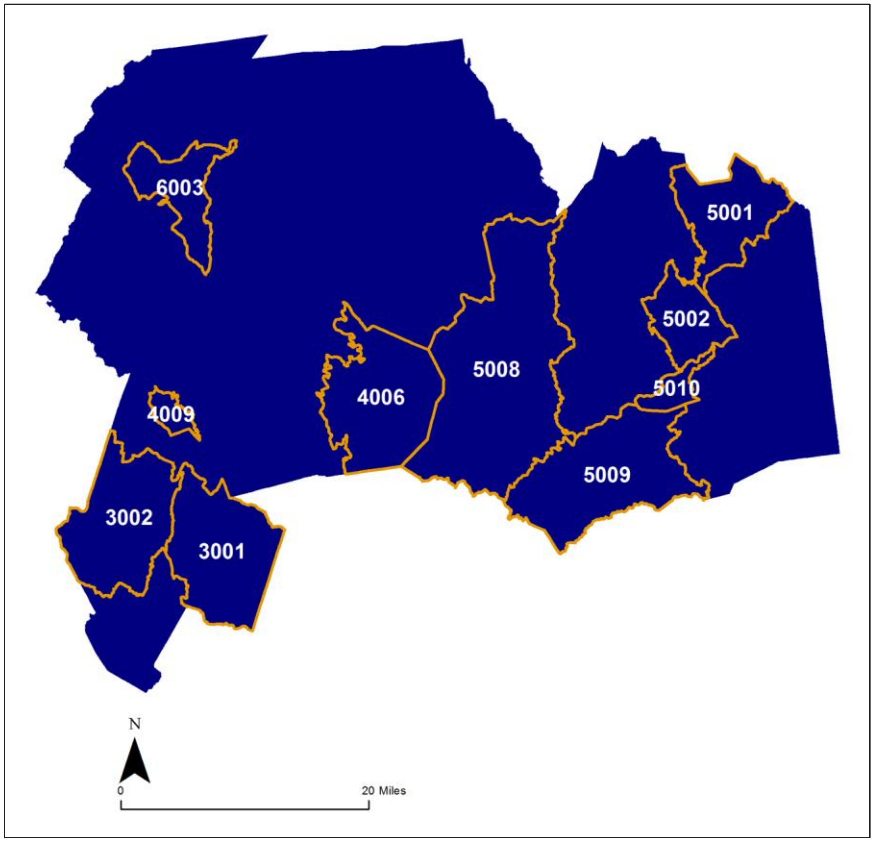


Figure 7. NC-TN study area: growth target zones in the 10 Single Zone (SZ) scenarios.

Two scenarios illustrate the extremes in the impact of growth on travel: SZ-4006, in which daily VMT increases by 1.69 miles per person, and SZ-4009, in which daily VMT increases by 18.11 miles per person. In both scenarios, the analysis zone in which population growth occurs is a magnet for commercial jobs growth in multiple census tracts nearby. One or more census tracts must also provide those employees.

Figure 8 (below) shows the jobs and households (left) and the changes in jobs and households after the simulated growth (right) for SZ-4006 (low VMT). The overall pattern of change in commercial jobs is centralization: jobs increase noticeably in the growth target zone (shown in dark green) and in a few adjacent zones (shown in light green) which had relatively high population in the year 2000, and jobs decrease at many of the more distant zones (shown in shades of brown).

In scenario SZ-4009 (high VMT) shown in Figure 9 (below), the increase in commercial jobs is more dispersed, increasing in zones (shown in light green) that are some distance to the east of the growth target (zone 4009, in dark green); the declines in commercial jobs are concentrated in the study area's northwest and southwest (shown in shades of brown). (Note: Figure 8 and Figure 9 show jobs in all civilian industries, but because all new manufacturing jobs are in the growth target zone, changes in jobs in other zones effectively represent changes only in commercial jobs.)

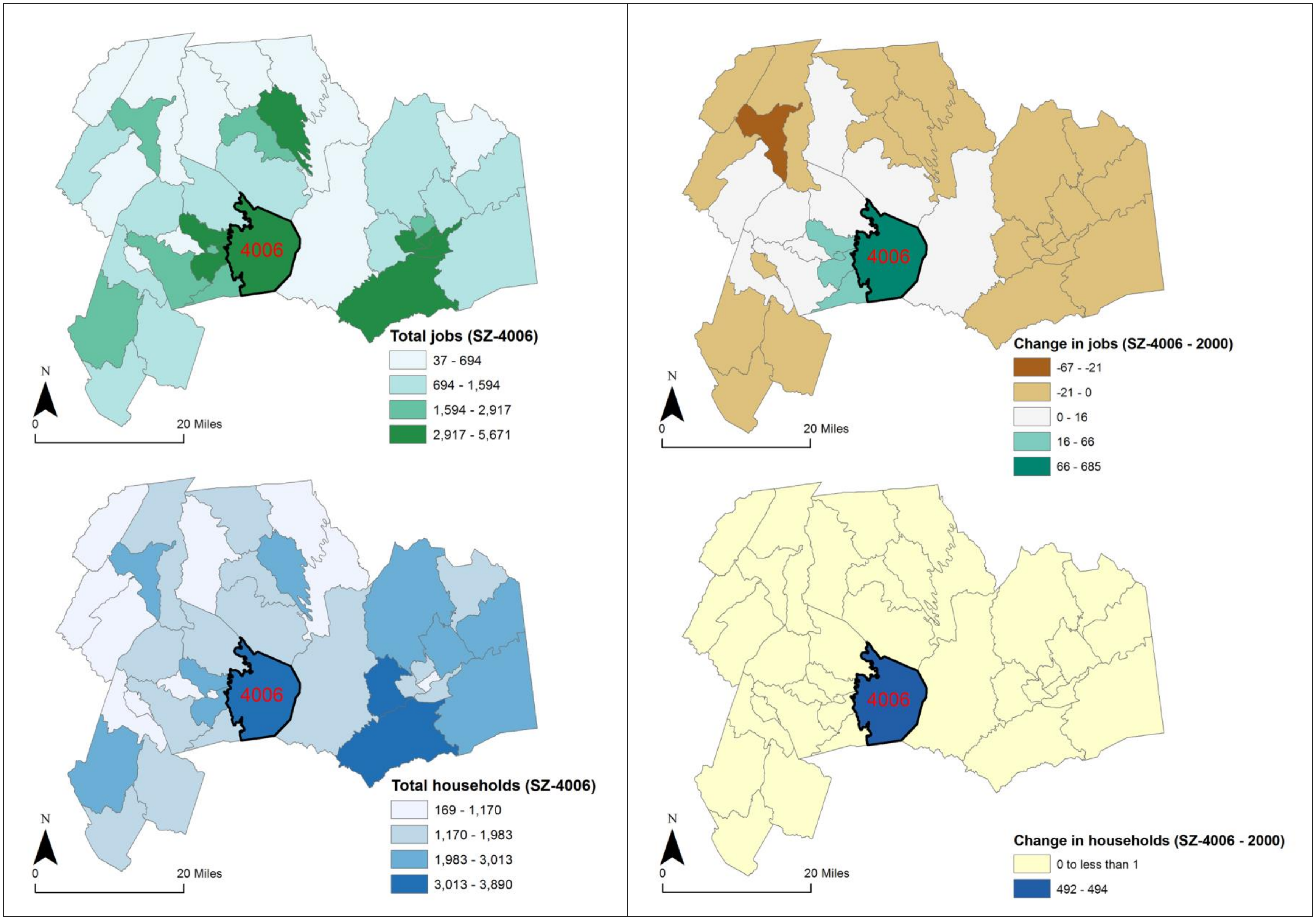


Figure 8. NC-TN study area, scenario SZ-4006 (low VMT): total jobs and households after simulated growth (left) and change in jobs and households after simulated growth (right).

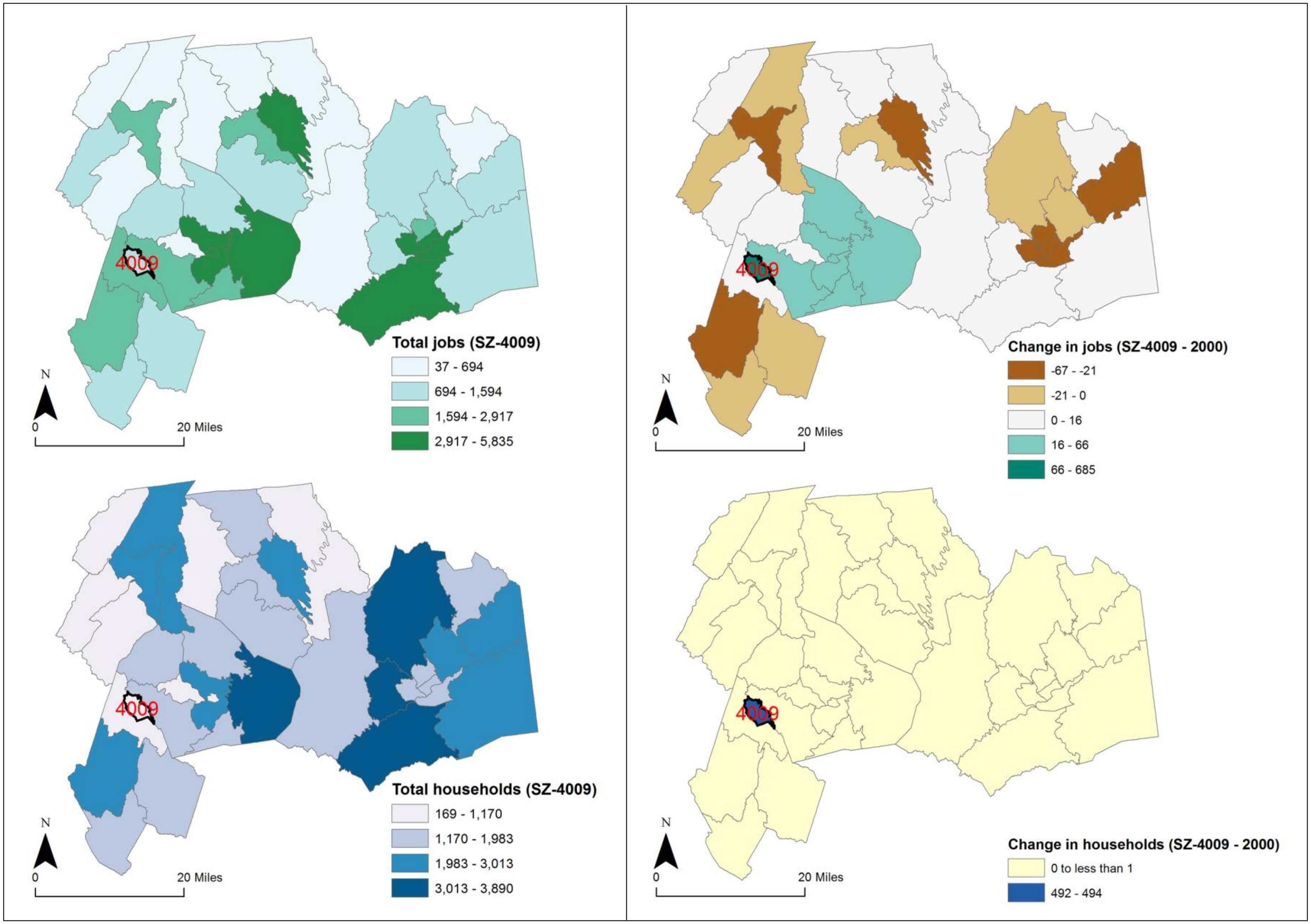


Figure 9. NC-TN study area, scenario SZ-4009 (high VMT): total jobs and households after simulated growth (left) and changes in jobs and households after simulated growth (right).

Scenario SZ-4009's land use pattern leads to a separation of homes and commercial establishments (represented by commercial jobs) that is substantially greater than that of SZ-4006. This can be illustrated in a graph showing the average length of a household's commercial trips—trips between home and a store, restaurant, or other commonly visited destination. Figure 10 plots the average length of the cumulative percentage of all daily commercial trips. (Average length is represented by generalized travel cost, which correlates with length.) The median trip length in scenario SZ-4006 is less than 3 units, while the median trip length in scenario SZ-4009 is nearly 5.

In SZ-4009 (high VMT), the growth target zone has the following characteristics relative to zone 4006 (low VMT), as measured

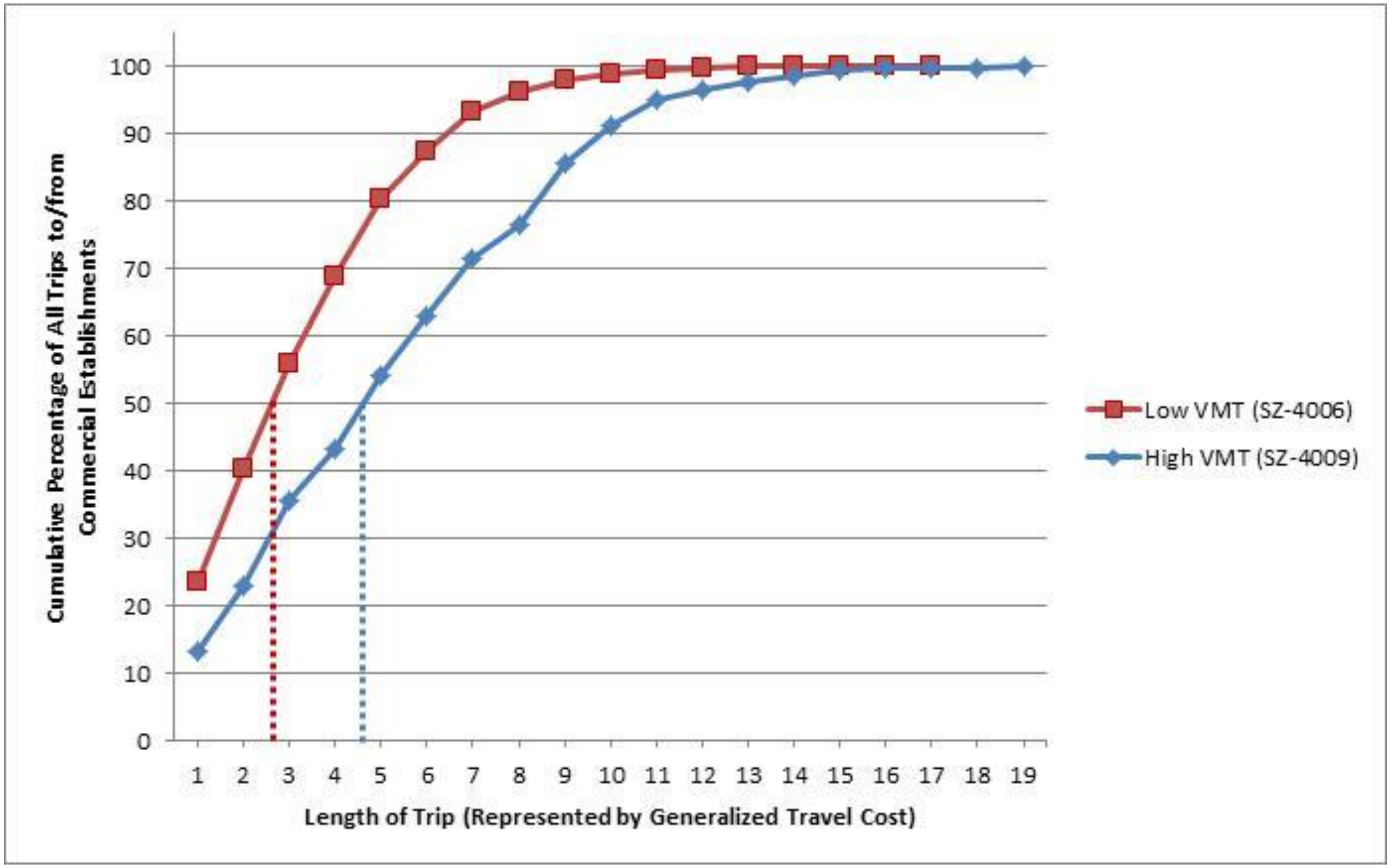


Figure 10. NC-TN study area: average length of the cumulative percentage of all daily commercial trips.

before growth: fewer jobs, fewer total households, lower access to the study area's commercial establishments, and lower access to the region's households (Table 5).

Is this relationship between travel and land use unique to these two particular analysis zones? No: total jobs, total households, regional access to commercial establishments, and regional access to households are fundamental influences on daily VMT in this study area.

In fact, when compared to SZ-4009, all nine other SZ scenarios have lower increases in daily VMT. In addition, when compared to analysis zone 4009, all other analysis zones have more jobs, more households, greater access to commercial establishments, and greater access to households, as measured before growth. (Analysis zones 5008, 5001, and 6003 have similar values to 4009 for either total jobs or access to households, but none of their other attributes resemble those of 4009.)

The results from the 10 SZ scenarios confirm the inverse relationship between change in VMT and an analysis zone's total jobs, total households, access to commercial establishments in the study area, and access to households in the study area, all as measured pre-growth (Figure 11).

Table 5. NC-TN study area: selected attributes of the growth target zones in two scenarios with very different impacts on VMT.

Scenario	Change in VMT†	Total Jobs, year 2000	Total Households, year 2000	Access to "Commercial" Establishments, year 2000	Access to Households, year 2000
SZ-4006	1.69	Higher	Higher	Higher	Higher
SZ-4009	18.11	Lower	Lower	Lower	Lower

† Change in VMT compared to year 2000.

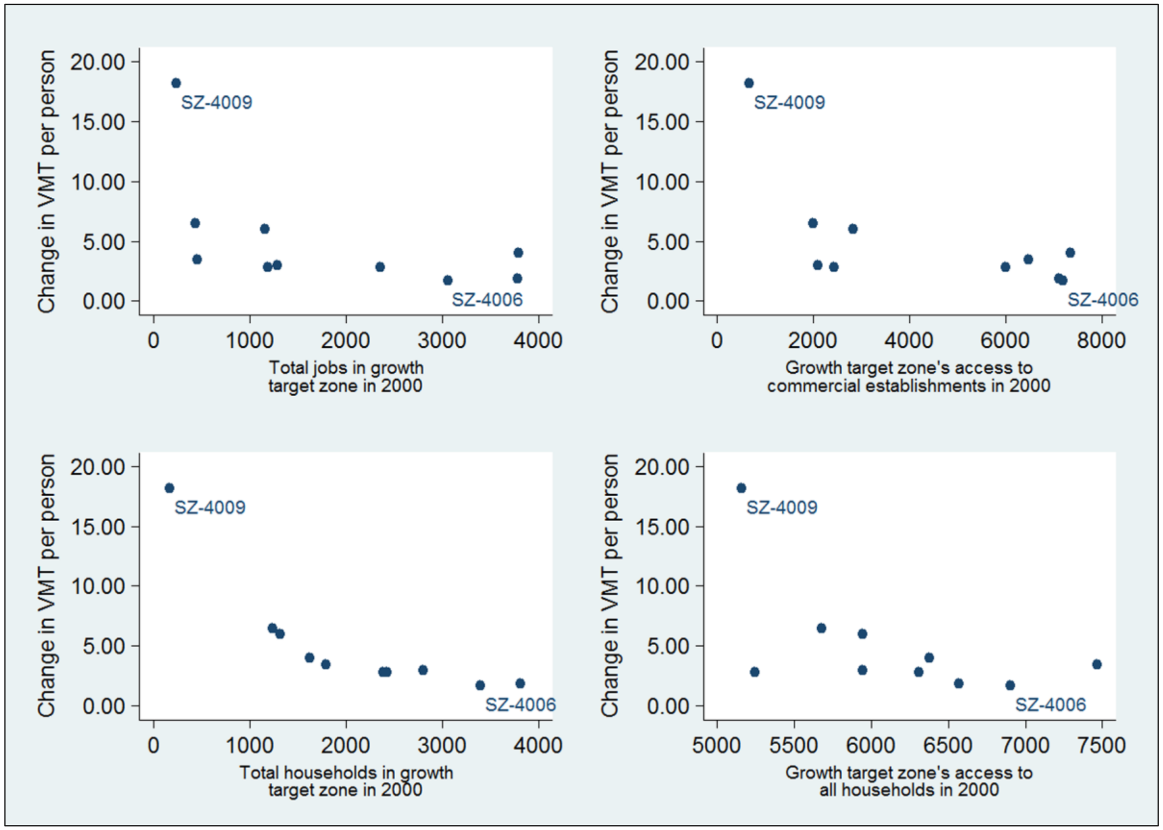


Figure 11. NC-TN study area: relationships between four land use attributes of the analysis zones, as measured pre-growth, and change in VMT after growth for the 10 Single Zone (SZ) scenarios.

Largest Towns Scenario

What happens to VMT when growth occurs in multiple locations—specifically when jobs growth and household growth occur together in each county's largest town? This is the intention underlying the Largest Towns (LT) scenario, in which growth is dispersed across several towns.

In the LT scenario, employment in manufacturing increases by 100 in each of five analysis zones, one in each county's largest town (Figure 12). Those analysis zones are the growth targets not just for new manufacturing jobs but also for new commercial jobs and new households. Yet, when there are five growth target zones, precise control over the locations of the new commercial jobs and new households is difficult to achieve in the computer model. Consequently, the growth of jobs and households is not perfectly balanced in each growth target zone. (Perfectly balanced growth would require each growth target zone's increase in households to be just enough to provide the workers for the zone's new manufacturing and commercial jobs, and the number of new commercial establishments to be just enough to provide the commercial goods and services demanded by the zone's new households.)

However, the 183 new commercial jobs in the study area are just enough to ensure that all of the new households are able to purchase locally the commercial goods and services that they demand. Some growth target zones in the LT scenario have more commercial jobs than perfectly balanced growth would require, and some have less; the same is true of households (see Table 6 below).

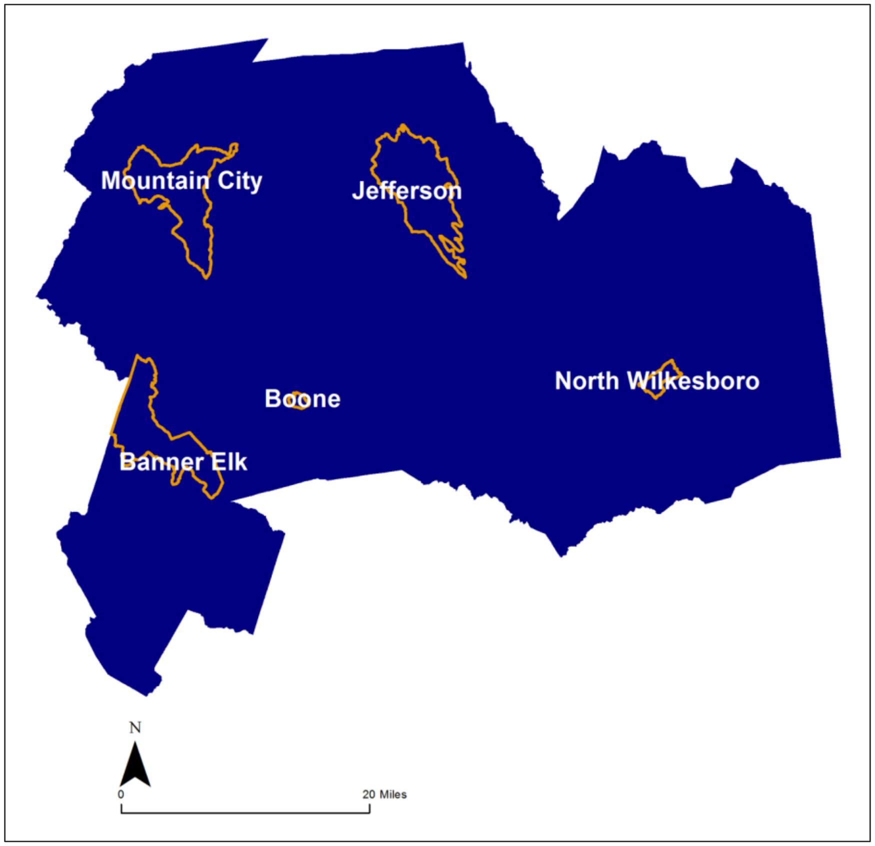


Figure 12. NC-TN study area: growth target zones in the Largest Towns (LT) scenario.

Table 6. NC-TN study area: growth in jobs and households in Largest Towns (LT) scenario, and variance from perfectly balanced growth.

Zone	Defined Growth in Manufacturing Jobs†	Predicted Growth in Households†	Predicted Growth in Commercial Jobs†	Perfectly Balanced Growth in Commercial Jobs	Predicted Minus Perfectly Balanced Growth in Commercial Jobs
2004 (Jefferson, NC)	100	147	22	56	-34
3000 (Banner Elk, NC)	100	81	27	31	-4
4004 (Boone, NC)	100	44	68	17	51
5005 (N. Wilkesboro, NC)	100	67	43	25	18
6003 (Mountain. City, TN)	100	145	24	55	-31
Total	500	484	184	183	1

† Compared to the base scenario.

Table 6 reports each census tract's growth in total jobs and in total households. Figure 13 (below) displays all zones' total jobs and total households after the simulated growth (upper and lower maps on the left) and the changes in total jobs and in total households after the simulated growth. The influence of household growth on the location of commercial jobs is strong: there is a widespread shift of commercial jobs toward the locations of household growth, reflecting the movement of commercial establishments to analysis zones with better access to households (customers).

(Note: Figure 13 shows both manufacturing and commercial jobs, but because all new manufacturing jobs are in the five growth target zones, changes in jobs in other zones represent only changes in commercial jobs.)

The LT scenario increases daily VMT by 1.24 miles per person. The increase is somewhat less than the increase of 1.69 miles per person predicted for the SZ-4006 scenario, the Single Zone scenario with the lowest increase in daily VMT.

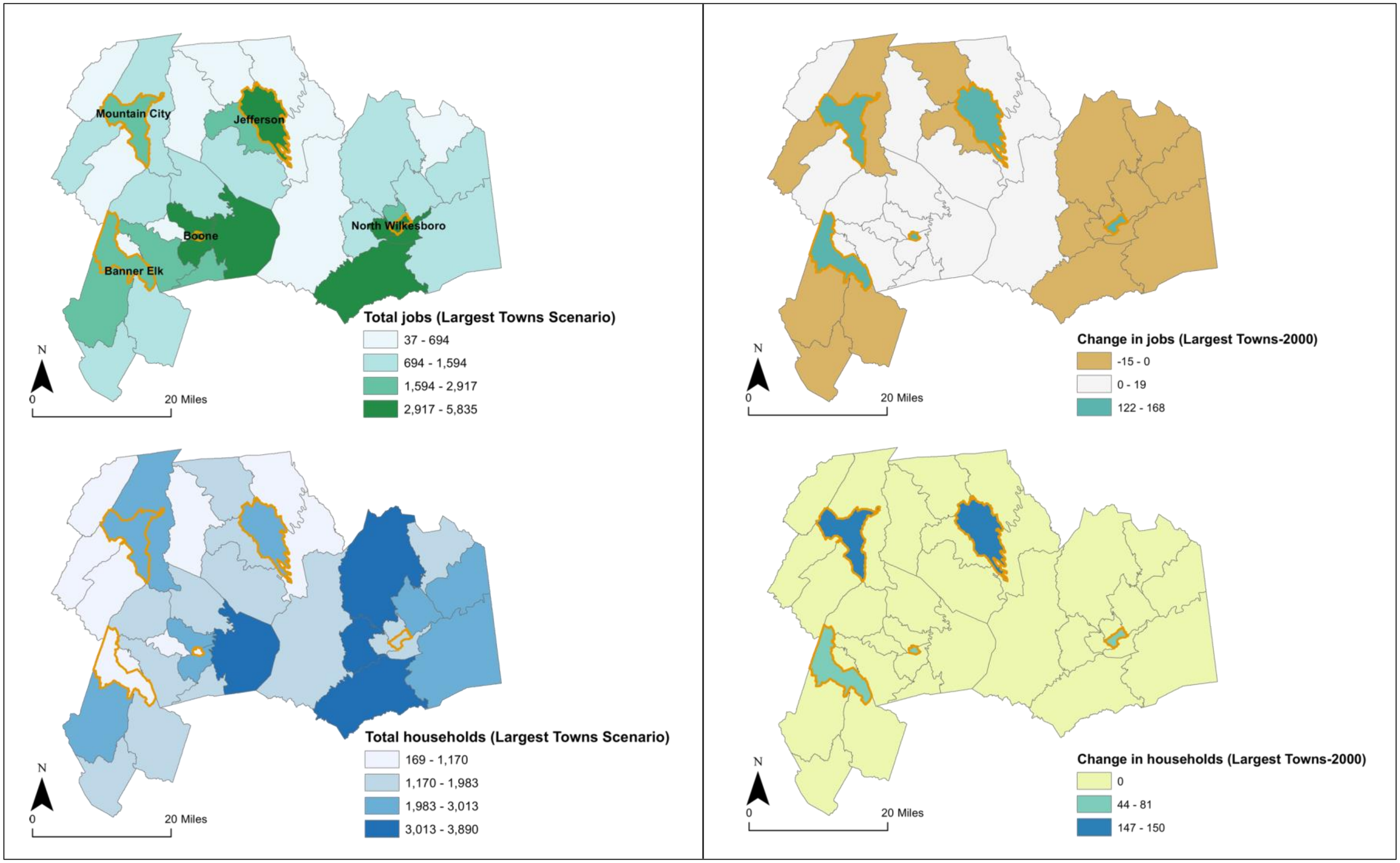


Figure 13. NC-TN study area, LT scenario: total jobs and households after simulated growth (left) and changes in jobs and households after simulated growth (right).

CHECKLIST FOR LOW POPULATION DENSITY COMMUTING ZONES (FAMILY 1)

- [ ] Consult the interactive map of small communities and rural areas to determine which family your commuting zone belongs to: http://go.ncsu.edu/scara-commuting-zones-map. If Family 1, use this checklist. If Family 2 or 3, consult the relevant checklist.
- [ ] List all the counties in your commuting zone.
- [ ] Develop your own database of land use characteristics. For each census tract or census block group in your commuting zone, develop tables showing the total number of households, total number of civilian jobs, access to households in the commuting zone, access to commercial establishments in the commuting zone, and the ratio of the total number of civilian jobs to the total number of households. (See note below.)
- [ ] To minimize the increase in average weekday VMT per person, plan for balanced growth (locating new jobs and new households in the same census tract or census block group) **and**…
- [ ] Divide the balanced growth among the towns in the commuting zone that are the largest in their respective counties **or** locate the growth in a single census tract or census block group that has the following characteristics *relative to the other census tracts and census block groups* in the commuting zone:
    - high number of civilian jobs
    - high number of households
    - high access to commercial establishments in the entire commuting zone
    - high access to households in the entire commuting zone

Note: Use census data to obtain total number of households and total number of civilian jobs for census tracts and census block groups. The access measures used in this chapter can be exactly replicated only by using a computer model that parallels the one developed for the North Carolina–Tennessee study area. However, your state department of transportation may be able to provide alternative access measures (called "gravity models") obtained from a conventional travel demand model developed for the region of interest. These measures of access to jobs or to households may help identify the census tracts or census block groups that are especially isolated.

If you are unable to develop or obtain access measures for your area, you may be able to use the results from this chapter in a more qualitative way. To minimize the increase in average weekday VMT per person, avoid locating household and job growth in census tracts or census block groups that are undeveloped and isolated.

Streetscape Visualizations: North Carolina-Tennessee Study Area

In the Largest Towns scenario, the growth in jobs and households is spread out among five towns—the largest town in each of the five counties. These towns are Boone, Jefferson, North Wilkesboro, and Banner Elk in North Carolina, and Mountain City in Tennessee. The following streetscape visualizations and aerial perspectives show examples of how the growth in the Largest Towns scenario could be accommodated while maintaining each town's character.

Target levels of residential density were established based on a town or city's existing size, starting with a density of seven dwelling units per acre. Development at or above this density encourages walking, public transit usage (where provided), and neighborhood retail.[5]

The visualization studies maintain a town's existing scale, so that development in smaller towns tends toward one- and two-story buildings, and in larger towns, four- to six-story buildings. Development is placed where it can work with existing social and economic institutions, reflecting an assumed intent of planners and town officials to increase utilization of existing infrastructure and to support "Main Street." New housing is placed close to existing colleges, employment centers, and public schools. Mixed use developments are sited in downtown areas.

[5] Congress for the New Urbanism, Natural Resources Defense Council, and U.S. Green Building Council (October 2013). *LEED 2009 for Neighborhood Development*, p. 45. http://www.usgbc.org/sites/default/files/LEED%202009%20RS_ND_07.01.14_current%20version.pdf

Boone, North Carolina

Context

Boone is the home of Appalachian State University, the largest employer in the town. The town and the college each have 17,000 people. Boone is located in the Appalachian Mountains, a natural resource for the town. The city is structured around three main roads: Highway 105, Highway 321, and Highway 421. The convergence of the three main roads develops boundaries within the city. Appalachian State University is west of Highway 321 and south of Highway 421, while not actually touching Highway 421.

Strategy

Appalachian State University could extend to Highway 421 by adding more dorms, apartments, or another entrance to the college. Highway 105 contains a sparsely developed commercial area, which could accommodate the addition of mixed-use buildings (see Figures 14-19).

Figure 14 (top).
Aerial 1 of Boone: Present.

Figure 15 (bottom).
Aerial 1 of Boone: Proposal.

Figure 16 (above).
View 1 of Boone: Present.

Figure 17 (below).
View 1 of Boone: Proposal.

Figure 19 (below).
View 2 of Boone: Proposal.

Figure 18 (above).
View 2 of Boone: Present.

Jefferson, North Carolina

Context

Jefferson, population 1,600, is located in the foothills of the Appalachian Mountains. It encompasses just 50 acres.

Strategy

Main Street in Jefferson is characterized by low density, automobile-oriented retail leaving little in the way of a walkable downtown. One solution to bringing back pedestrian development could be to start anew. Creating a denser, more pedestrian friendly residential neighborhood may influence future downtown development. This new residential community could be sited just north of Main Street, shown in Figures 20-23.

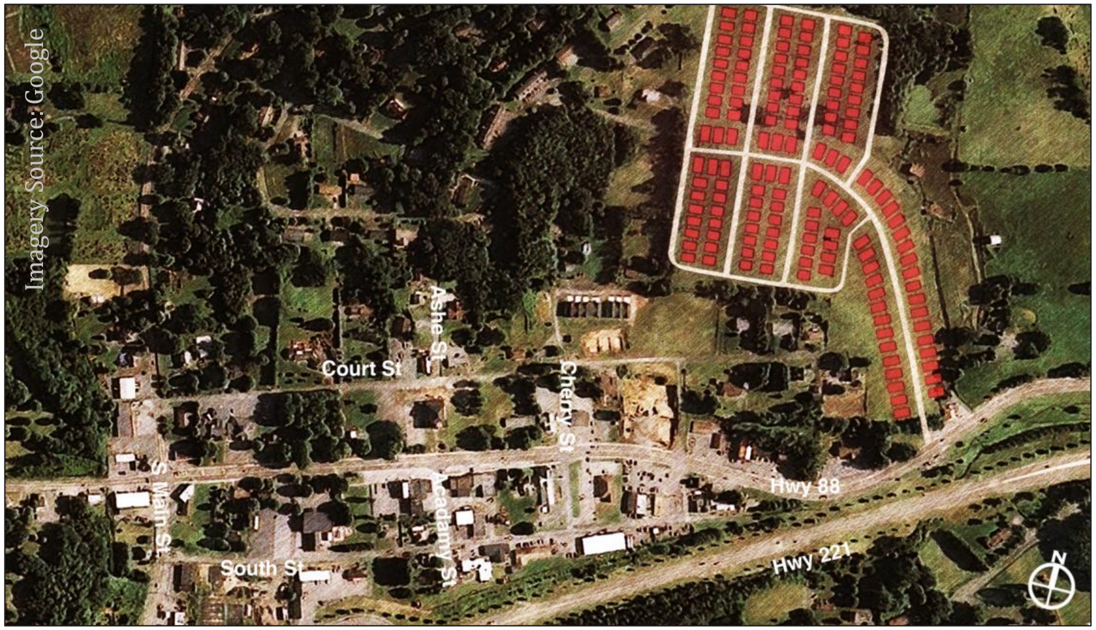


Figure 20 (top).
Aerial 1 of Jefferson: Present.

Figure 21 (bottom).
Aerial 1 of Jefferson: Proposal.

Figure 22 (above).
View 1 of Jefferson: Present.

Figure 23 (below).
View 1 of Jefferson: Proposal.

North Wilkesboro, North Carolina

Context

North Wilkesboro, population just over 4,000, is the county seat of Wilkes County in northwest North Carolina. The Lowe's home improvement store chain began in North Wilkesboro. Near Stone Mountain State Park and the Blue Ridge Parkway, North Wilkesboro is known as the Key to the Blue Ridge.

Strategy

North Wilkesboro's downtown is well developed, so the visualizations show proposed growth on open fields that are south of the downtown area and near a sports complex to create a small, pedestrian friendly community. The new community would have sidewalks and paths from every house to the sporting complex, and to the shopping center on the other side of the sporting complex. Walking paths would also be developed across the railroad tracks and Cherry Street into the downtown district (see Figures 24-27).

Figure 24 (top).
Aerial 1 of North Wilkesboro: Present.

Figure 25 (bottom).
Aerial 1 of North Wilkesboro: Proposal.

Figure 26 (above).
View 1 of North Wilkesboro: Present.

Figure 27 (below).
View 1 of North Wilkesboro: Proposal.

Banner Elk, North Carolina

Context

Located in the Appalachian Mountains, Banner Elk, founded in 1848, has a population of just over 1,000. Banner Elk strives to preserve its small town history and atmosphere, which attracts many tourists, visitors, and part-time residents. In addition, its location makes it a short drive to Boone, North Carolina, and many ski resorts. Banner Elk is also home to Lees McRae College.

Strategy

The visualization shows small residential dwellings along Tynecastle Highway. Placing the dwellings near the road and adding a sidewalk would allow residents to walk safely to the college. The development also complements the small town atmosphere with its higher density and mixed uses (see Figures 28-31).

Figure 28 (top). Aerial 1 of Banner Elk: Present.

Figure 29 (bottom). Aerial 1 of Banner Elk: Proposal.

Figure 30 (above).
View 1 of Banner Elk: Present.

Figure 31 (below).
View 1 of Banner Elk: Proposal.

Mountain City, Tennessee

Context

Mountain City is located at the northeastern corner of Tennessee and is only minutes away from the North Carolina border. The county's only high school and Career and Technical School are both located in Mountain City.

Strategy

Because of the ability of families to locate near the tech school and high school, dense neighborhoods and communities could be added across from Mountain City Elementary School along Shady Street as well as off Oak Street to the west. A new community is shown along Shady Street within walking distance to the school. Adding these new communities will allow the town to continue to increase in density and will encourage growth in the commercial and downtown areas (see Figures 32-35).

Figure 32 (top). Aerial 1 of Mountain City: Present.

Figure 33 (bottom). Aerial 1 of Mountain City: Proposal.

Figure 34 (above).
View 1 of Mountain City: Present.

Figure 35 (below).
View 1 of Mountain City: Proposal.

Ohio Study Area: Medium Population Density (Family 2)

Study Area Overview

The Ohio study area is a six-county commuting zone in the south-central region of the state, south of Columbus and extending to the Ohio River (Figure 36). The study area is a member of the medium population density family of small communities and rural areas, characterized by:

- moderate population density (per square mile of developed or developable land),
- moderate road density,
- low diversity of land use, and
- moderately variable population density.

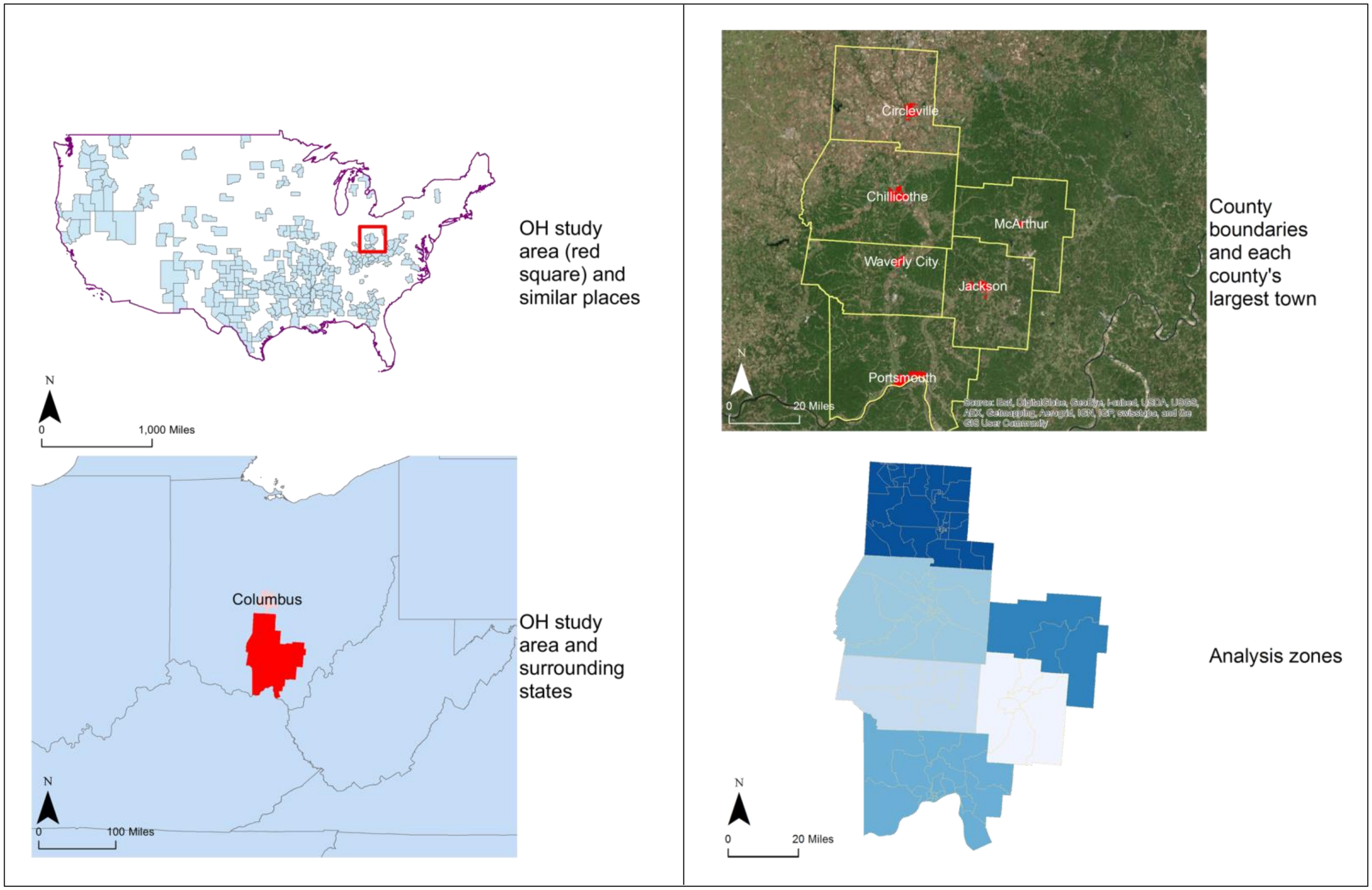


Figure 36. Ohio study area: geographical context, counties, and analysis zones.

In this study area, both census tracts and census block groups were used as the analysis zones; there are 53 census tracts in Jackson, Pike, Ross, Scioto, and Vincent Counties, and 33 census block groups in Pickaway County.

Data from 2000 census:

- Households: 103,561
- Persons: 261,996
- Total number of civilian jobs: 97,424 (including 11,610 workers whose residence was located in a 80-mile buffer drawn around the six counties)
    - Agricultural and natural resource jobs: 2,684
    - Commercial jobs (retail, professional services, social services, public administration, etc.): 54,448
    - Construction and manufacturing jobs: 28,682

Figure 37 shows each analysis zone's number of jobs and number of households.

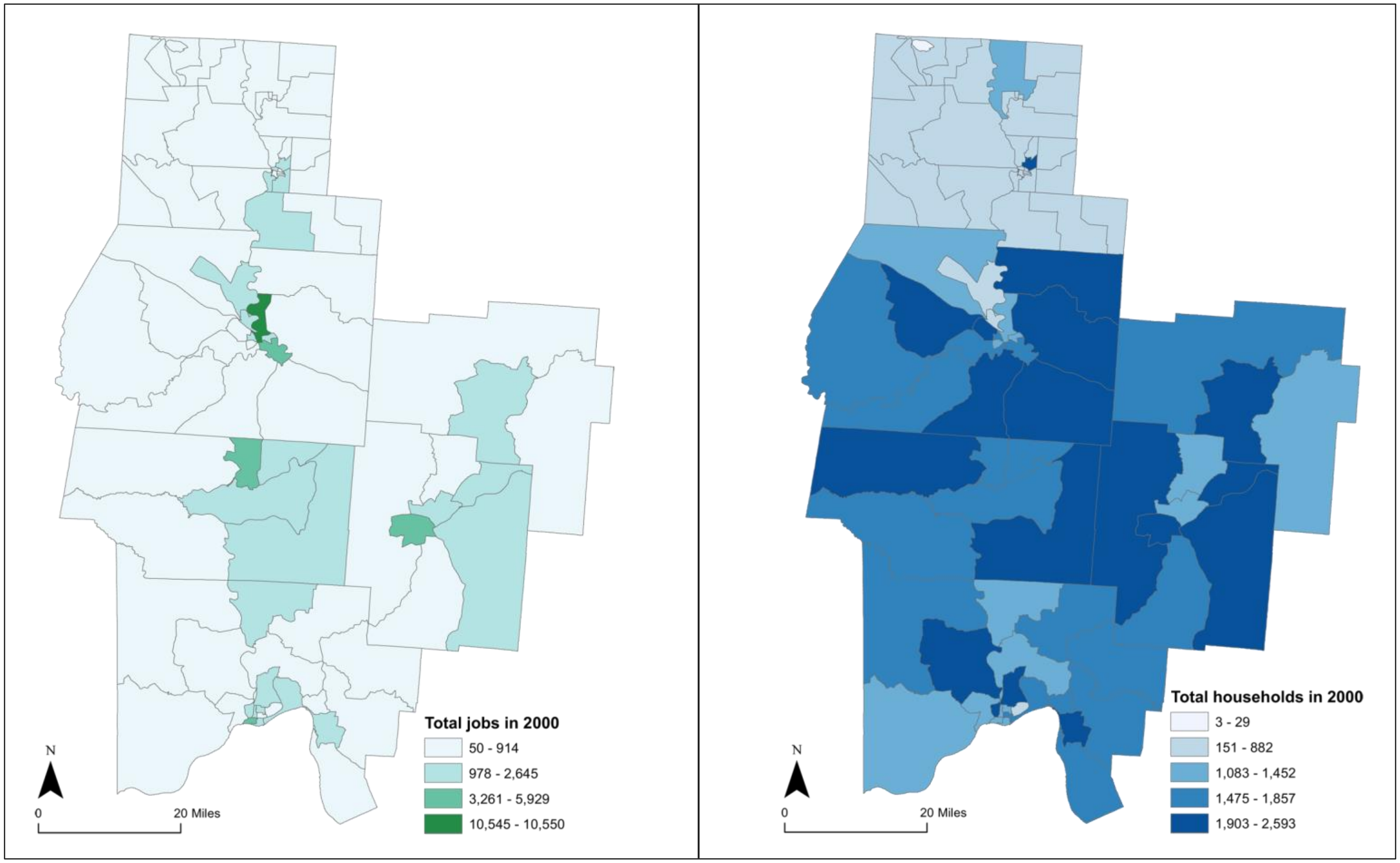


Figure 37. Ohio study area: total civilian jobs (resident jobs) and households in the year 2000.

In the year 2000, the study area's civilian household population and inbound commuters (who did not live in the study area) had a VMT of almost 77 miles per person per day. The average refers to weekday travel, and accounts for all residents, including non-drivers, living in households. For the inbound commuters, only the mileage associated with their commuting trips is included in the average.

Implications for Practice

When balanced growth of jobs and households is targeted for a single analysis zone in the study area, daily VMT stays essentially the same—increasing or decreasing only slightly. (Results are based on nine Single Zone scenarios, each of which targeted a different analysis zone for growth.) When a growth target zone has high diversity of land use before growth, VMT increases less after growth.

Other attributes of the analysis zone have essentially no impact on the predicted change in daily VMT including total number of jobs, total number of households, access to commercial establishments, and access to households.

In the Largest Towns scenario, growth results in a negligible increase in daily VMT.

Increases and decreases in VMT have implications for driving-related fuel consumption and emissions. Increases in VMT per person will typically increase fuel consumption per person and vehicular emissions per person; decreases will typically lead to the reverse. It's important to note that the increases and decreases in fuel consumption and emissions may not be proportional to the changes in VMT.

Table 7. Ohio study area: key results of nine Single Zone (SZ) scenarios.

Scenario	Manufacturing Growth Target Zone	Commercial Growth Target Zone	Household Growth Target Zone	Change in VMT Per Person†
SZ-4009	4009			-0.06
SZ-4011	4011			-0.05
SZ-4002	4002			-0.04
SZ-4010	4010			-0.04
SZ-5000	5000			0.11
SZ-4005	4005			0.13
SZ-5017	5017			0.14
SZ-5003	5003			0.15
SZ-7081	7081			0.18

† Change in VMT per person compared to year 2000. Scenarios are listed in ascending order of change in VMT per person.

Single Zone Scenarios

Table 7 identifies the zones targeted for growth in nine Single Zone (SZ) scenarios, and provides each scenario's predicted change in VMT. In each scenario, the named analysis zone is targeted for perfectly balanced growth in jobs and households (see Figure 38 below). Across all SZ scenarios, daily VMT changes after growth between -0.06 and 0.18 miles per person.

Figure 39 (below) shows the relationship between the diversity of land use in each growth target zone in 2000 and the change in daily VMT after growth. The graph illustrates that growth target zones with higher diversity of land use as measured pre-growth have lower increases in VMT after simulated growth.

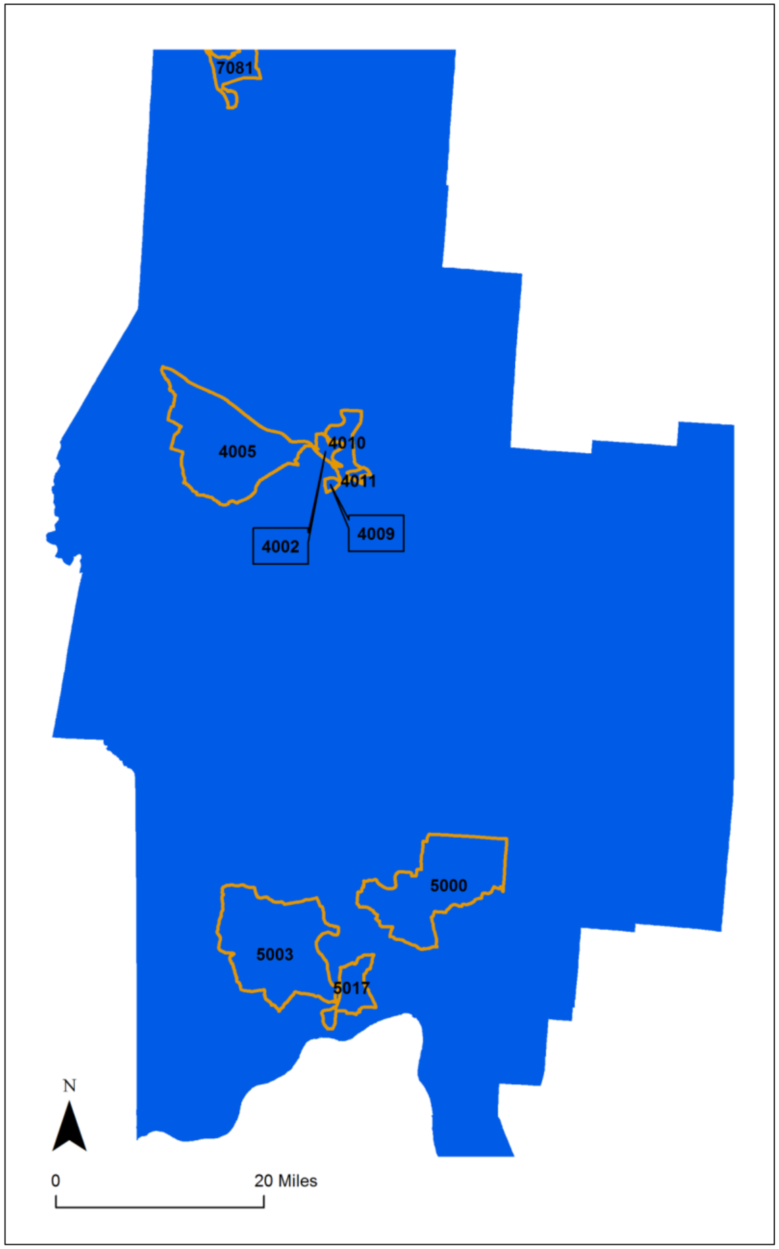


Figure 38. Ohio study area: growth target zones of nine Single Zone (SZ) scenarios.

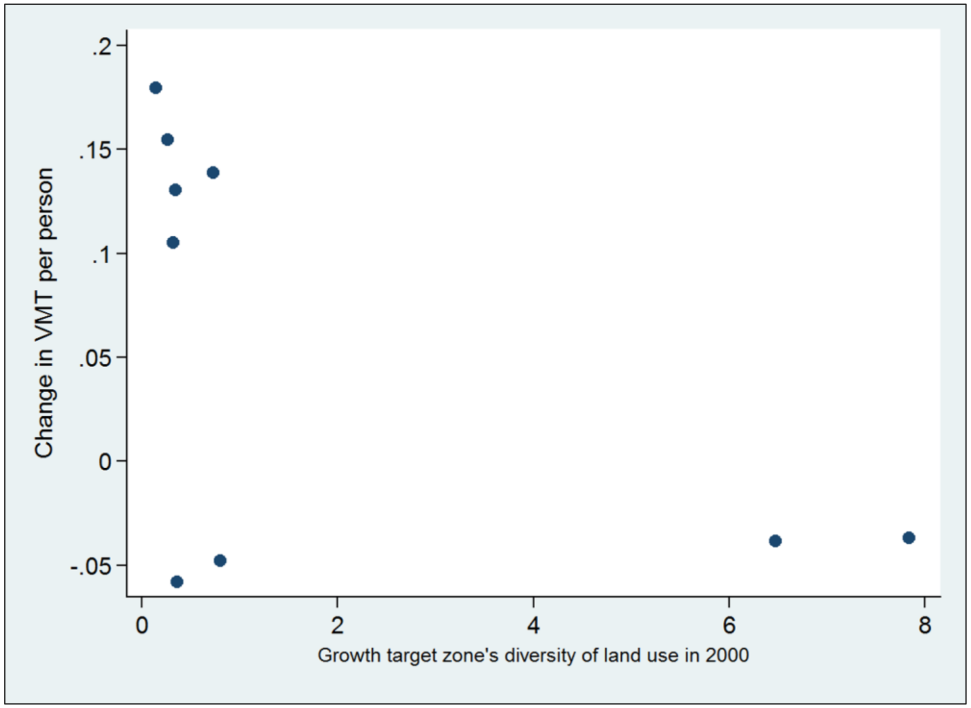


Figure 39. Ohio study area: relationship between diversity of land use in each growth target zone pre-growth and change in VMT after simulated growth.

Largest Towns Scenario

What happens to VMT when growth occurs in multiple locations, and jobs growth and household growth occur together in each county's largest town? This is the intention underlying the Largest Towns (LT) scenario, in which growth is dispersed among six towns.

In this scenario, employment in manufacturing increases by 83 (500 ÷ 6) in each of six analysis zones, one in each county's largest town (Figure 40). Those zones are the growth target zones not just for new manufacturing jobs but also for new commercial jobs and new households.

When there are six growth target zones, precise control over the locations of the new commercial jobs and new households is difficult to achieve in the computer model. Consequently, the growth of jobs and households is not perfectly balanced in each growth target zone. However, the new commercial jobs in the study area increase by 183 in total, just enough to ensure that all of the new households in the growth target zones are able to purchase locally the commercial goods and services they demand.

Table 8 (below) reports each zone's growth in total jobs and in total households. Figure 41 (below) displays all zones' total jobs and total households after the simulated growth. Figure 42 (below) displays the changes (compared to the year 2000) in total jobs and in total households. The influence of household growth on the location of commercial jobs is strong: there is a widespread shift of commercial jobs toward the locations of household growth, reflecting the movement of commercial establishments to analysis zones with better access to households (customers).

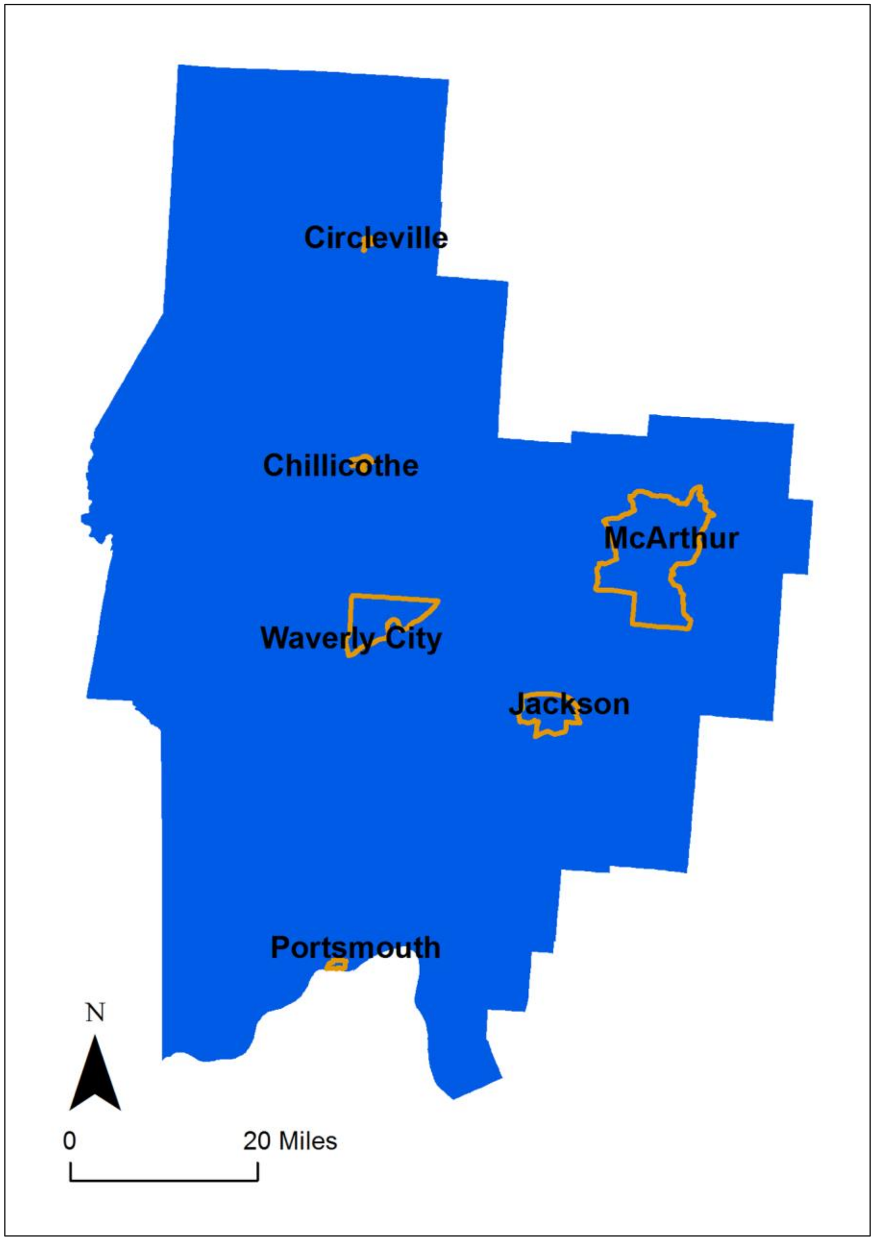


Figure 40. Ohio case study: growth target zones in the Largest Towns (LT) scenario.

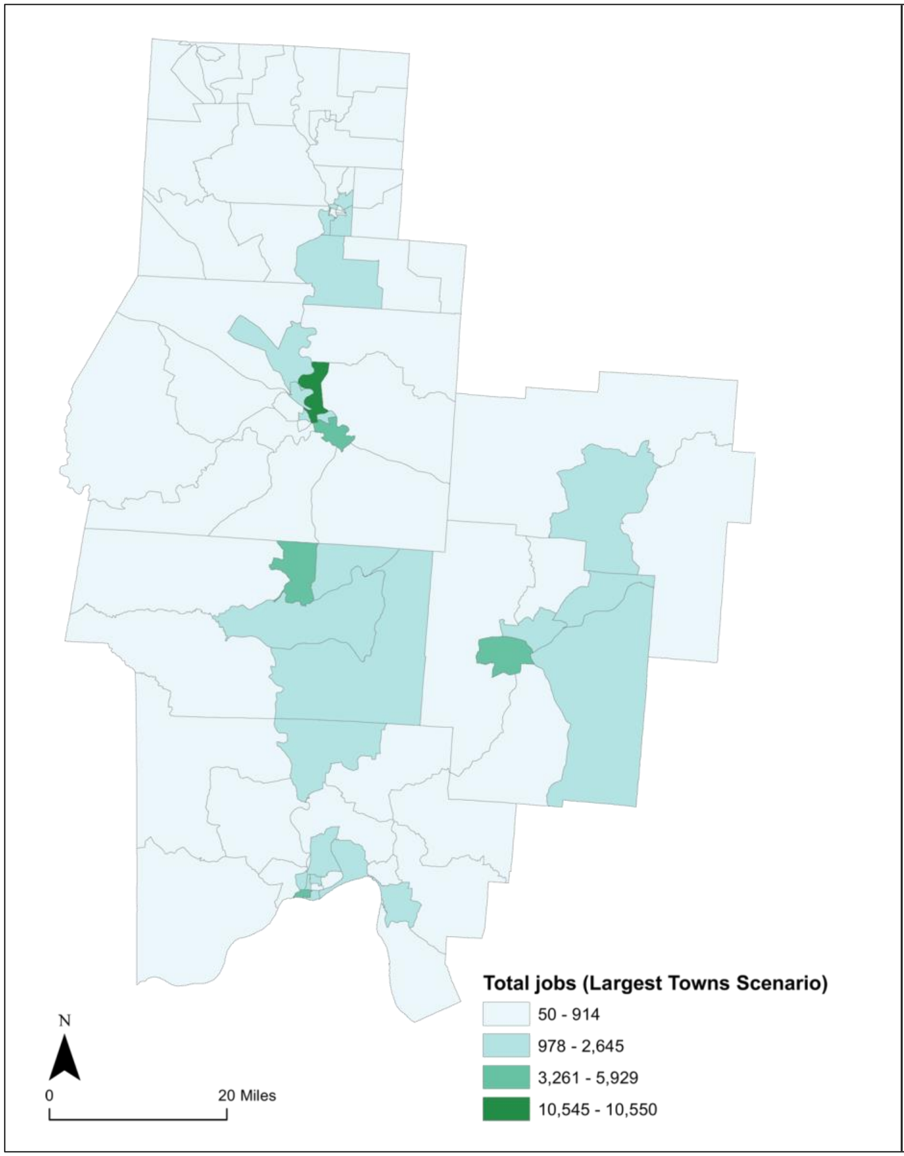
(Note: Figures 41 and 42 show jobs in all civilian industries, but because all new manufacturing jobs are in the six growth target zones, changes in jobs in other zones effectively represent changes only in commercial jobs.)

The Largest Towns scenario increases daily VMT by only 0.05 miles per person. The change is in the range encompassed by the other growth scenarios, which balance growth in a single analysis zone.

Table 8. Ohio study area: growth in jobs and households in Largest Towns (LT) scenario, and variance from perfectly balanced growth.

Zone	Defined Growth in Manufacturing Jobs†	Predicted Growth in Households†	Predicted Growth in Commercial Jobs†	Perfectly Balanced Growth in Commercial Jobs	Predicted Minus Perfectly Balanced Growth in Commercial Jobs
2003 (Jackson)	83.33	144	43	54	-11
3002 (Waverly)	83.33	81	16	30	-15
4011 (Chillicothe)	83.33	91	13	34	-21
5015 (Portsmouth)	83.33	43	72	16	56
6001 (McArthur)	83.33	121	17	45	-29
7001 (Circleville)	83.33	10	24	4	20
Total	500	490	183	183	0

† Compared to the base scenario.



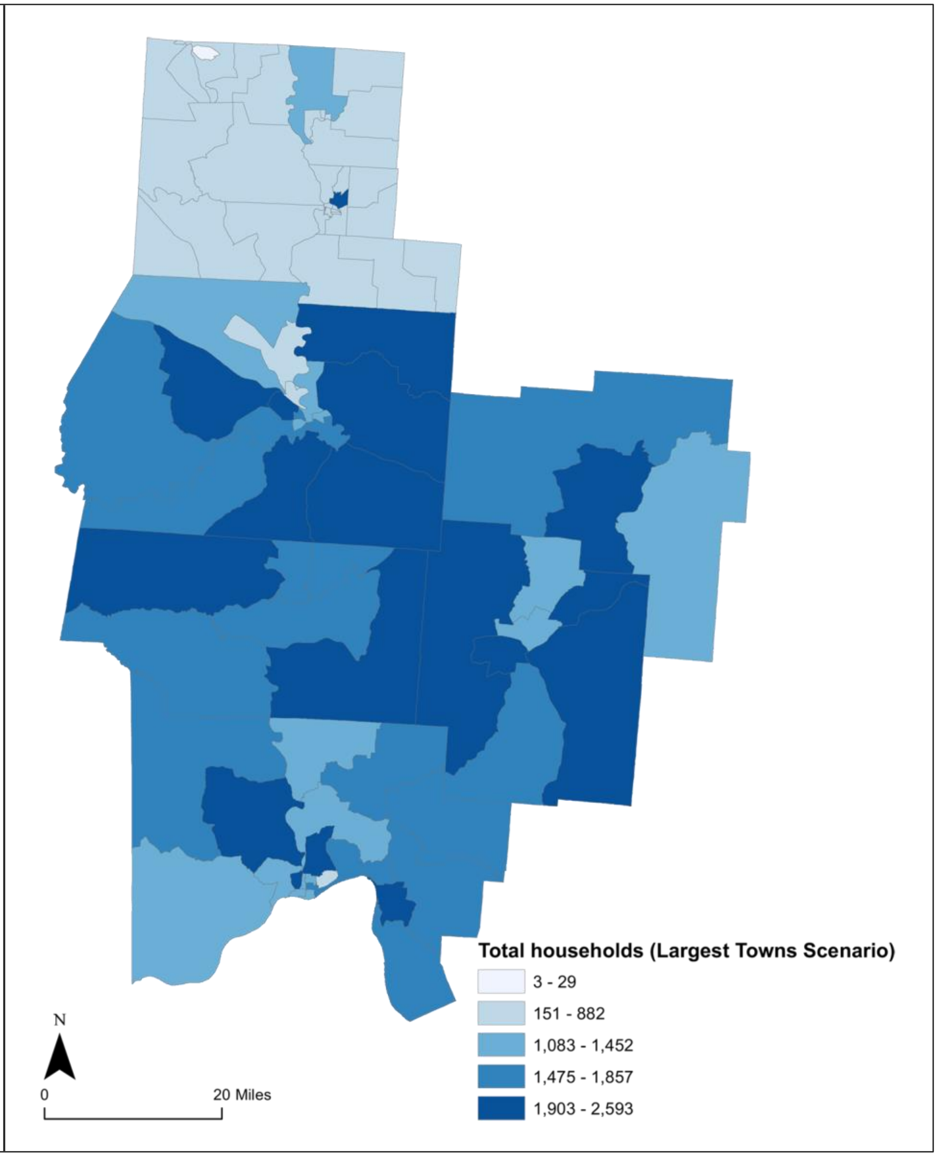


Figure 41. Ohio study area: total jobs and households in the Largest Towns (LT) scenario after simulated growth.

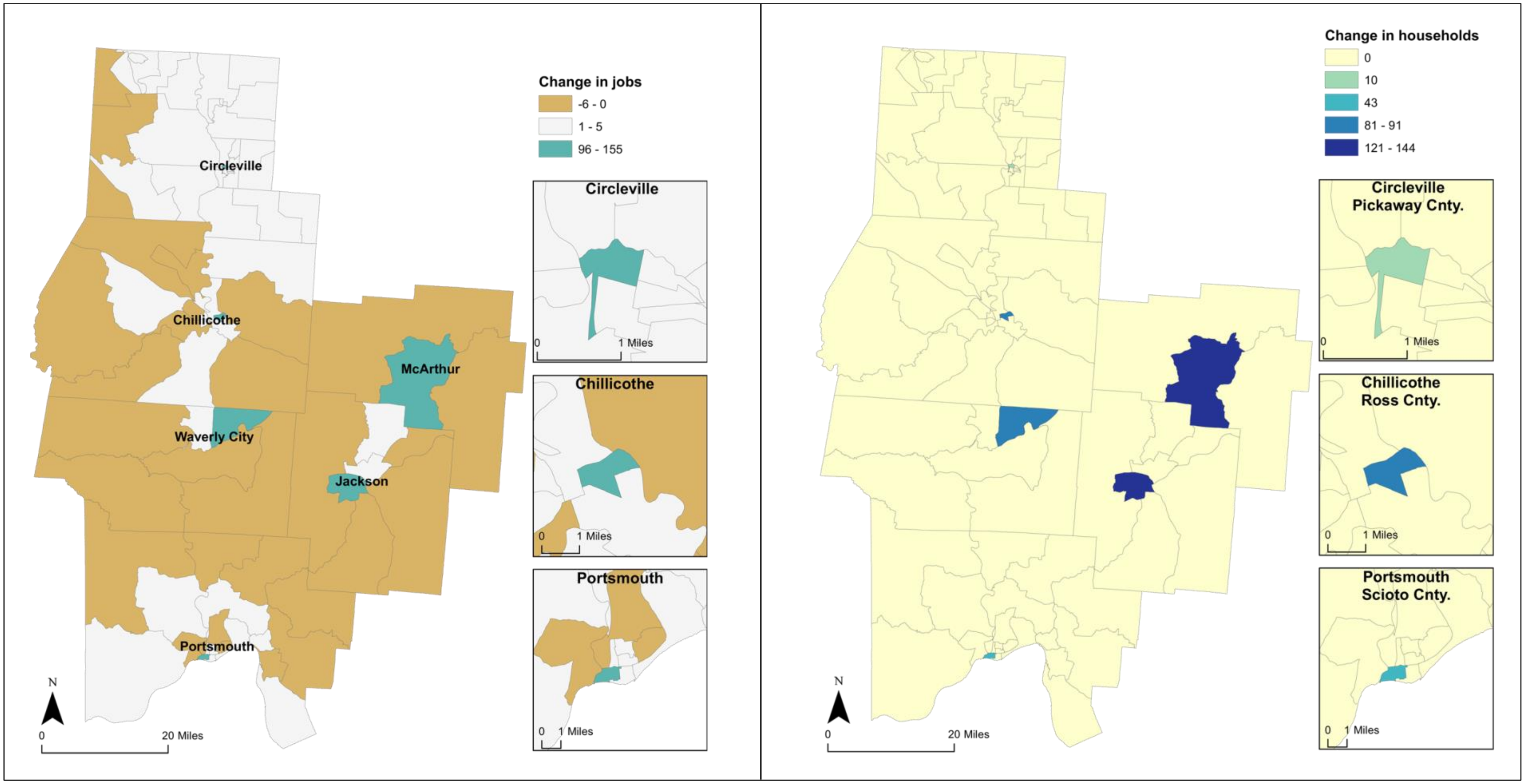


Figure 42. Ohio study area: changes in jobs and households in the LT scenario, compared to the year 2000.

CHECKLIST FOR MEDIUM POPULATION DENSITY COMMUTING ZONES (FAMILY 2)

- [ ] Consult the interactive map of small communities and rural areas to determine which family your commuting zone belongs to: http://go.ncsu.edu/scara-commuting-zones-map. If Family 2, use this checklist. If Family 1 or 3, consult the relevant checklist.

- [ ] List all the counties in your commuting zone.

- [ ] Develop your own database of land-use characteristics. For each census tract or census block group in your commuting zone, use census data to develop tables showing the total number of households, total number of civilian jobs, and the ratio of the total number of civilian jobs to the total number of households (representing land-use diversity).

- [ ] To minimize the increase in average weekday VMT per person, plan for balanced growth (locating new jobs and new households in the same census tract or census block group) and choose one of the following scenarios:

    - Divide the balanced growth among the towns in the commuting zone that are the largest in their respective counties, **or**

    - Locate the growth in a single census tract or census block group that has high land-use diversity *relative to the other census tracts and census block groups* in the commuting zone.

Streetscape Visualizations: Ohio Study Area

In the Largest Towns scenario, the growth in jobs and households is spread out among a group of six towns consisting of the largest town from each of the six counties. The towns are Jackson, Portsmouth, Waverly, McArthur, Circleville, and Chillicothe. The following streetscape visualizations and aerial perspectives show examples of how the growth in the Largest Towns scenario could be accommodated while maintaining each town's character.

Target levels of residential density were established based on a town or city's existing size, starting with a density of seven dwelling units per acre. Development at or above this density encourages walking, public transit usage (where provided), and neighborhood retail.[6]

The visualization studies maintain a town's existing scale, so that development in smaller towns tends toward one- and two-story buildings, and in larger towns, four- to six-story buildings. Development is placed where it can work with existing social and economic institutions, reflecting an assumed intent of planners and town officials to increase utilization of existing infrastructure and to support "Main Street." New housing is placed close to existing colleges, employment centers, and public schools. Mixed use developments are sited in downtown areas. Where waterfronts provide a defining sense of place, they present a natural focus for development.

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[6] Congress for the New Urbanism, Natural Resources Defense Council, and U.S. Green Building Council (October 2013). *LEED 2009 for Neighborhood Development*, p. 45. http://www.usgbc.org/sites/default/files/LEED%202009%20RS_ND_07.01.14_current%20version.pdf

Jackson, Ohio

Context

Jackson is connected to larger population centers, such as Chillicothe and Athens, by Highway 35 and Highway 124. These highways bypass downtown Jackson, centered on Main and Broadway Street. Residential areas in Jackson are west and northwest of Main and Broadway Street. The population of Jackson is just over 6,000.

Strategy

The existing housing in Jackson is mostly single-family residential just outside the downtown district, with no real transition between downtown and residential areas.
A transition could be created by placing mixed-use buildings on the outer edge of downtown. The ground floor of these mixed-use buildings could be shops, cafés, or other commercial spaces, while the upper levels could be apartments. There is currently open space on the back side of downtown buildings where parking or other commercial buildings could be introduced.

The mixed-use district could grow from three- to four-story buildings (Proposal 1) to six- to eight-story buildings (Proposal 2), by placing the new buildings in back of the existing downtown buildings (see Figures 43-49).

Figure 43 (above). Aerial 1 of Jackson: Present.

Figure 44. Aerial 1 of Jackson: Proposal 1.

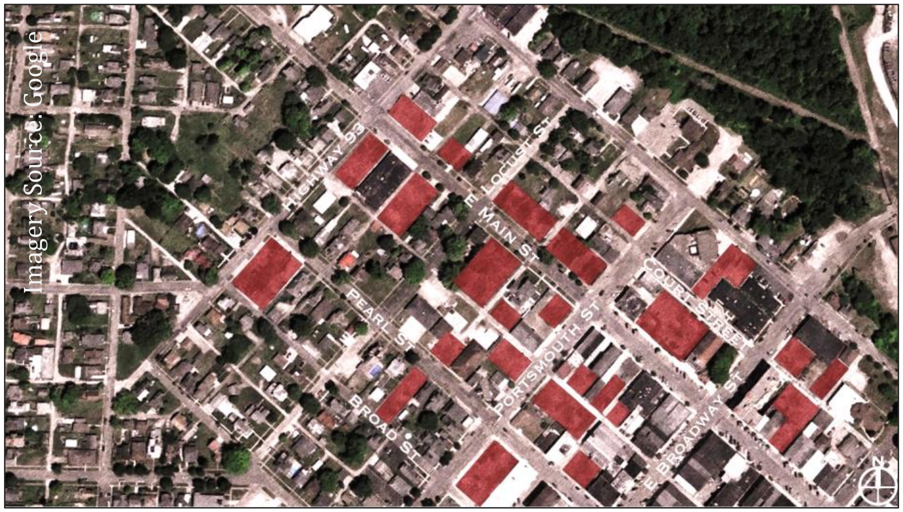

Figure 45. Aerial 1 of Jackson: Proposal 2.

Figure 46 (above).
View 1 of Jackson: Present.

Figure 47 (below).
View 1 of Jackson: Proposal 2.

Figure 48 (above).
View 2 of Jackson: Present.

Figure 49 (below).
View 2 of Jackson: Proposal 1.

Portsmouth, Ohio

Context

Portsmouth is located in southern Ohio on the banks of the Ohio and Scioto Rivers. It is within two hours of both Cincinnati and Columbus. The county seat of Scioto County, Portsmouth has a population of nearly 21,000 and is home to Shawnee State University, Daymar College, and Ashland Community and Tech College.
A large floodwall along the Ohio River protects the town from flood damage and also attracts many tourists to see the large historical murals that are painted on the wall. The prominent floodwall cuts off much of the city from the river. Parallel to the floodwall is Portsmouth's downtown, which is currently the site of most of the existing building density.

Strategy

Figure 50 and Figure 51 show proposed residential growth between Front Street and 2nd Street, and the mix of additional commercial spaces and residential dwellings in western Portsmouth.

Figure 50 (top).
Aerial 1 of Portsmouth: Present.

Figure 51 (bottom).
Aerial 1 of Portsmouth: Proposal.

The first streetscape visualization (Figures 52 and 53) shows the addition of four buildings of five- to six-stories to increase the density in the downtown district.

Figure 52 (top).
View 1 of Portsmouth: Present.

Figure 53 (bottom).
View 1 of Portsmouth: Proposal.

The second visualization (Figures 54 and 55) shows increased residential density at the eastern end of the downtown, which is also parallel to the flood wall. A pedestrian bridge over the wall at this point would connect the park along the river with the downtown.

Figure 54 (top).
View 2 of Portsmouth: Present.

Figure 55 (bottom).
View 2 of Portsmouth: Proposal.

Figures 56 and 57 show additional dwellings (for residents and students) and commercial buildings around the local college campus in eastern Portsmouth.

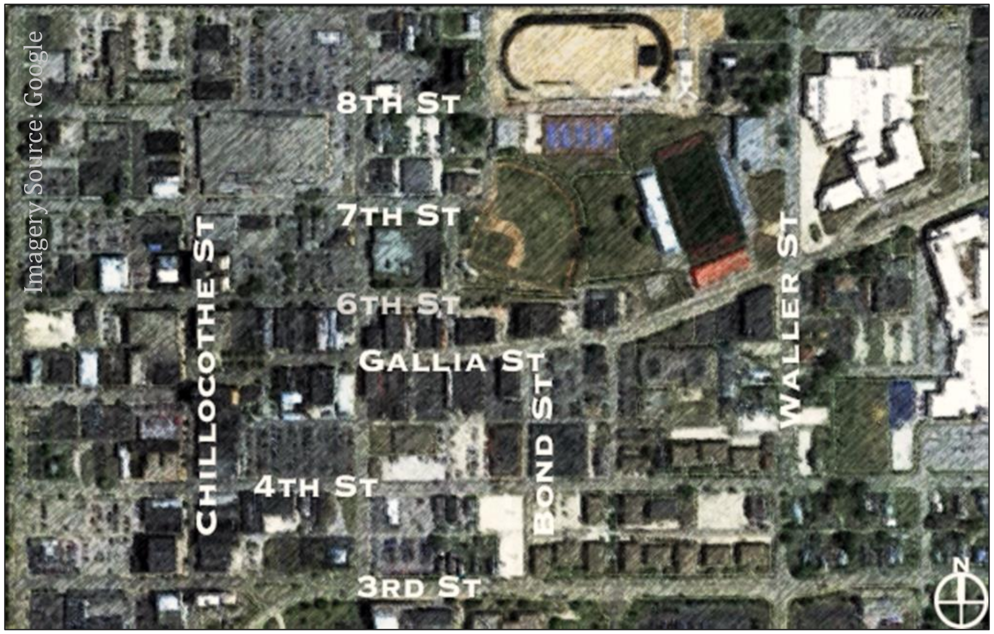

Figure 56 (top).
Aerial 2 of Portsmouth: Present.

Figure 57 (bottom).
Aerial 2 of Portsmouth: Proposal.

Waverly, Ohio

Context

Waverly is the county seat of Pike County. The construction of the Ohio and Erie Canal brought people to this area around 1829 where they established the village of Waverly. Currently, Waverly's population is approximately 4,400.

Strategy

The streetscape visualizations show the addition of mixed use buildings to downtown, with first floor commercial space and housing above (see Figures 58-61).

Figure 58 (top).
Aerial 1 of Waverly: Present.

Figure 59 (bottom).
Aerial 1 of Waverly: Proposal.

Figure 60 (above).
View 1 of Waverly: Present.

Figure 61 (below).
View 1 of Waverly: Proposal.

McArthur, Ohio

Context

McArthur was founded in 1815 and has a population just barely over 1,700. It is approximately 40 miles east of Chillicothe and 76 miles southeast of Columbus. As the county seat of Vinton County, it is home to the county's only middle school and high school.

Strategy

Since the downtown is still relatively small, the proposal adds more commercial space in the open lots downtown. Developing the west end of downtown could create a stronger entrance into the town, add new life, and attract more visitors to McArthur (see Figures 62-65).

Figure 62 (top). Aerial 1 of McArthur: Present.

Figure 63 (bottom). Aerial 1 of McArthur: Proposal.

Figure 64 (above).
View 1 of McArthur: Present.

Figure 65 (below).
View 1 of McArthur: Proposal.

In addition, Figures 66 and 67 show additional residential communities surrounding the middle and high schools.

Figure 66 (top).
Aerial 2 of McArthur: Present.

Figure 67 (bottom).
Aerial 2 of McArthur: Proposal.

Circleville, Ohio

Context

Circleville, population more than 13,000, was initially organized in a radial grid system. Today the town has been reshaped as a conventional grid with the only hint of the town's radial past being a circular building (a bank) located on the corner of North Street and West Main (Figure 68).

Strategy

The proposal incorporates a radial grid by replacing the circular bank with a park that resembles the town's original form. The park will be a good place to host the town's annual Pumpkin Festival, which attracts over 300,000 visitors; it is currently held on downtown streets. The aerial views show two proposals for adding residential and commercial density to downtown: a medium density streetscape (Figure 69) and a higher density one (Figure 70).

The medium density proposal shows a filling-in of the vacant lots downtown with new commercial businesses (Figure 69). With this approach, the new buildings (at the same scale as the historical ones) would be added in the vacant lots.

Figure 68 (above). Aerial 1 of Circleville: Present.

Figure 69. Aerial 1 of Circleville: Proposal 1.

Figure 70. Aerial 1 of Circleville: Proposal 2.

Figure 71 shows the existing conditions looking down East Main Street, and Figure 72 shows the medium density proposal for this location.

Figure 71 (top).
View 2 of Circleville: Present.

Figure 72 (bottom).
View 2 of Circleville: Proposal 1.

Figure 73 shows the current conditions in another downtown location. The higher density proposal shown in Figure 74 suggests placing larger scale buildings behind the existing ones. This would allow the town to accommodate a greater density while preserving the historical character of the downtown. In addition, the medium density proposal could be added to the high density.

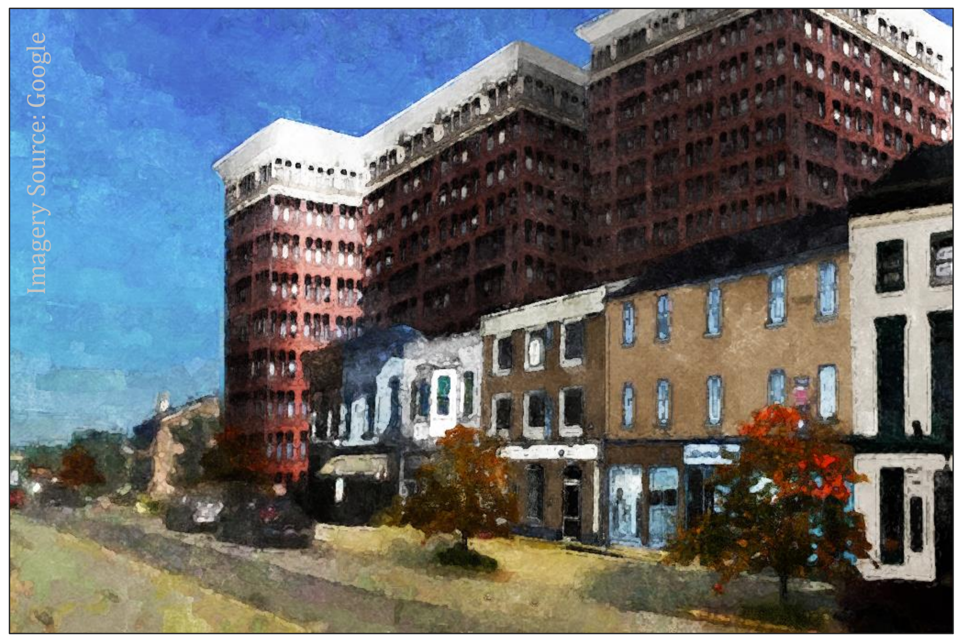

Figure 73 (top).
View 2 of Circleville: Present.

Figure 74 (bottom).
View 2 of Circleville: Proposal 2.

Chillicothe, Ohio

Context

Situated between Cincinnati and Columbus, Chillicothe was the first capital of Ohio and, much earlier, a center of the Native American Hopewell culture. Located on the Scioto River between two ridges, Chillicothe's main entrances on Highway 50 (E. Main St.) and Bridge Street intersect in the downtown district where the majority of commercial space is located (Figure 75).

Strategy

Since the entry roads are important to Chillicothe, the streetscape visualizations show buildings added along and near these roads. Figure 76 shows commercial areas added along North Bridge Street. By adding more apartment buildings north of downtown toward the river, the residential area will expand while allowing residents to easily walk to the existing park along the river.

Figure 75 (top).
Aerial 1 of Chillicothe: Present.

Figure 76 (bottom).
Aerial 1 of Chillicothe: Proposals 1 and 2.

Figure 77 shows the current conditions in the downtown area along Hickory Street. Figure 78 shows what the street would look with the addition of several four- to six-story buildings. A second Hickory Street rendering (Figure 79), shows a more dramatic change with higher density buildings, at least six stories high.

Figure 77 (above). View 1 of Hickory St., Chillicothe: Present.

Figure 78. View 1 of Hickory St., Chillicothe: Proposal 1.

Figure 79. View 1 of Hickory St., Chillicothe: Proposal 2.

Figure 80 shows the existing conditions in another downtown location in Chillicothe. Figure 81 shows commercial spaces filling in the blocks between and around Paint Street and Walnut Street. Increasing building density along North Paint Street and Water Street will help connect the west part of town back to the downtown area. The existing conditions and the proposed changes for Water Street are shown in Figures 82 and 83, respectively.

Figure 80 (top).
Aerial 2 of Chillicothe: Present.

Figure 81 (bottom).
Aerial 2 of Chillicothe: Proposal.

Figure 82 (above).
View 2 of Water St., Chillicothe: Present.

Figure 83 (below).
View 2 of Water St., Chillicothe: Proposal.

Washington Study Area: High Population Density (Family 3)

Study Area Overview

The Washington study area is a three-county commuting zone adjacent to the southern portion of Puget Sound. It includes Olympia, the state capitol (Figure 84). The study area is a member of the high population density family of small communities and rural areas, characterized by:

- high population density (per square mile of developed or developable land),
- high road density,
- moderate diversity of land use, and
- low variation in population density.

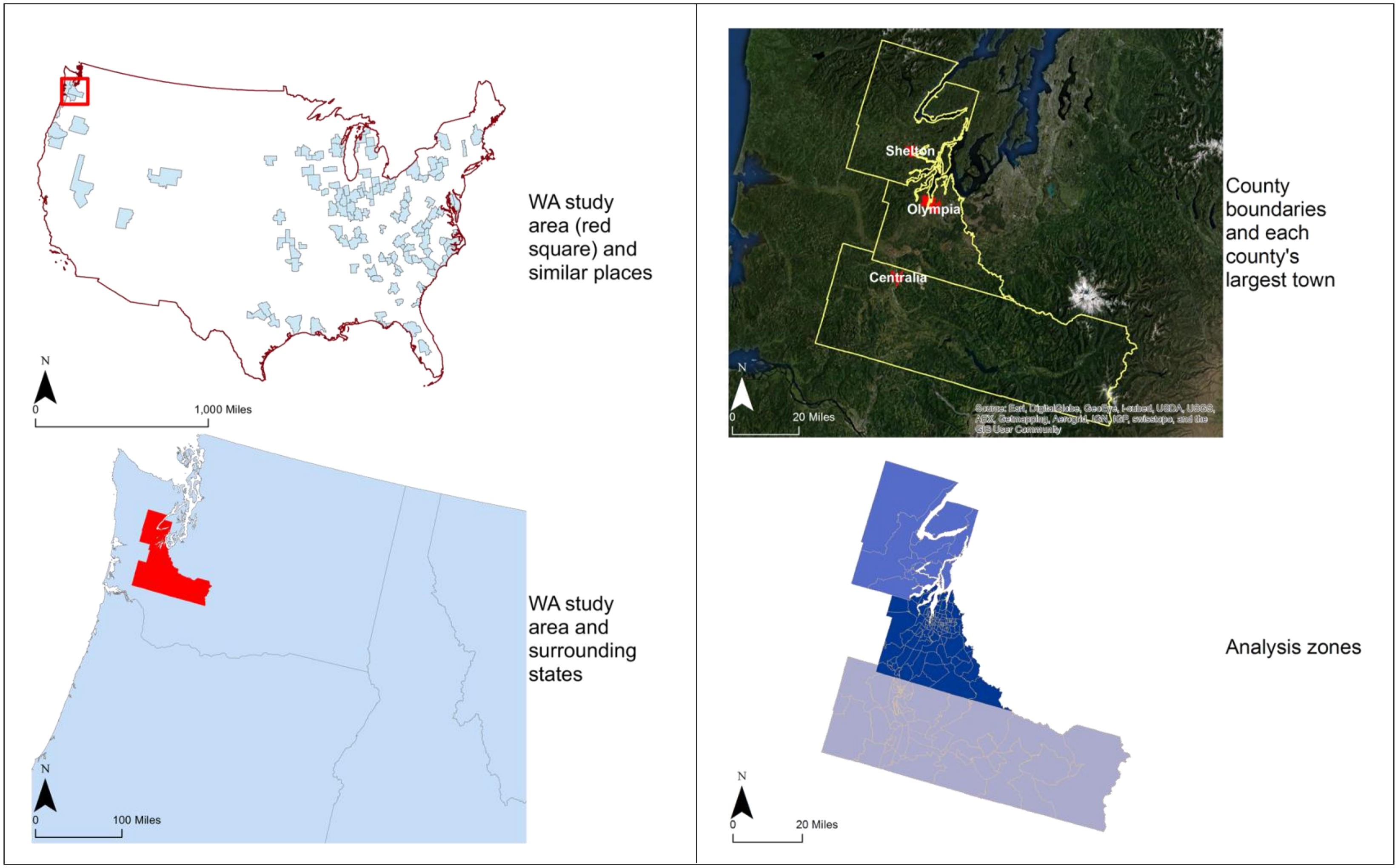

Figure 84. Washington state study area: geographical context, counties, and analysis zones.

In this study area, both census tracts and census block groups were used as the analysis zones; there are 14 census tracts in Mason County, and 195 census block groups in Lewis and Thurston Counties.

Data from 2000 census:

- Households: 114,438
- Persons: 318,612
- Total number of civilian jobs: 129,383 (including 11,345 workers whose residence was located in a 35-mile buffer drawn around the six counties)
    - Agricultural and natural resource jobs: 4,270
    - Commercial jobs (retail, professional services, social services, public administration, etc.): 89,023
    - Construction and manufacturing jobs: 24,744

Figures 85 and 86 (below) show each analysis zone's number of civilian jobs (resident) and number of households in the year 2000.

In the year 2000, the study area's civilian household population and inbound commuters (who did not live in the study area) had a VMT of almost 47 miles per person per day. The average refers to daily weekday travel in privately owned vehicles such as cars, vans, pickup trucks, and motorcycles, and accounts for all residents, including non-drivers, living in households. For the inbound commuters, only the mileage associated with their commuting trips is included in the average.

Implications for Practice

In this study area, when balanced growth of jobs and households is targeted for a single analysis zone, daily VMT stays essentially the same—increasing or decreasing only slightly. (Results are based on eight Single Zone scenarios, each of which targeted a different analysis zone for growth.) For each of the following attributes of a growth target analysis zone, higher values pre-growth are associated with smaller increases in VMT after growth:

- diversity in land use
- total number of jobs
- access to commercial establishments
- access to households

Total number of households in an analysis zone targeted for growth has essentially no impact on the predicted change in daily VMT.

In the Largest Towns scenario, growth results in a negligible decrease in daily VMT.

Increases and decreases in VMT have implications for driving-related fuel consumption and emissions. Increases in VMT per person will typically increase fuel consumption per person and vehicular emissions per person; decreases will typically lead to the reverse. It's important to note that the increases and decreases in fuel consumption and emissions may not be proportional to the changes in VMT.

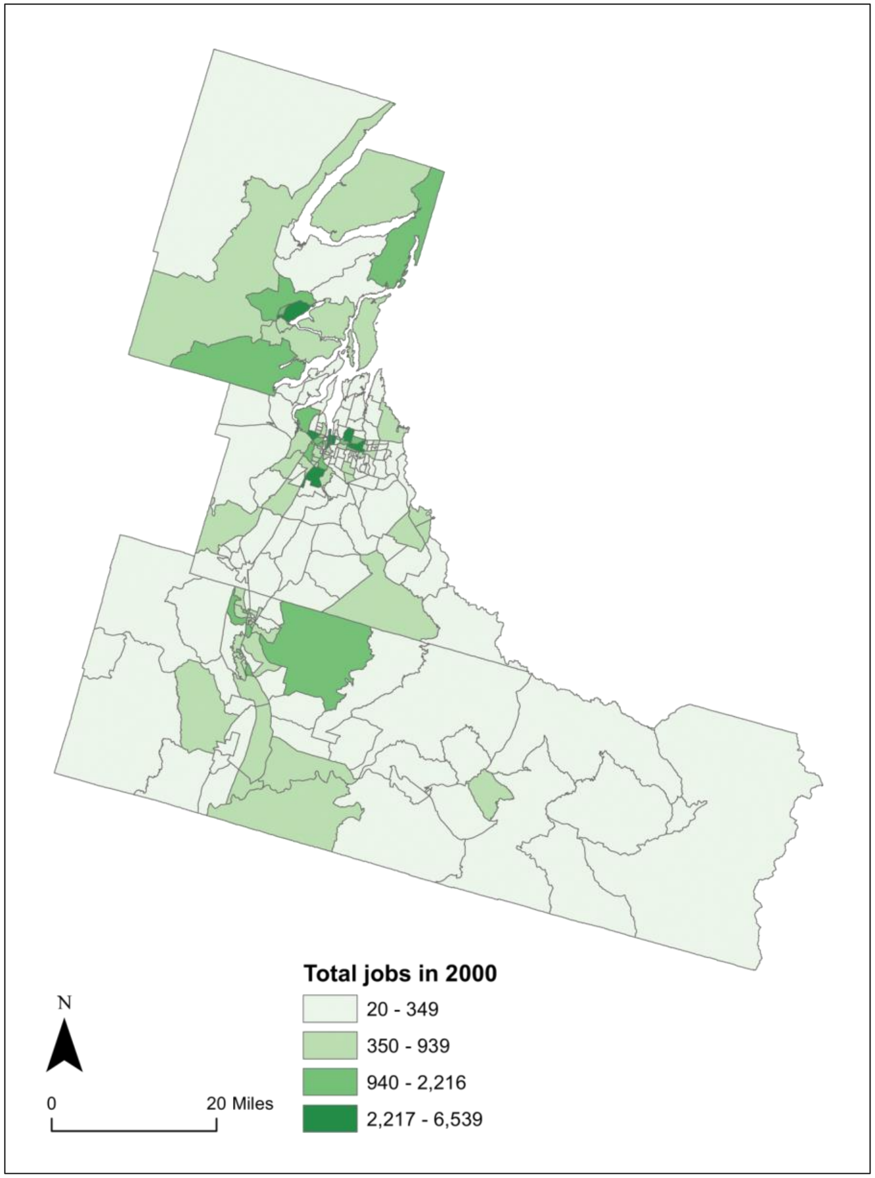

Figure 85. Washington study area: total civilian jobs (resident jobs) in the year 2000.

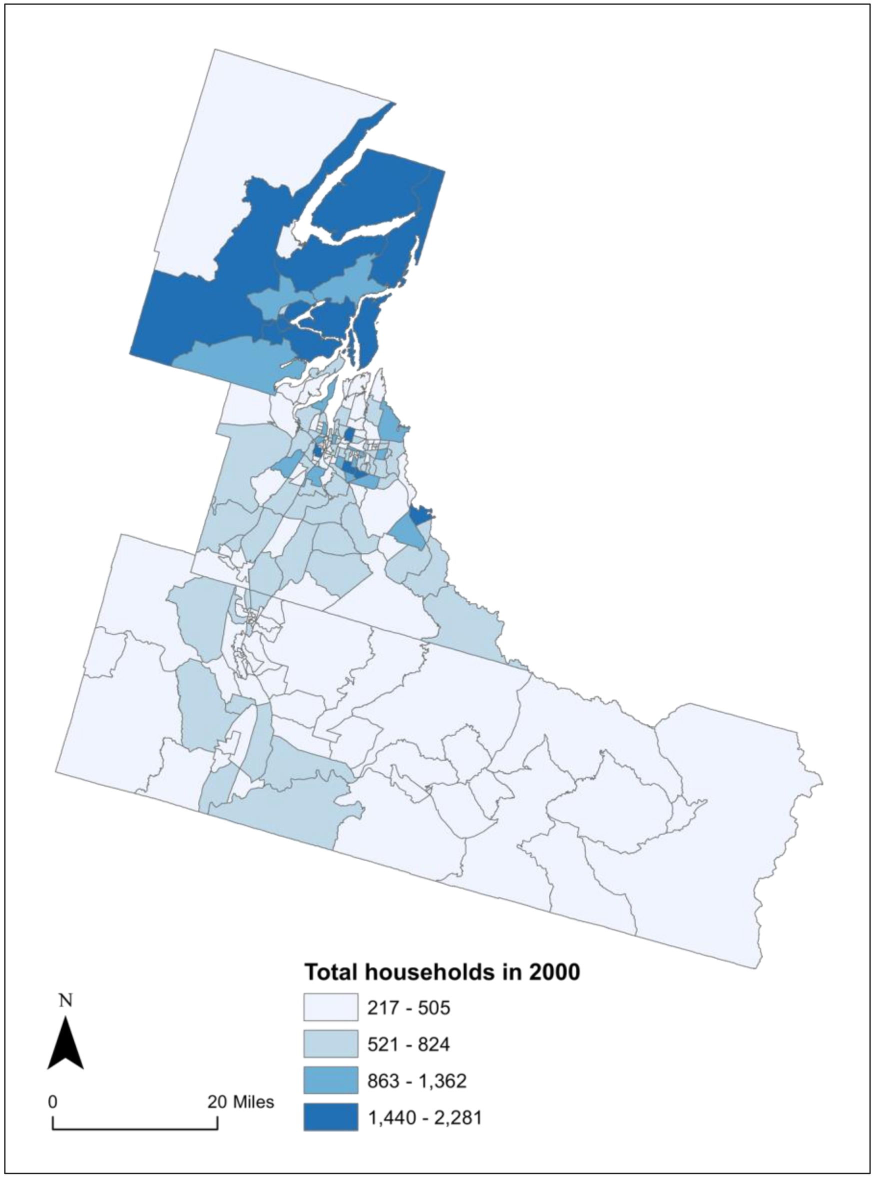

Figure 86. Washington study area: total households in the year 2000.

Single Zone Scenarios

Table 9 identifies the zones targeted for growth in eight scenarios, and provides each scenario's predicted change in daily VMT. In each Single Zone (SZ) scenario, a different analysis zone is targeted for growth (Figure 87). Across all SZ scenarios, daily weekday VMT changes between -0.52 and 0.31 miles per person.

Figure 88 (below) provides insight into the relationship between the change in daily VMT and each of the following characteristics of the growth target zone, as measured pre-growth: total jobs, access to commercial establishments, access to households and diversity in land use. The results from the eight SZ scenarios show an inverse relationship between change in VMT and each characteristic.

Table 9. Washington study area: key results of the eight Single Zone (SZ) scenarios.

Scenario	Manufacturing Growth Target Zone	Commercial Growth Target Zone	Household Growth Target Zone	Change in VMT Per Person†
SZ-4040	4040			-0.52
SZ-4001	4001			-0.51
SZ-4033	4033			-0.46
SZ-2021	2021			-0.27
SZ-3000	3000			0.02
SZ-2057	2057			0.10
SZ-3003	3003			0.15
SZ-2051	2051			0.31

† Change in VMT per person compared to year 2000. Scenarios are listed in ascending order of change in VMT per person.

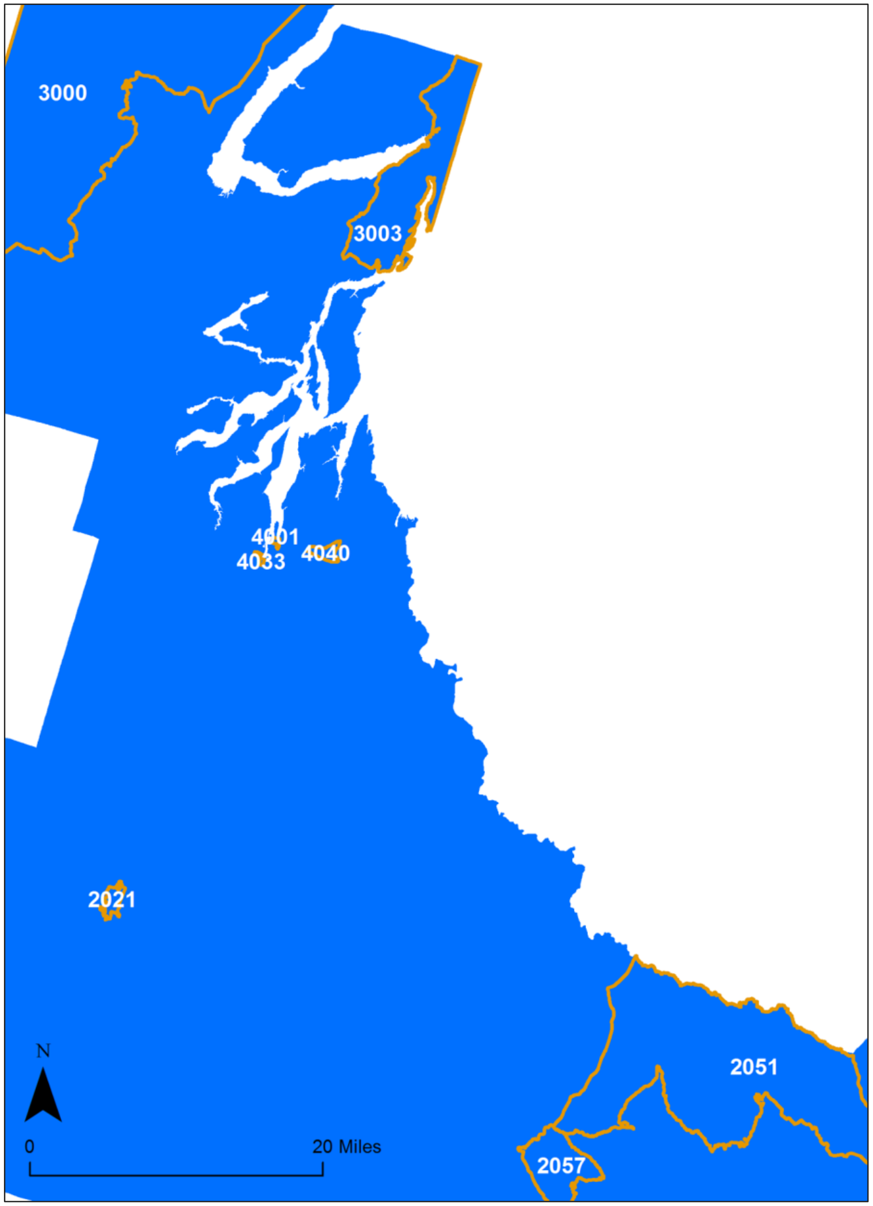

Figure 87. Washington study area: growth target zones of the eight Single Zone scenarios (portions of Mason, Thurston, and Lewis counties).

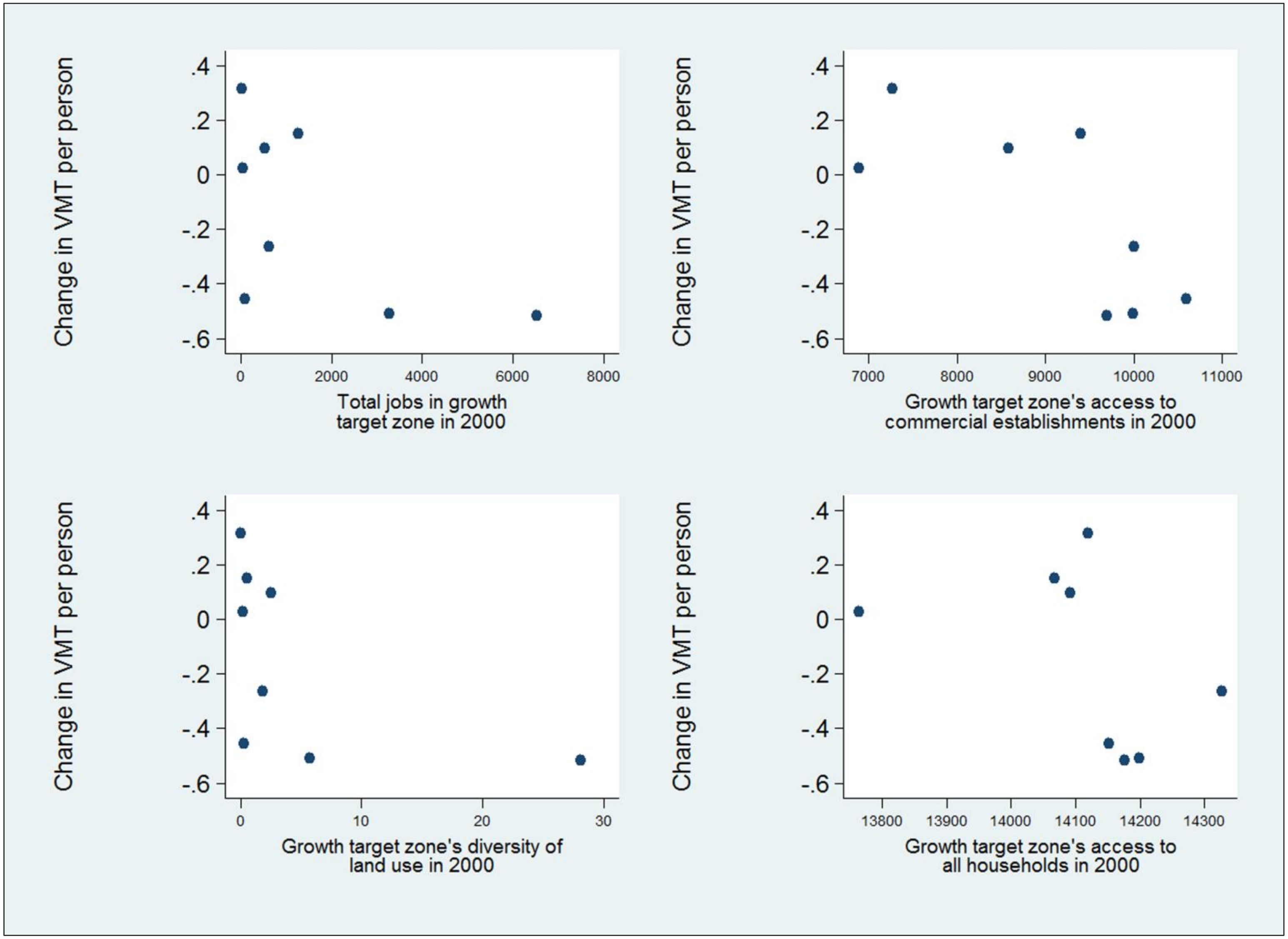

Figure 88. Washington study area: relationships between four land use attributes of the analysis zones, as measured pre-growth, and change in VMT after simulated growth for the eight Single Zone (SZ) scenarios.

Largest Towns Scenario

What happens to VMT when growth occurs in multiple locations, and jobs growth and household growth occur together in each county's largest town? This is the intention underlying the Largest Towns (LT) scenario, in which growth is dispersed among three towns.

In this scenario, the 500 new manufacturing jobs are spread among three analysis zones, so that each receives 167 new manufacturing jobs (see Figure 89 below). Those zones are the growth targets not just for new manufacturing jobs but also for new commercial jobs and new households. When there are three growth target zones, precise control over the locations of the new commercial jobs and new households is difficult to achieve in the computer model. Consequently, the growth of jobs and households is not perfectly balanced in each growth target zone. However, the commercial jobs in the study area increase by 152 in total, just enough to ensure that the new households in all of the growth target zones are able to purchase locally the commercial goods and services they demand.

Table 10 reports each zone's growth in total jobs and in total households. Figure 90 (below) displays all zones' total jobs (left) and total households (right) after the simulated growth. Figure 91 (below) displays the changes, compared to the year 2000, in total jobs (left) and in total households (right). The influence of household growth on the location of commercial jobs is strong: there is a widespread shift of commercial jobs toward the locations of household growth, reflecting the movement of commercial establishments to analysis zones with better access to households (customers).

(Note: Figure 91 shows jobs in all civilian industries, but because all new manufacturing jobs are in the three growth target zones, changes in jobs in other zones effectively represent changes only in commercial jobs.)

The Largest Towns scenario does not substantially change daily VMT, reducing it by 0.10 miles per person. The change is in the range encompassed by the other growth scenarios, which balance growth in a single analysis zone.

Table 10. Washington study area: growth in jobs and households in Largest Towns (LT) scenario, and variance from perfectly balanced growth.

Zone	Defined Growth in Manufacturing Jobs†	Predicted Growth in Households†	Predicted Growth in Commercial Jobs†	Perfectly Balanced Growth in Commercial Jobs	Predicted Minus Perfectly Balanced Growth in Commercial Jobs
2014 (Centralia	166.67	105	19	39	-20
3007 (Shelton)	166.67	225	50	84	-34
4001 (Olympia)	166.67	77	82	29	54
Total	500	407	152	152	0

† Compared to the base scenario.

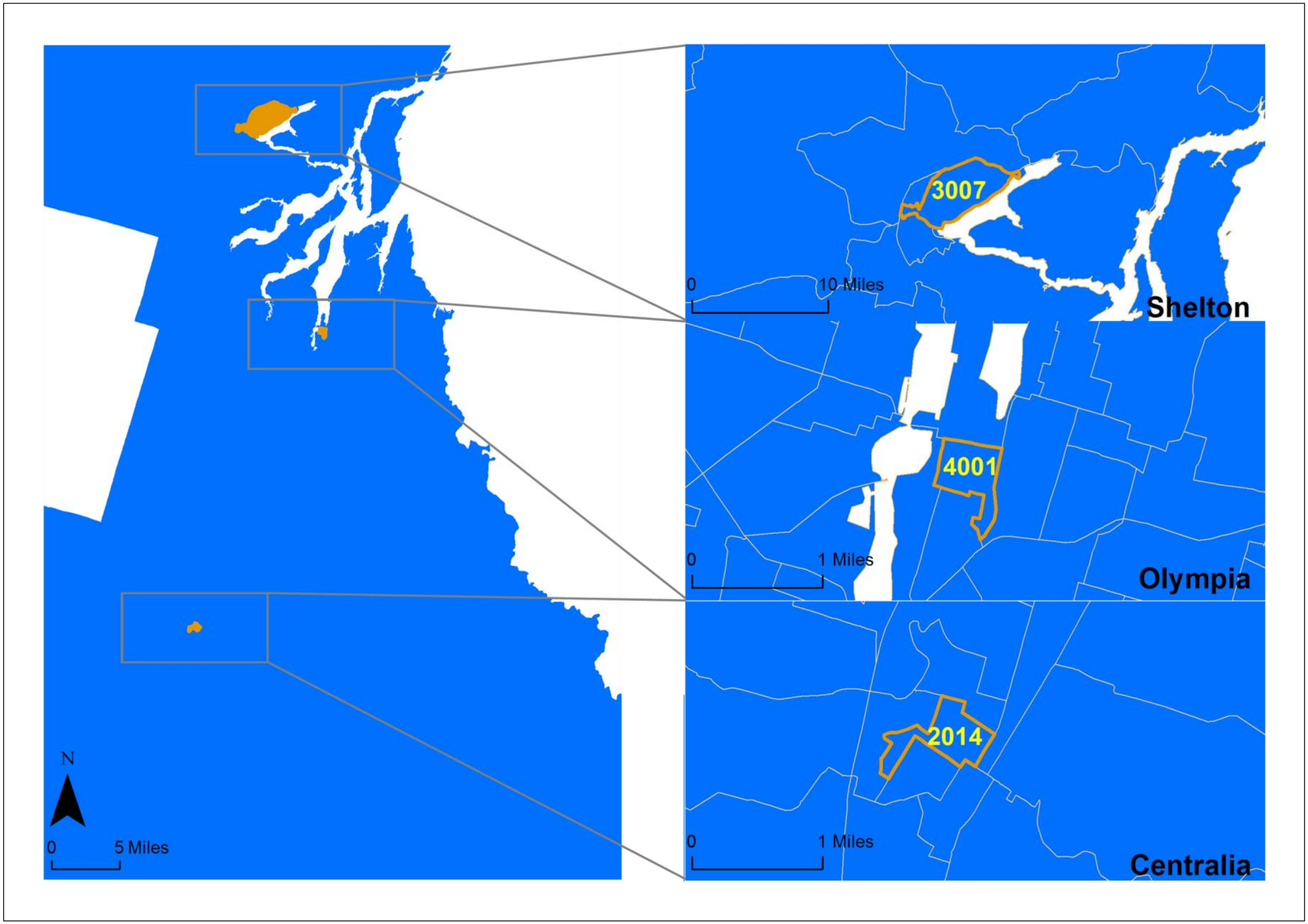

Figure 89. Washington case study: growth target zones in the Largest Towns (LT) scenario.

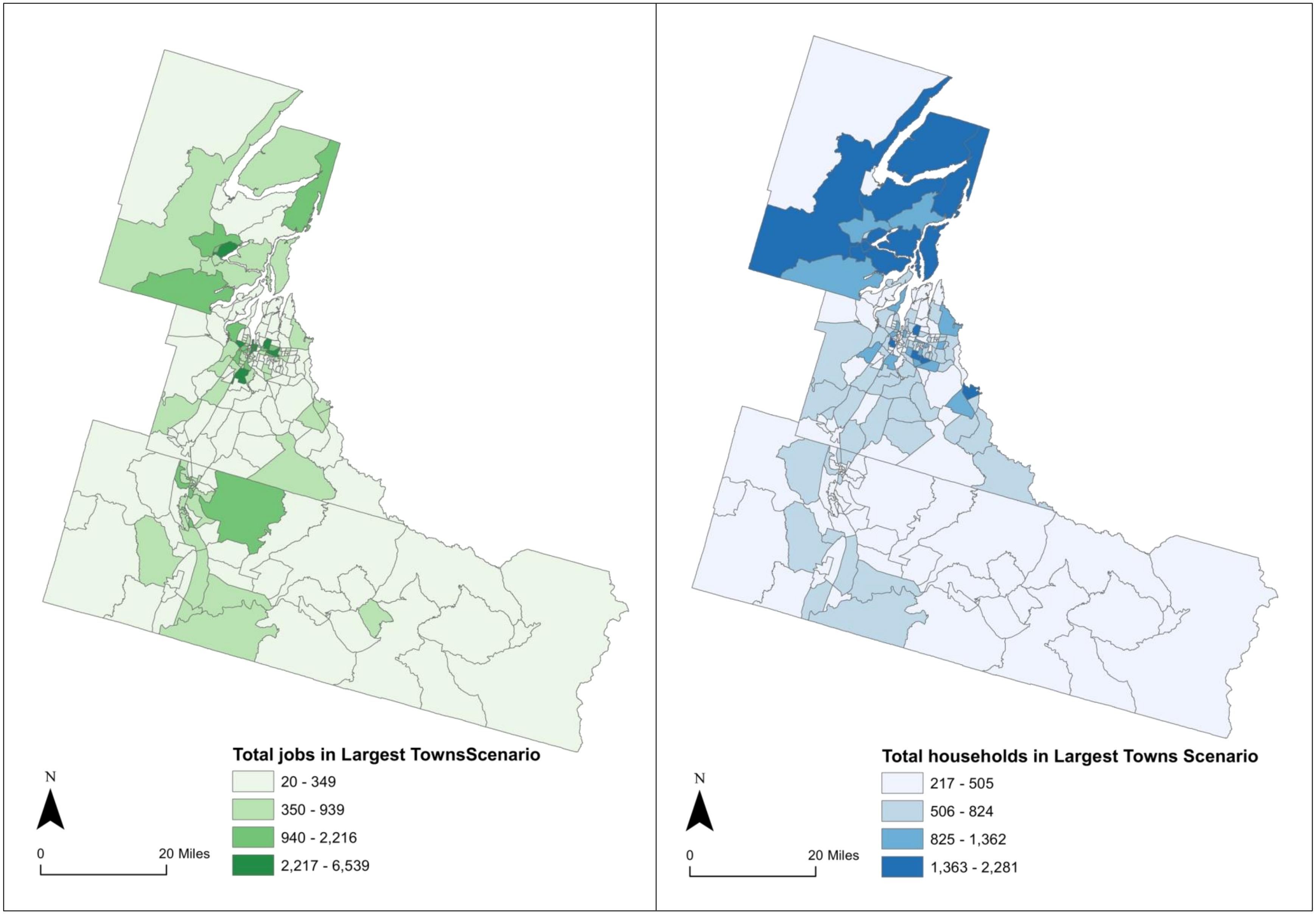

Figure 90. Washington study area: total jobs (left) and households (right) in the Largest Towns (LT) scenario after simulated growth.

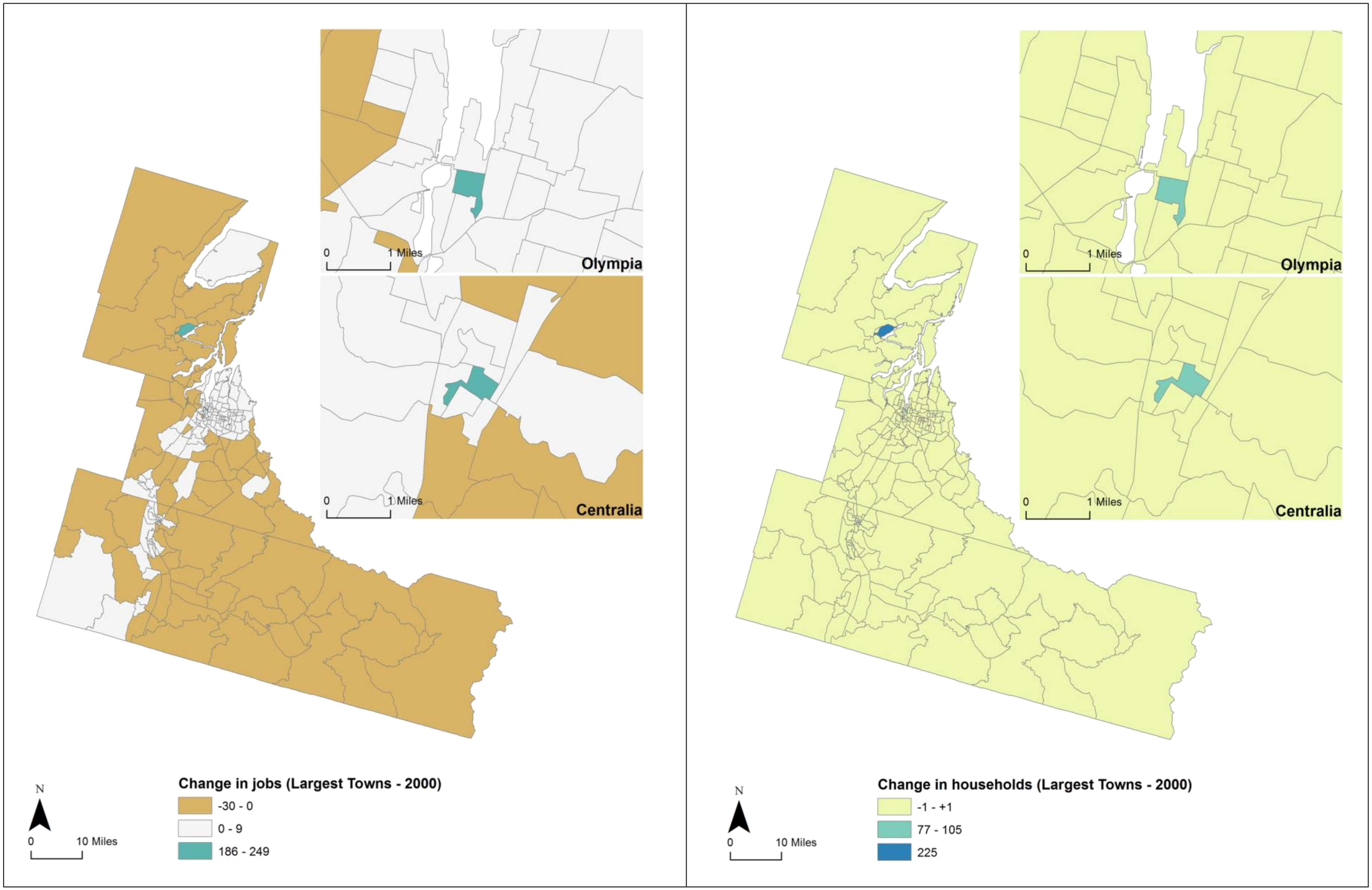

Figure 91. Washington study area: changes in total jobs (left) and households (right) in the Largest Towns (LT) scenario, compared to the year 2000.

CHECKLIST FOR HIGH POPULATION DENSITY COMMUTING ZONES (FAMILY 3)

- [ ] Consult the interactive map of small communities and rural areas to determine which family your commuting zone belongs to: http://go.ncsu.edu/scara-commuting-zones-map. If Family 3, use this checklist. If Family 1 or 2, consult the relevant checklist.
- [ ] List all the counties in your commuting zone.
- [ ] Develop your own database of land-use characteristics. For each census tract or census block group in your commuting zone, develop tables showing the total number of households, total number of civilian jobs, access to households in the commuting zone, access to commercial establishments in the commuting zone, and the ratio of the total number of civilian jobs to the total number of households (representing land-use diversity). See note below.
- [ ] To minimize the increase in average weekday VMT per person, plan for balanced growth (locating new jobs and new households in the same analysis zone) **and** . . .
- [ ] Divide the balanced growth among the towns in the commuting zone that are the largest in their respective counties **or** locate the growth in a single census tract or census block group that has the following characteristics *relative to the other census tracts and census block groups* in the commuting zone:
    - high diversity of land use
    - high total number of civilian jobs
    - high access to commercial establishments
    - high access to households

Note: Use census data to obtain total number of households and total number of civilian jobs for census tracts and census block groups. The access measures used in this chapter can be exactly replicated only by using a computer model that parallels the one developed for the Washington study area. However, your state department of transportation may be able to provide alternative access measures (called "gravity models") obtained from a conventional travel demand model developed for the region of interest. These measures of access to civilian jobs or to households may help identify the census tracts or census block groups that are especially isolated.

If you are unable to develop or obtain access measures for your commuting zone, you may be able to use the results from this chapter in a more qualitative way. To minimize the increase in average weekday VMT per person, locate household and job growth in census tracts or census block groups that have a large ratio of civilian jobs to households, a large number of civilian jobs, and are not isolated.

Streetscape Visualizations: Washington Study Area

In the Largest Towns scenario, the growth in jobs and households is spread out among three towns—the largest town from each of the three counties in the study area. These towns are Shelton, Olympia, and Centralia. The following streetscape visualizations and aerial perspectives show examples of how the growth in the Largest Towns scenario could be accommodated while maintaining each town's character.

Target levels of residential density were established based on a town or city's existing size, starting with a density of seven dwelling units per acre. Development at or above this density encourages walking, public transit usage (where provided), and neighborhood retail.[7]

The visualization studies maintain a town's existing scale, so that development in smaller towns tends toward one- and two-story buildings, and in larger towns, four- to six-story buildings. Development is placed where it can work with existing social and economic institutions, reflecting an assumed intent of planners and town officials to increase utilization of existing infrastructure and to support "Main Street." New housing is placed close to existing colleges, employment centers, and public schools. Mixed use developments are sited in downtown areas. Where waterfronts provide a defining sense of place, they present a natural focus for development.

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[7] Congress for the New Urbanism, Natural Resources Defense Council, and U.S. Green Building Council (October 2013). *LEED 2009 for Neighborhood Development*, p. 45. http://www.usgbc.org/sites/default/files/LEED%202009%20RS_ND_07.01.14_current%20version.pdf

Shelton, Washington

Context

Shelton, population about 10,000, is located on Puget Sound. The town spreads out from the downtown area near the water. At the east end, a lumber yard on the shore separates the downtown from the water.

Strategy

By developing the border area between the lumber yard and the existing commercial area, a denser downtown could be created while hiding the lumber yard and other industrial buildings. There are also many opportunities to fill out the rest of the downtown to the west with commercial buildings. If further population growth occurs, pockets for new residential areas can be found in existing residential areas (see Figures 92-99).

Figure 92 (top).
Aerial 1 of Shelton: Present.

Figure 93 (bottom).
Aerial 1 of Shelton: Proposal.

Figure 94 (above).
Aerial 2 of Shelton: Present.

Figure 95 (below).
Aerial 2 of Shelton: Proposal.

Figure 96 (above).
View 1 of Shelton: Present.

Figure 97 (below).
View 1 of Shelton: Proposal.

Figure 98 (above).
View 2 of Shelton: Present.

Figure 99 (below).
View 2 of Shelton: Proposal.

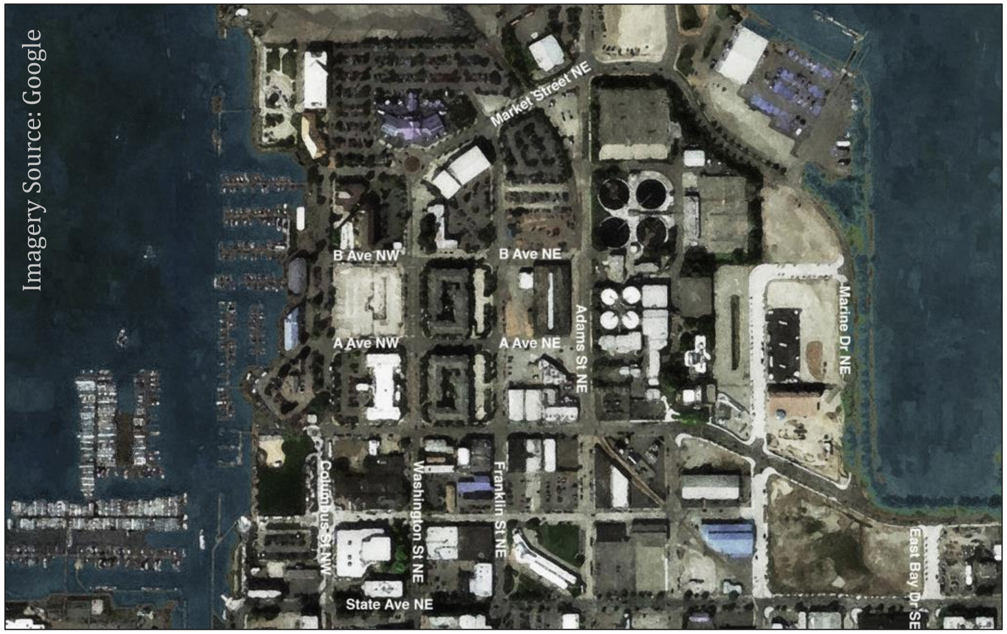
Olympia, Washington

Context

Olympia has a population of over 46,000 people and is the state capital. State government buildings are located in the downtown area, but the majority of the city is low to medium density commercial and residential buildings. Budd Inlet, which connects to Puget Sound, establishes Olympia's northern boundary. A peninsula extending into Budd Inlet is a prominent feature. The peninsula is the site of a lumber yard, marina (on East Bay), and open space to the marina's south.

Strategy

The peninsula could be the start of an area for residential and commercial growth. The streetscape visualizations show mixed-use buildings and apartments at the city center. As shown, some lots are left empty, leaving room for further development. The new buildings would be between three and five stories, and the mixed-use buildings would face East Bay. The bay would serve as an attraction for people to come stroll by the stores that would be on the first floor of the buildings (see Figures 100-107).



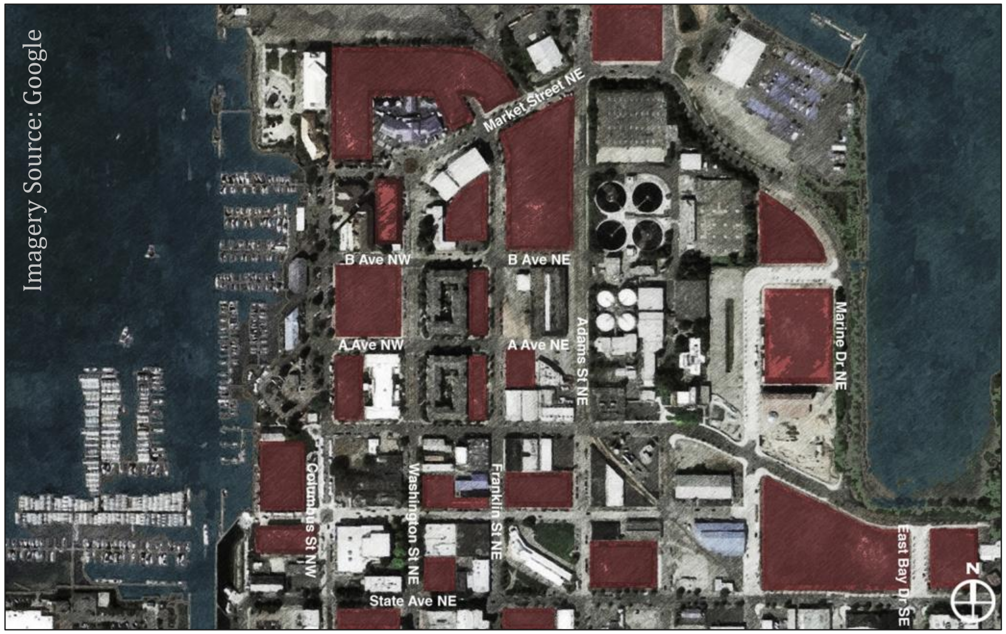


Figure 100 (top). Aerial 1 of Olympia: Present.

Figure 101 (bottom). Aerial 1 of Olympia: Proposal.

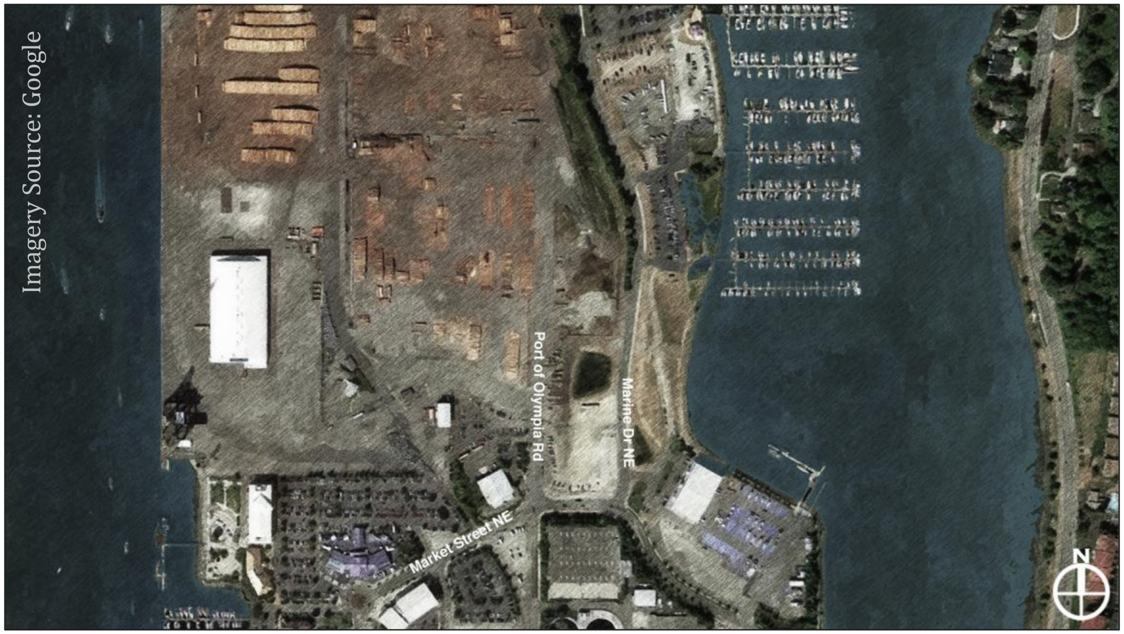


Figure 102 (above).
Aerial 2 of Olympia: Present.

Figure 103 (below).
Aerial 2 of Olympia: Proposal.

Figure 105 (below).
View 1 of Olympia: Proposal.

Figure 104 (above).
View 1 of Olympia: Present.

Figure 106 (above).
View 2 of Olympia: Present.

Figure 107 (below).
View 2 of Olympia: Proposal.

Centralia, Washington

Context
Centralia, population 16,000, is home to a two-year community college, Centralia College.

Strategy
Centralia could accommodate increased housing and commercial density downtown as well as around Centralia College. Filling in vacant lots downtown with mixed use buildings could increase commercial and residential square footage. In addition, increasing the number and size of buildings on North Tower Avenue would create a stronger and more appealing entrance to the downtown (see Figures 108-111).

The town could also extend the downtown area along West Main Street, near Centralia College. Mixed use buildings in this new downtown area would create an entertainment district as well as more residential space. Students would have easy access from the downtown to Centralia College (see Figures 112-115).

Figure 108 (top). Aerial 1 of Centralia: Present.
Figure 109 (bottom). Aerial 1 of Centralia: Proposal.

Figure 110 (above).
View 1 of Centralia: Present.

Figure 111 (below).
View 1 of Centralia: Proposal.

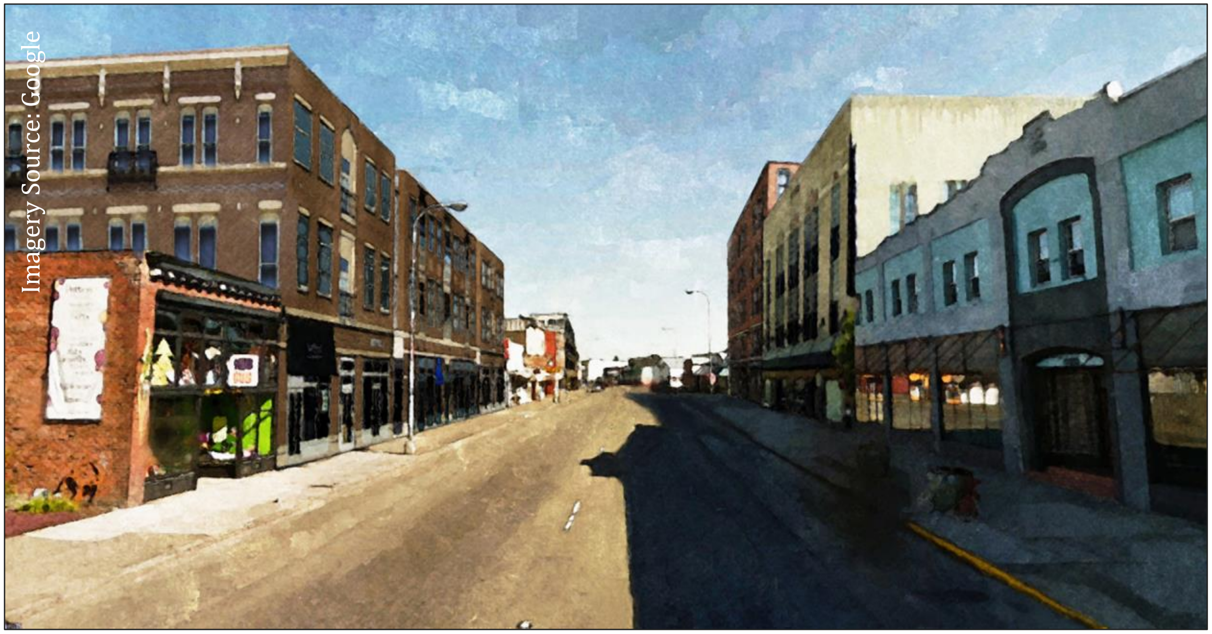
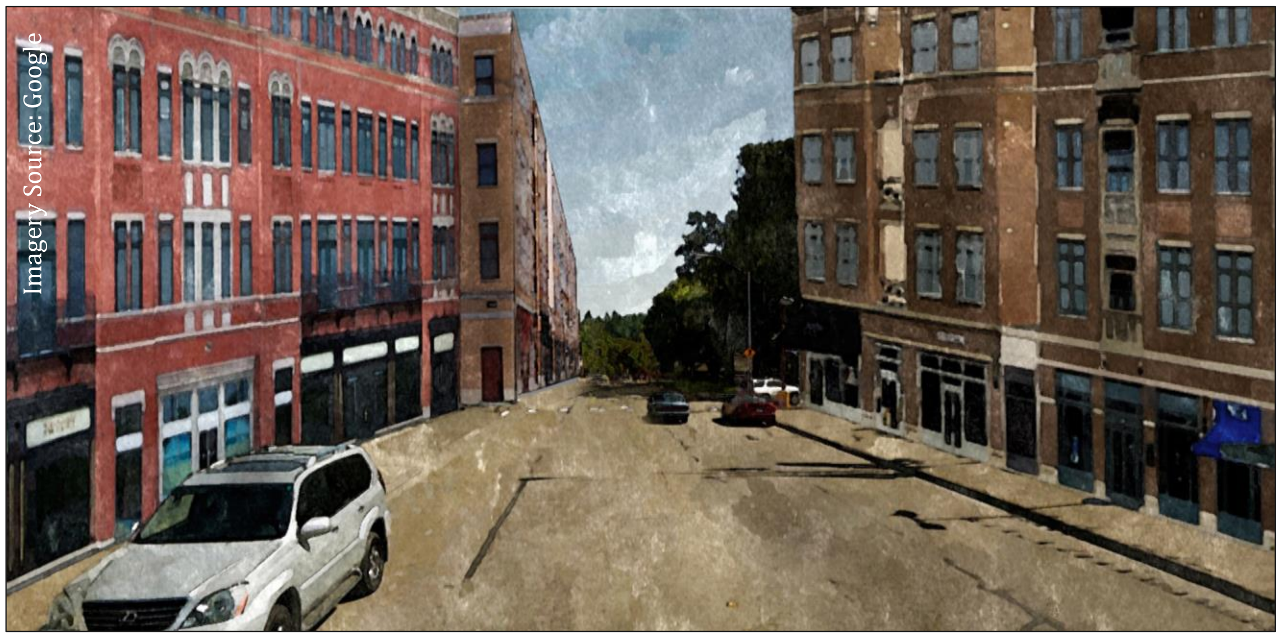


Figure 113 (below).
Aerial 2 of Centralia: Proposal.

Figure 112 (above).
Aerial 2 of Centralia: Present.

Figure 114 (above).
View 2 of Centralia: Present.

Figure 115 (below).
View 2 of Centralia: Proposal.



Appendix

Using the "Five D's" to Characterize Small Communities and Rural Areas

Research has identified five main factors that influence how far people travel on a typical day, the routes they take, and whether they walk, bike, drive, or take public transit. Those factors are the "five D's": density, destination accessibility, diversity, design, and distance to transit.[8] By extension, the five D's influence the amount of fuel consumed for transportation and emissions produced by transportation. *Density* could be described by the number of residents, housing units, or jobs per acre. *Diversity* means whether housing and shopping or employment centers are close to each other. *Design* includes features such as sidewalks, frequent intersections, and attractive streets. *Destination accessibility* is a general term that can be measured different ways at different scales. Average distance or travel time from a neighborhood to shopping centers is one way of measuring. At a larger scale, another way of measuring is the density of roads in an entire commuting zone. *Distance to transit* could be measured by the proportion of houses in a neighborhood within ¼ mile of a transit stop.

The five D's served as the basis for characterizing the small communities and rural area commuting zones in this project. Nationally available data were used to ensure consistent measurement. The data permitted development of profiles including density, diversity, and destination accessibility. A summary of the information resources and specific characteristics that were used to create the community profiles is shown in Table A-1.

Table A-1. Information resources for each of the characteristics used to develop profiles of commuting zones.

Characteristic	Information Resource
Boundaries of counties, census tracts, census block groups, and census blocks	Census 2000 TIGER line files
Cartographic boundaries with accurate natural boundaries (i.e., coastlines)	National Historical Geographic Information System
Commuting zone boundaries	US Department of Agriculture Economic Research Service
Transportation Management Area boundaries	National Transportation Atlas Database 2010
Population, land areas, and water areas	Census 2000
Jobs at census tract level, by industry	Census Transportation Planning Package 2000
National parks, wilderness areas, natural areas managed by land trusts, etc.	US Geological Survey Protected Area Database of the United States
Roads, excluding vehicular trails passable only by 4WD vehicle, walkways or trails for pedestrians, and driveways privately owned or used as access to residences, trailer parks, apartment complexes	Census 2000 TIGER/Line files

[8] National Research Council (U.S.), Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption (2009), *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions*, Transportation Research Board Special Report 298, Washington: Transportation Research Board, p. 52.

Density: population density

Population density is essential because of the obvious influence of the number of residents on trip generation and because population density is one measure of the overall intensity of settlement. **Population density is measured here by dividing the number of people by the square miles of developed or developable land (i.e., excluding water and protected areas) for each commuting zone.**

The 2000 census records population in some protected areas, which indicates that some portion of those protected areas actually is developed land. For that reason, all populated census blocks in a protected area were considered to be developed. Even after making that adjustment, the amount of developed or developable land identified is somewhat too large because not all wetlands and floodplains, or excessively steep slopes have been excluded. The U.S. Fish and Wildlife Service's National Wetlands Inventory (2009) includes large gaps in multiple states, including Arkansas, Louisiana, Montana, New York, and Wisconsin. Because the amount of developed or developable land is overstated, all density-based characteristics underlying the commuting zone profiles are somewhat understated.
In some commuting zones, protected areas represent a substantial proportion of the zone's area. Figure A-1 provides an illustration of one such commuting zone.

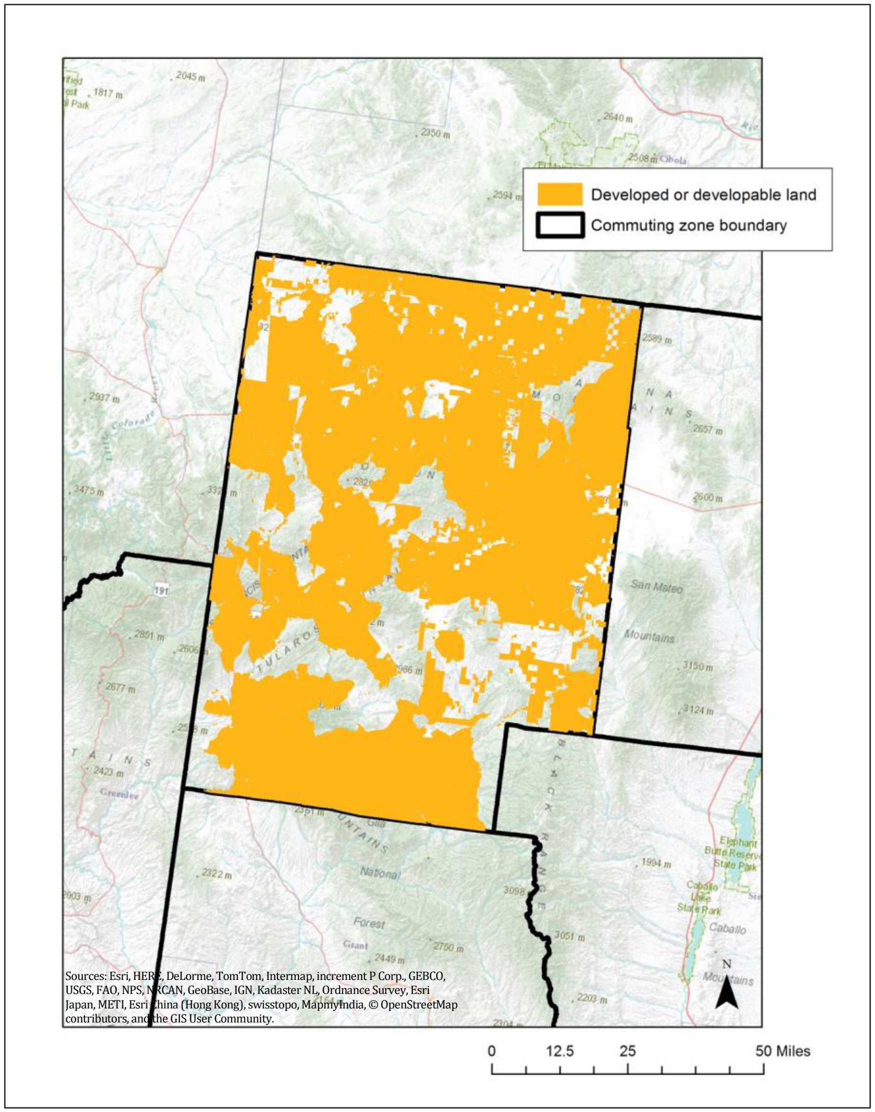


Figure A-1. West Central New Mexico commuting zone with a substantial proportion of protected areas.

Density: variation in population density

Variation in population density distinguishes commuting zones in two ways: 1) the commuting zones where most residents are located in relatively small areas of concentrated population density and 2) the commuting zones where residents are spread out more evenly. **The distribution of a population across a commuting zone is measured here with the coefficient of variation in population density.** The coefficient of variation is calculated by dividing the standard deviation of population density (measured at the census block group level) by the commuting zone's overall population density.

Destination accessibility: road density

Differences in road density indicate differences in destination accessibility for trips made by car, the most frequently used mode of travel in small communities and rural areas. Greater road density should allow more direct and shorter routes. **Road density is calculated here as road length in miles per square mile of developed or developable land in a commuting zone.**

The measure of road density is geared to route miles or centerline miles, i.e., the length of a road (or road segment) measured as a linear distance, not considering either pavement width or number of lanes. Lane miles (distance times number of lanes) would be a preferable measure of transportation supply because, of course, a greater volume of traffic can be accommodated by a multi-lane road than a single-lane road. The only national source of data on roads, the U.S. Census Bureau's TIGER/Line files, provide centerline miles but neither pavement width nor number of lanes.

In studies of the influence of the built environment on daily travel, an index of the connectivity of a road network is frequently used. A very common connectivity index is intersection density, but it could not be calculated using the Census 2000 TIGER/Line files because the junctions that are present in the data do not always indicate road intersections.

Diversity of land use: index of population near retail and services

Here, diversity refers to the variety of land uses according to categories such as population in housing units; jobs in retail establishments; jobs in establishments providing educational, health, and social services; etc. **The land use diversity index captures the extent to which residents are near (in the same census tract with) retail establishments and educational, health, social service, arts, entertainment, recreation, accommodation, and food service establishments.**

First, census data on population and jobs by industry were obtained for every commuting zone and every census tract within a commuting zone. Next, the following ratios were calculated for each census tract: 1) the ratio of the census tract's population to the commuting zone's population, and 2) the ratio of the census tract's retail- and services-oriented jobs to the sum of the census tract's population and retail- and services-oriented jobs. The two ratios for each census tract were multiplied and the products were summed over the commuting zone's census tracts to create a single index for every commuting zone.

This formula was used: $\sum_{i=1}^{n}\left[\frac{x_i}{X}\right]\times\left[\frac{y_i}{t_i}\right]$.

The quantities x_i and y_i are the numbers of household residents and retail and service-oriented jobs of census tract "i", respectively; t_i is the sum of x_i and y_i; X is the number of household residents in the commuting zone; and "n" is the number of census tracts in the commuting zone.

Results: three families of small-community / rural-area commuting zones

Population density, variation in population density, road density, and diversity of land use were measured in each of the 546 commuting zones. Next the analytical technique known as cluster analysis was used to look for patterns, i.e., natural groupings or families of commuting zones. The cluster analysis identified three distinct families of commuting zones, which were assigned these descriptive labels: "Low Population Density" (Family 1), "Medium Population Density" (Family 2), and "High Population Density" (Family 3).

Tables 1 and 2 in the earlier section, Project Overview: The Three Study Areas, show quantitative and qualitative characteristics of each family.

Gallery of Maps of the Three Families of Small Communities and Rural Areas

The maps in this section of the handbook illustrate the characteristics of the three families of small communities and rural areas. Maps show several essential characteristics of an actual commuting zone from each of the three families.
The extent of each map covers a commuting zone plus enough of the surrounding landscape to place the commuting zone in context and make it easier to locate the commuting zone.

For each commuting zone, the maps appear in the following order:

1. Commuting zone in its geographic context.
2. Developed land and land that can be developed in the future.
3. Road network.
4. Census block groups.
5. Population density of each census block group.

The first four maps for each commuting zone are drawn in two dimensions. Two-dimensional maps are best for portraying the boundaries of counties, commuting zones, and census block groups. Flat maps also work well for showing the distribution of roads across an area and distinguishing between developed/developable and protected (undevelopable) lands.

The fifth map in each set shows population density using the third, or vertical, dimension. The relative height of a block group corresponds to its population density. The maps of population density are rendered with a perspective that has been rotated and tilted to most clearly reveal contiguous block groups of relatively large or small population density.

Commuting zones are assigned to a family on the basis of not just one development characteristic but the "overall sum" of these four characteristics: population density, variation in population density, road density, and diversity of land use. Consequently, commuting zones assigned to different families may have similar population density or similar road density, but their overall characteristics are quite different.

Low population density small communities and rural areas (Family 1)

A low population density commuting zone is illustrated by a region in the State College area of central Pennsylvania.
The commuting zone identifier is 565. The counties in the commuting zone are Centre, Huntingdon, Juniata, and Mifflin (see Figures A-2 to A-6 below).

Medium population density small communities and rural areas (Family 2)

A medium population density commuting zone is illustrated by the region in south central Ohio that is one of the case studies in this project. The commuting zone identifier is 327. The counties in the commuting zone are Jackson, Pickaway, Pike, Ross, Scioto, and Vinton (see Figures A-7 to A-11 below).

High population density small communities and rural areas (Family 3)

A high population density commuting zone is illustrated by a region in north central Ohio. The commuting zone identifier is 417. The counties in the commuting zone are Erie, Huron, and Lorain (see Figures A-12 to A-16 below).

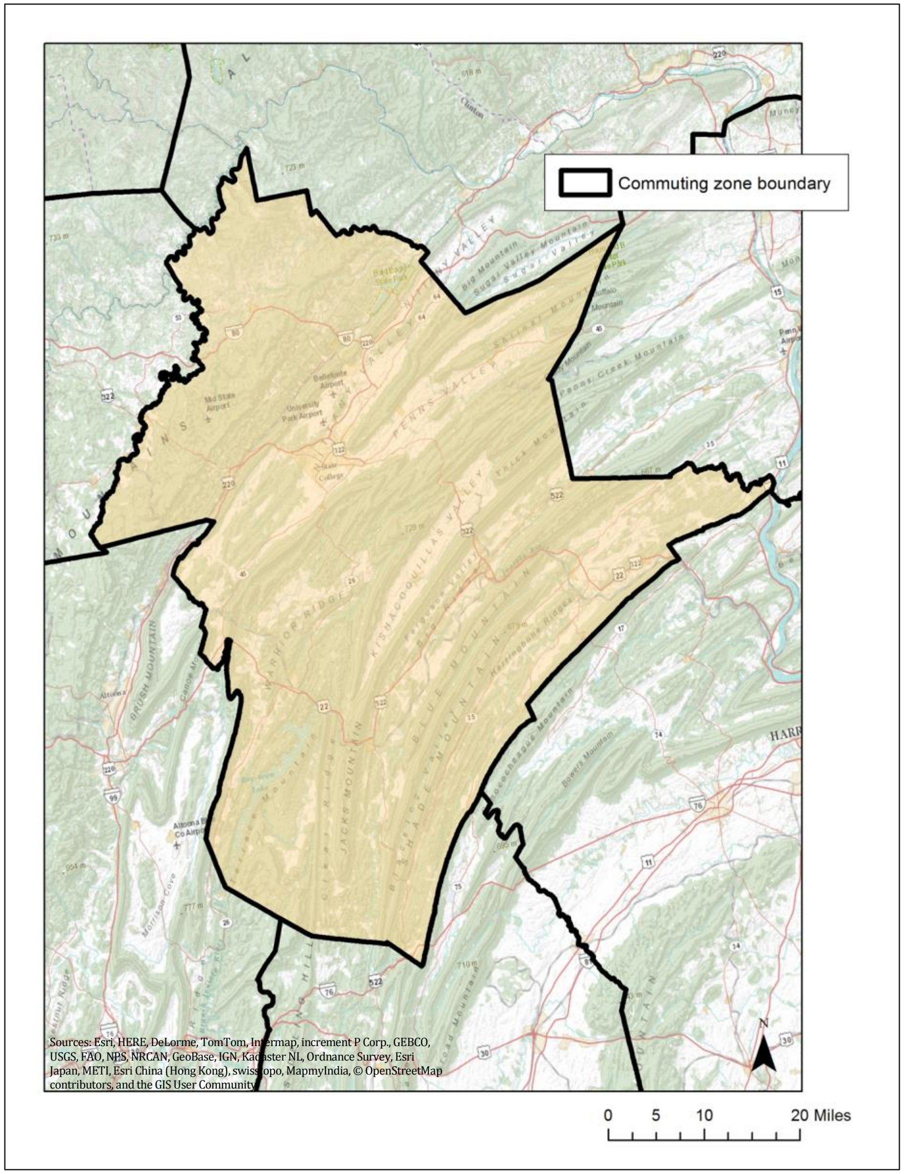


Figure A-2. Central Pennsylvania (State College area) commuting zone (Family 1) in geographical context.

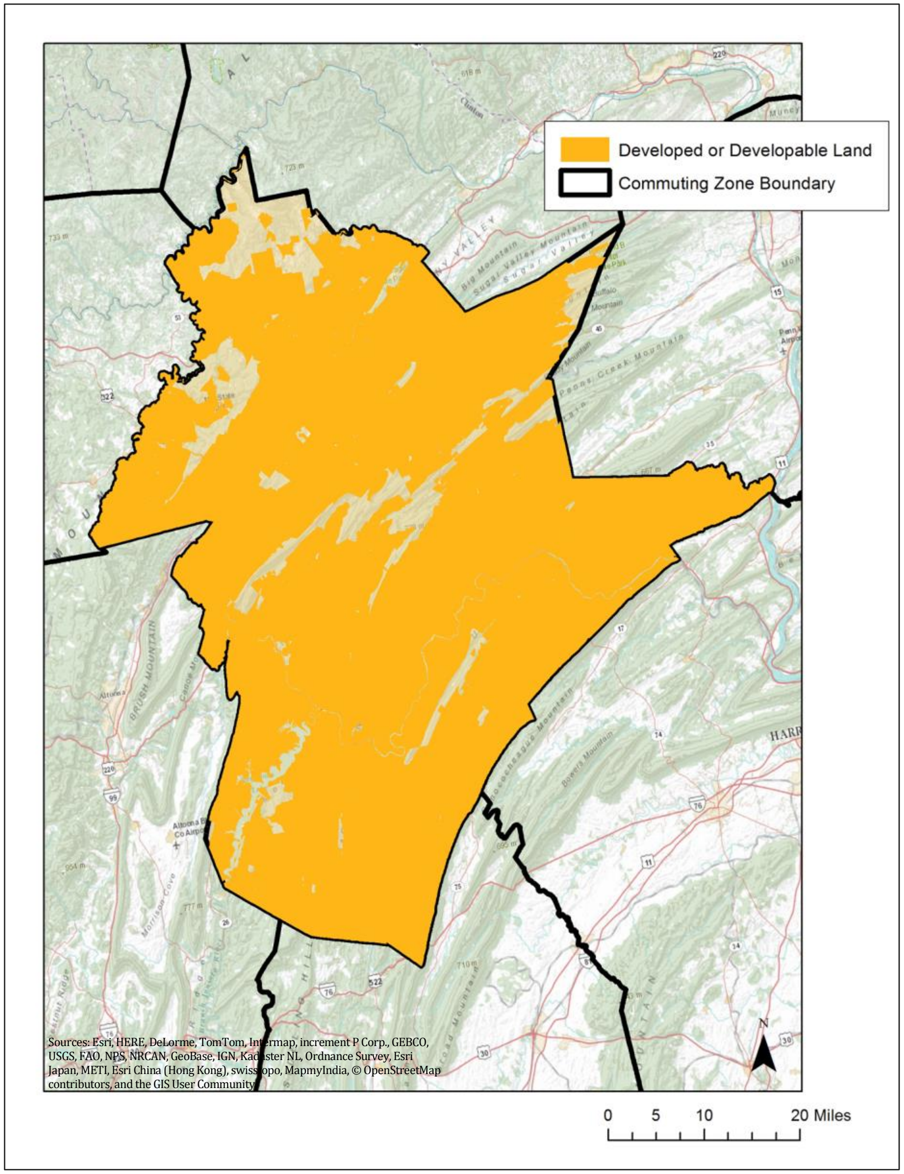


Figure A-3. Central Pennsylvania (State College area) commuting zone (Family 1): developed/developable land.

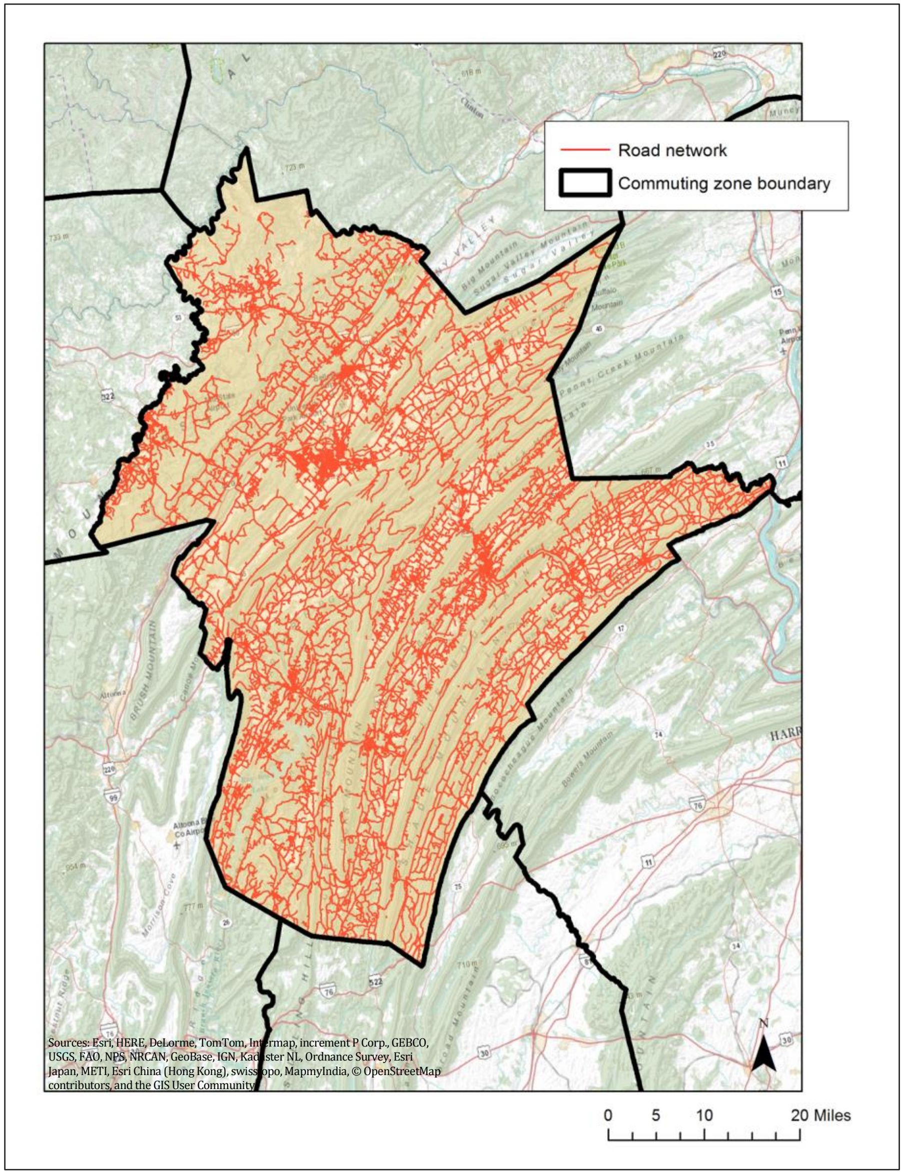


Figure A-4. Central Pennsylvania (State College area) commuting zone (Family 1): road network.

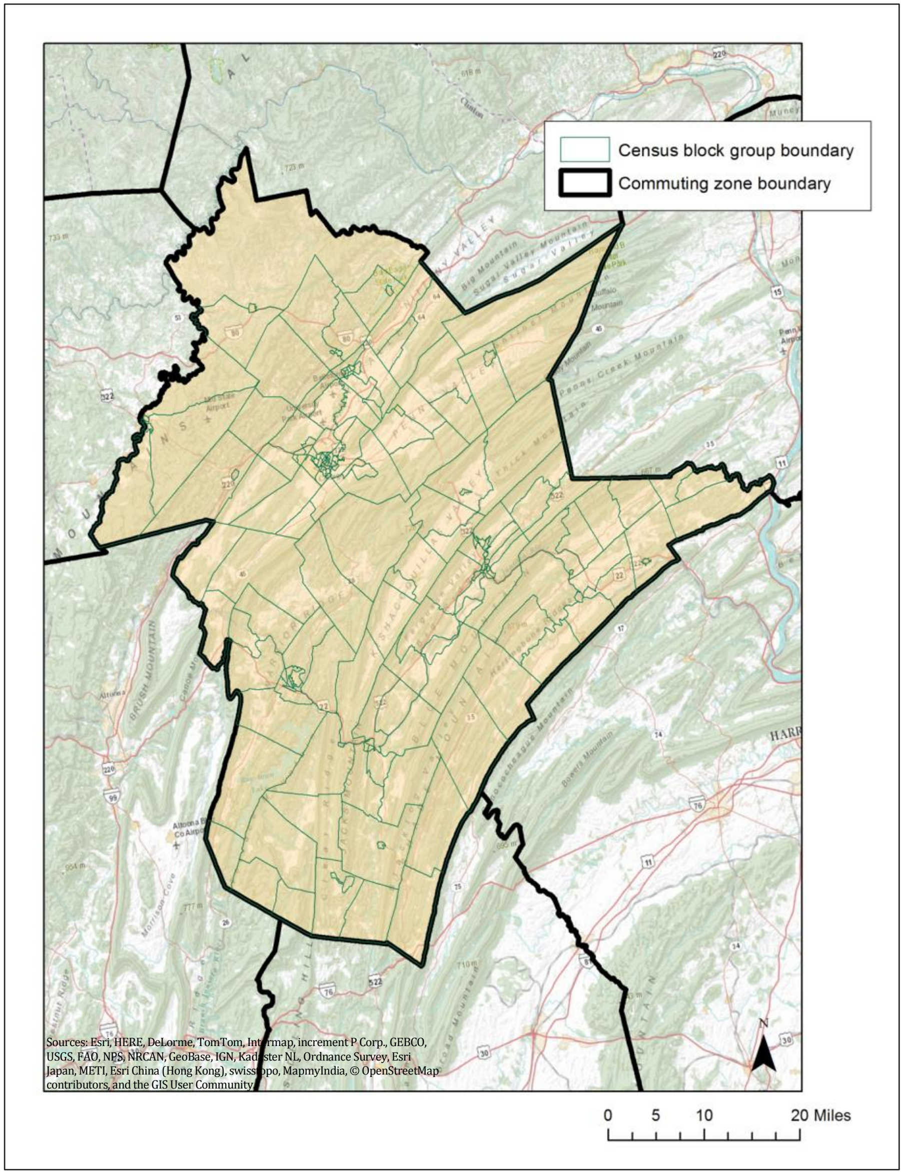


Figure A-5. Central Pennsylvania (State College area) commuting zone (Family 1): census block group boundaries.

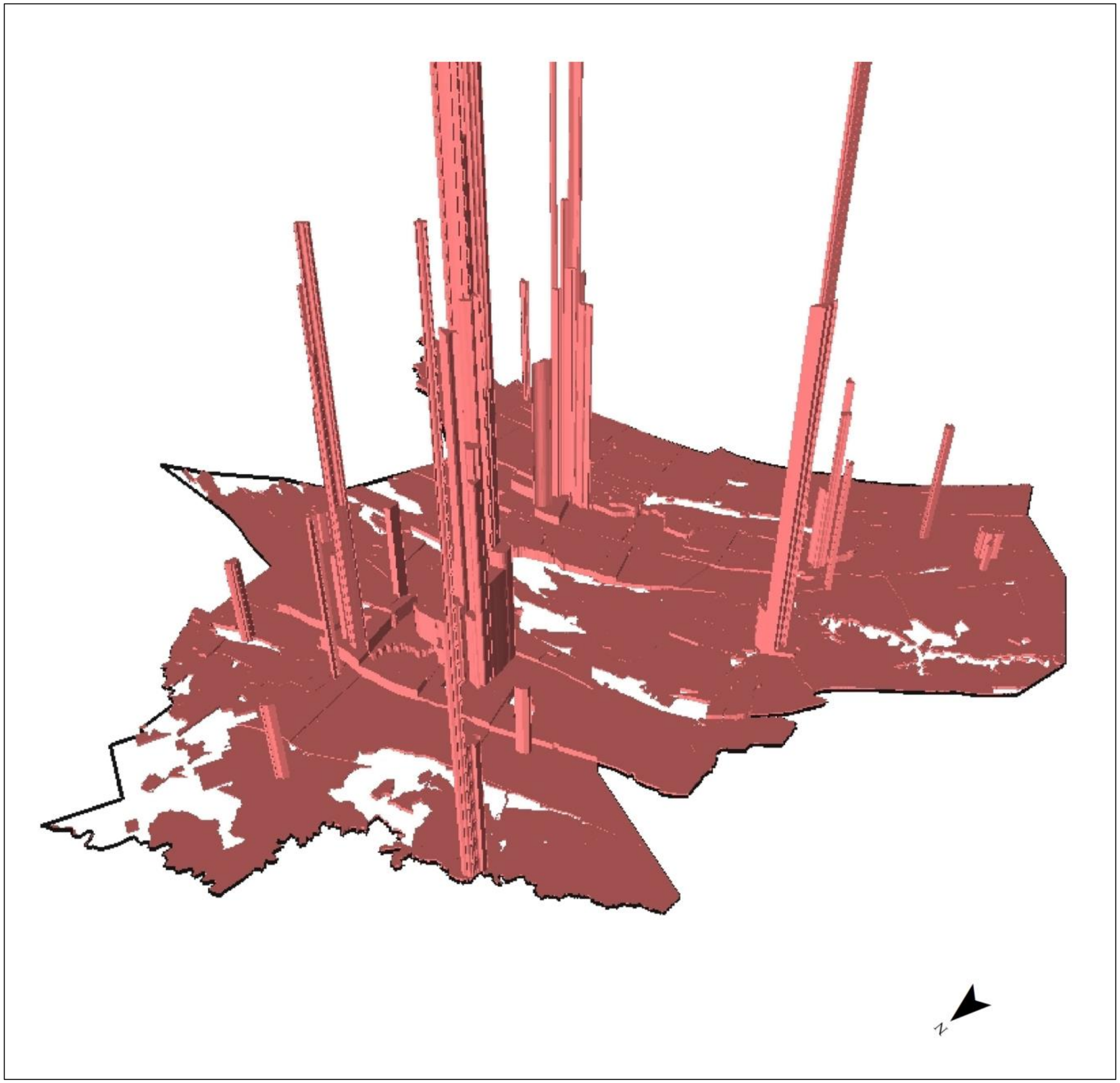


Figure A-6. Central-Pennsylvania/State-College Commuting Zone (Family 1): population density.

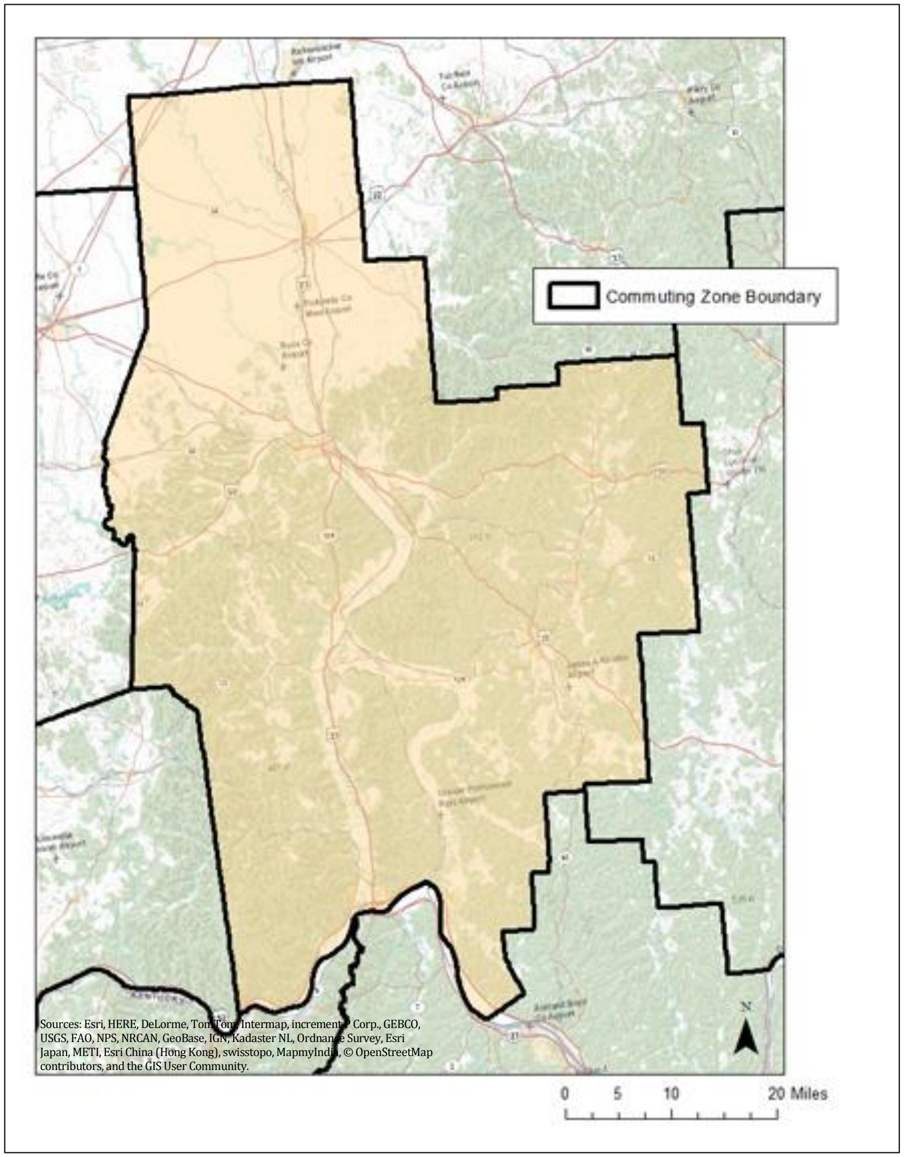


Figure A-7. South Central Ohio commuting zone (Family 2) in geographic context.

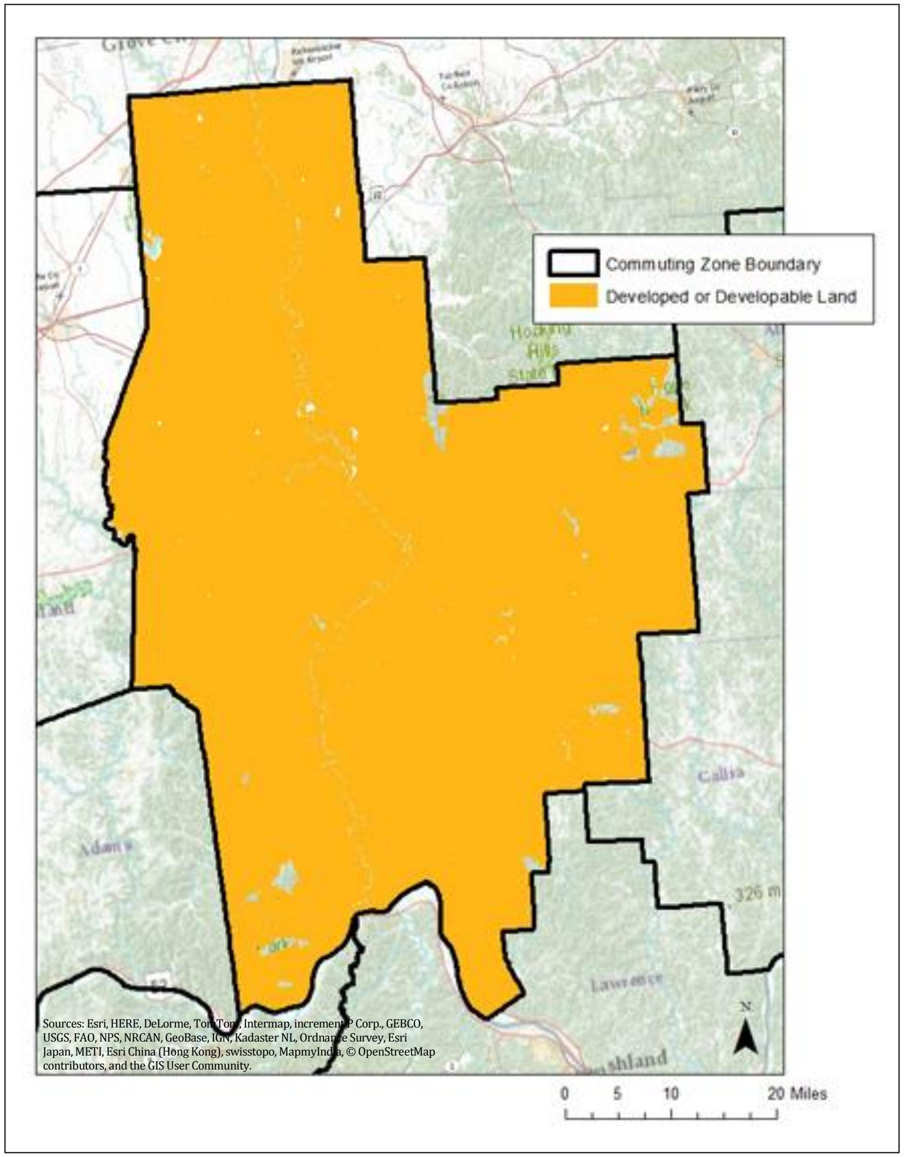


Figure A-8. South Central Ohio commuting zone (Family 2): developed/developable land.

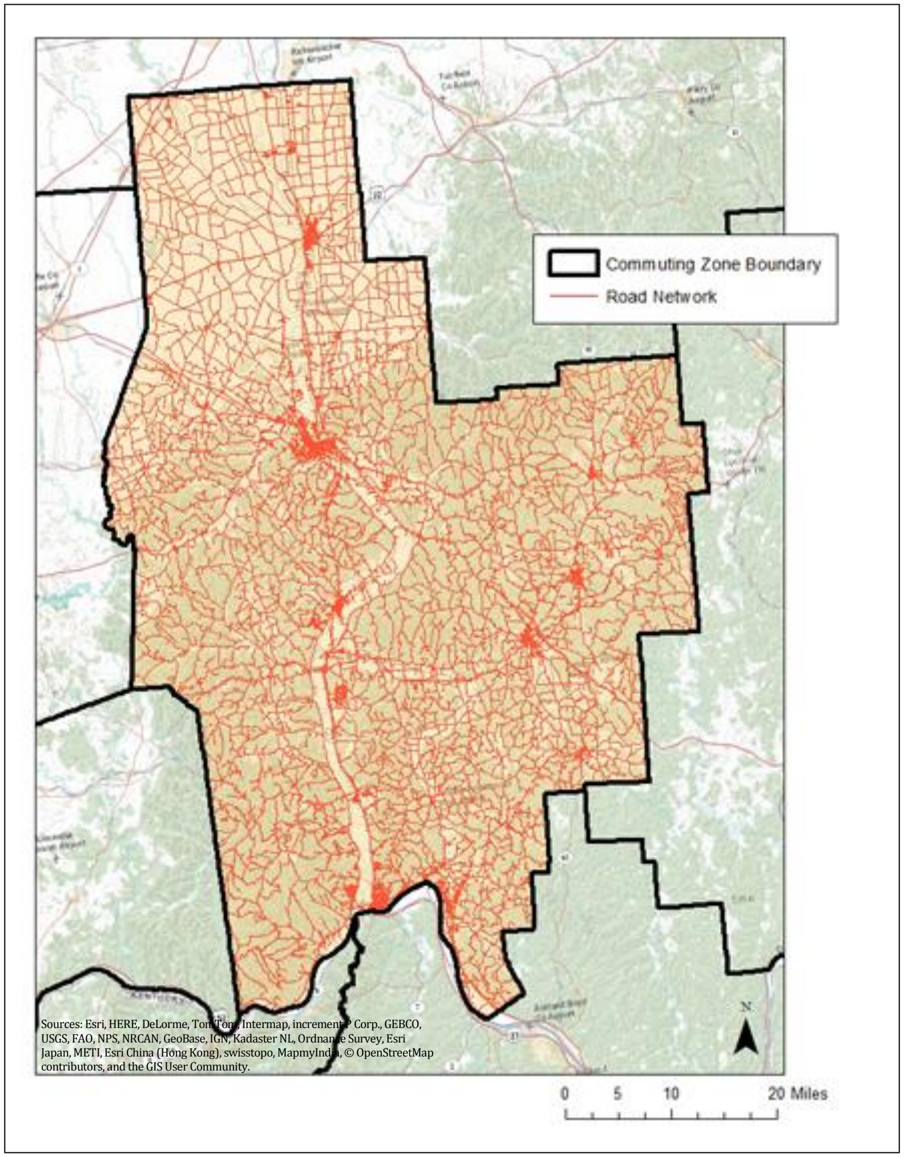


Figure A-9. South Central Ohio commuting zone (Family 2): road network.

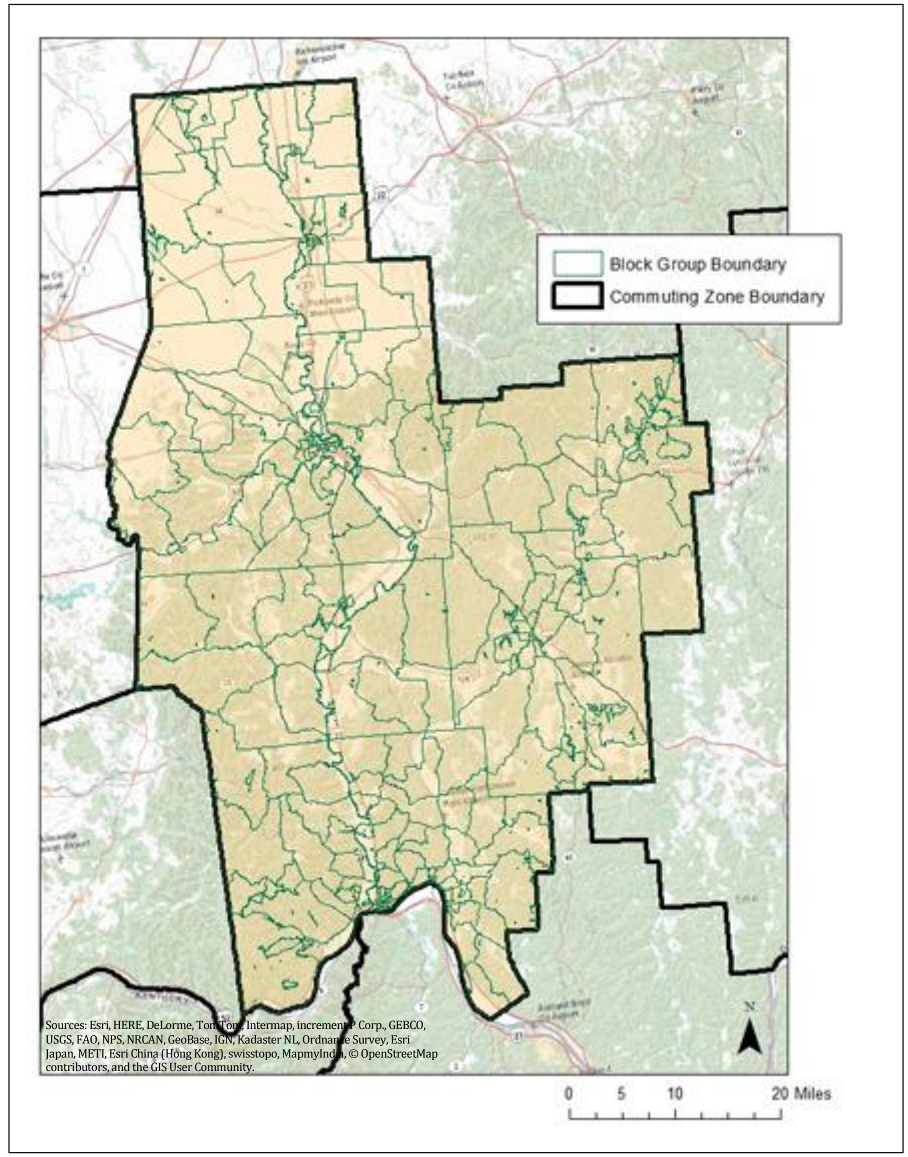


Figure A-10. South Central Ohio commuting zone (Family 2): census block group boundaries.

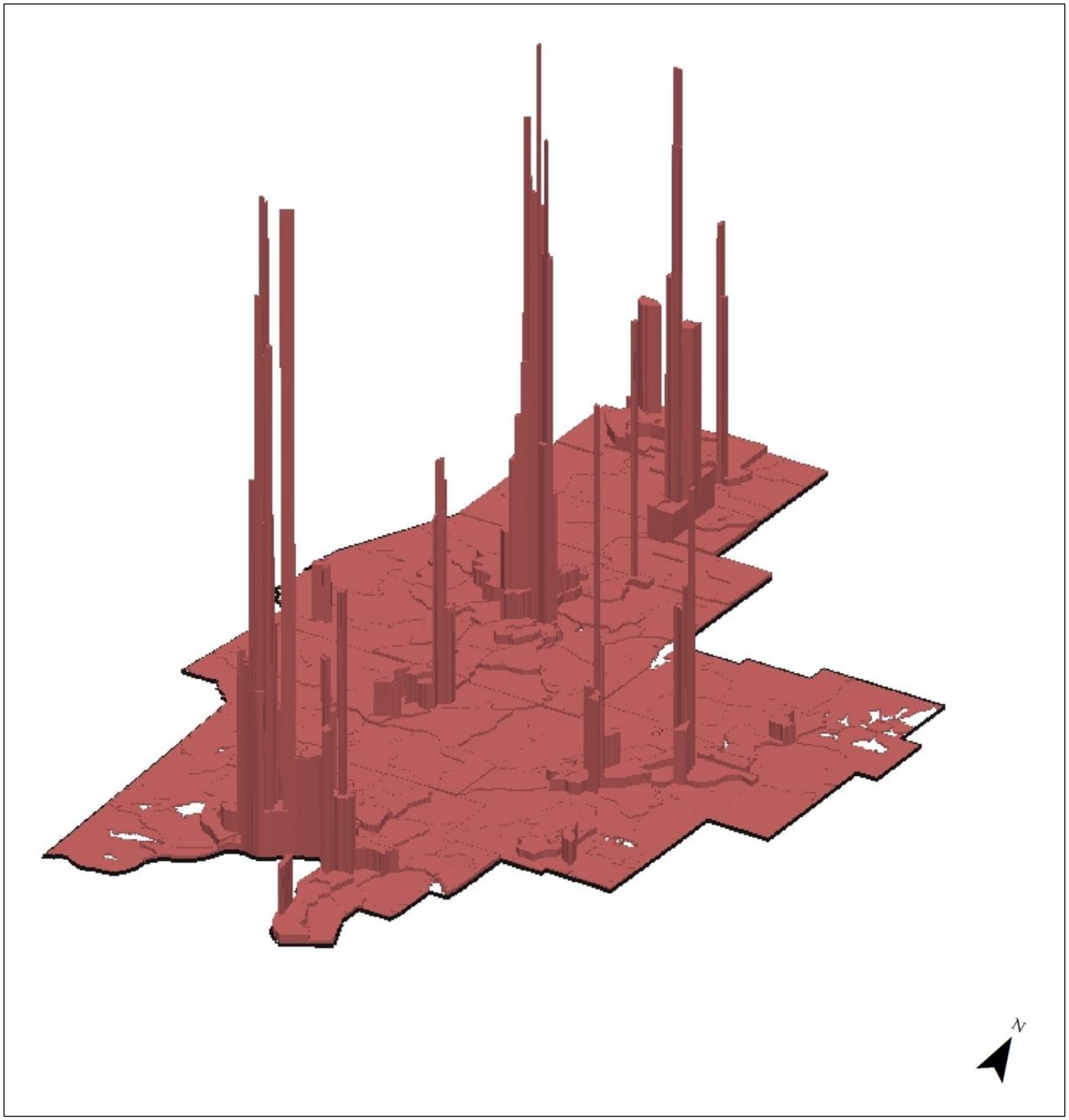


Figure A-11. South Central Ohio commuting zone (Family 2): population density.

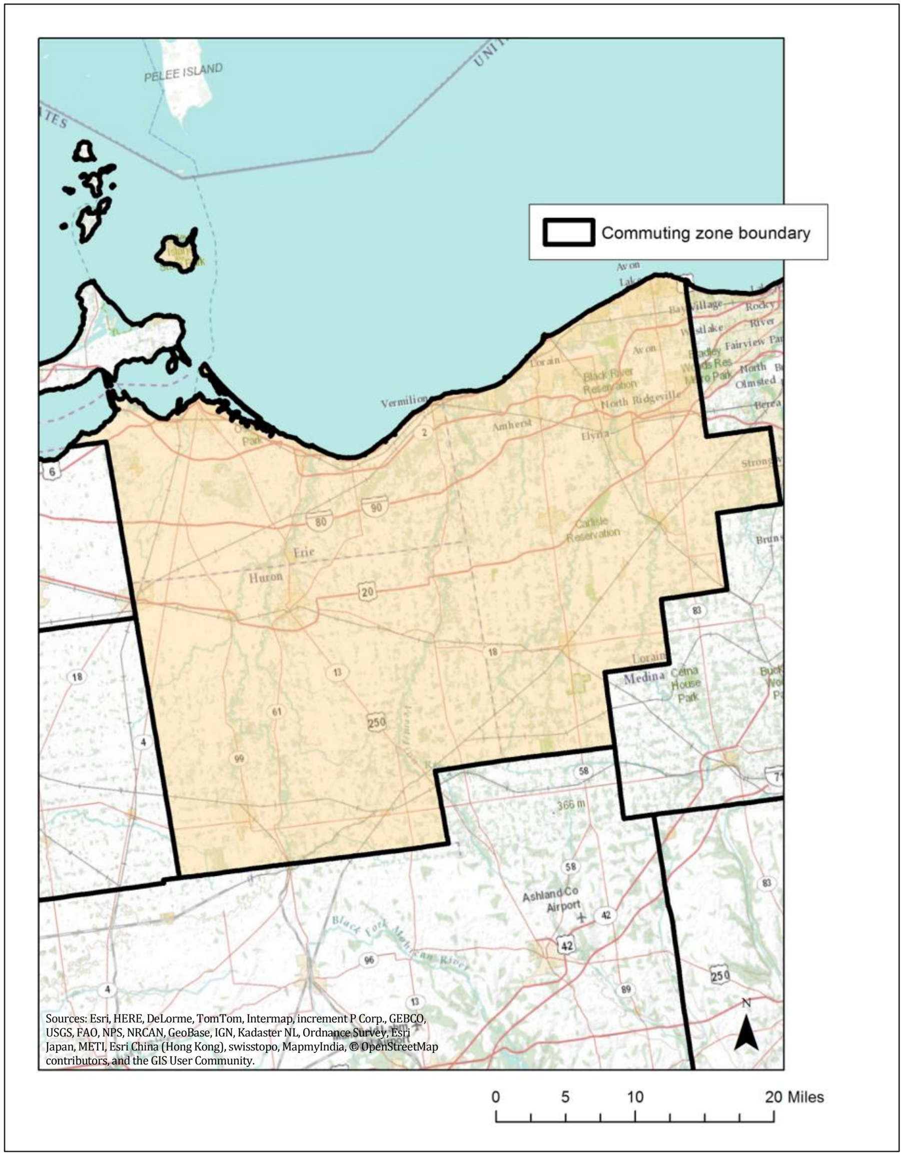


Figure A-12. North Central Ohio commuting zone (Family 3) in geographic context.

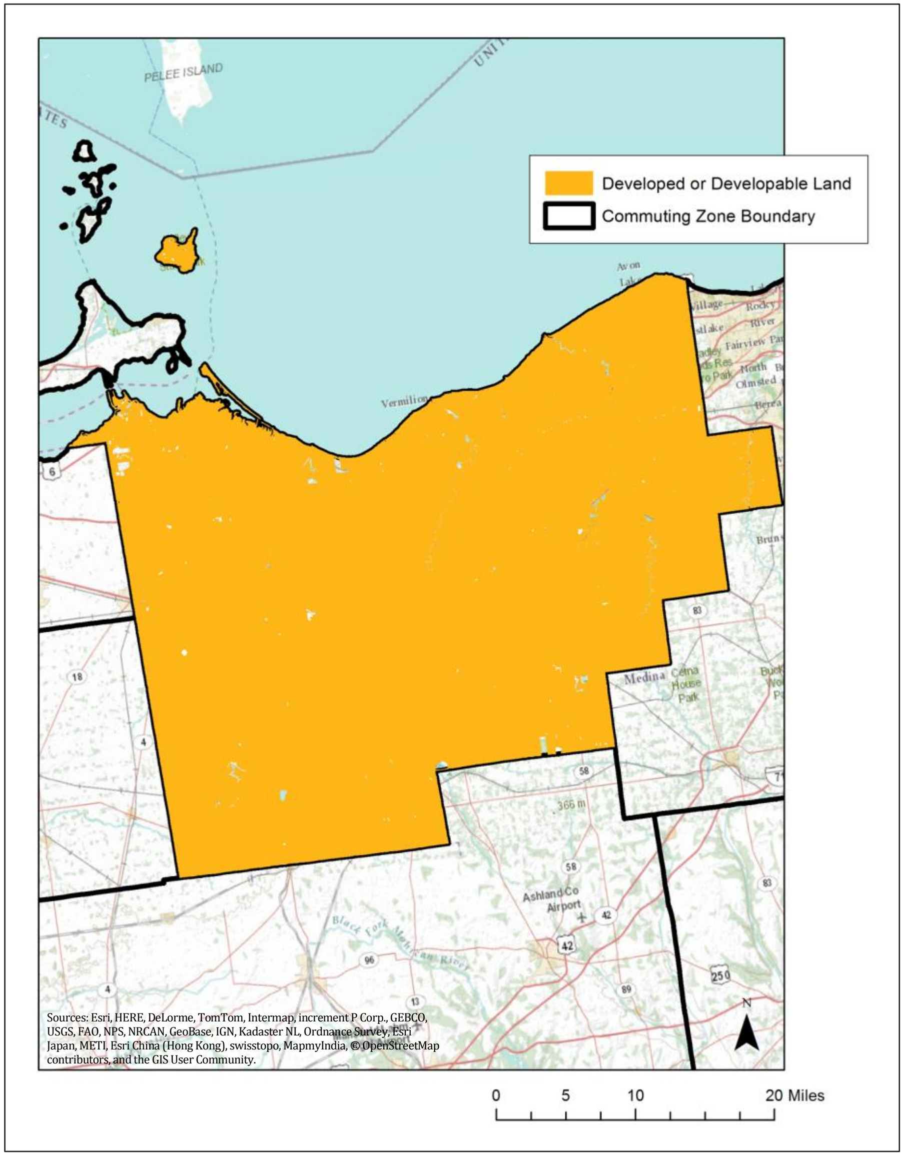


Figure A-13. North Central Ohio commuting zone (Family 3): developed/developable land.

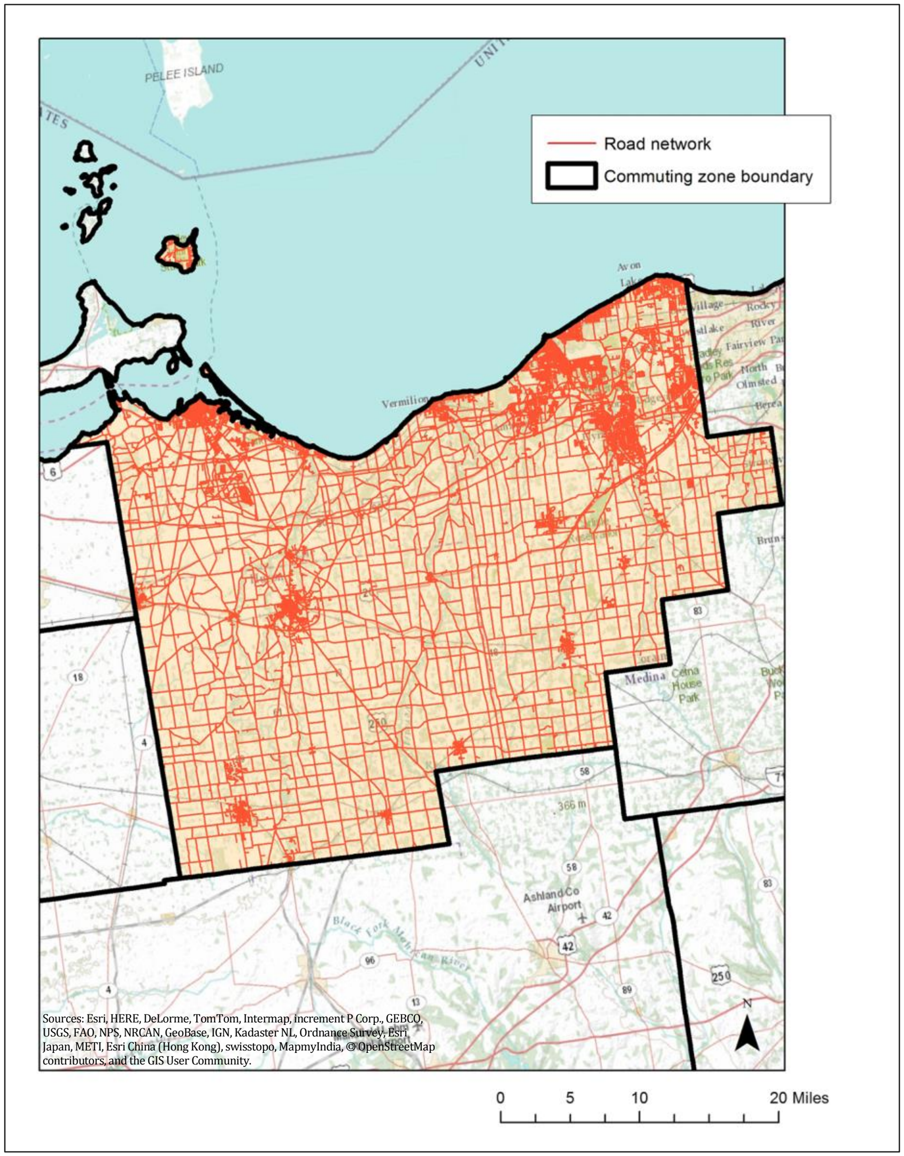


Figure A-14. North Central Ohio commuting zone (Family 3): road network.

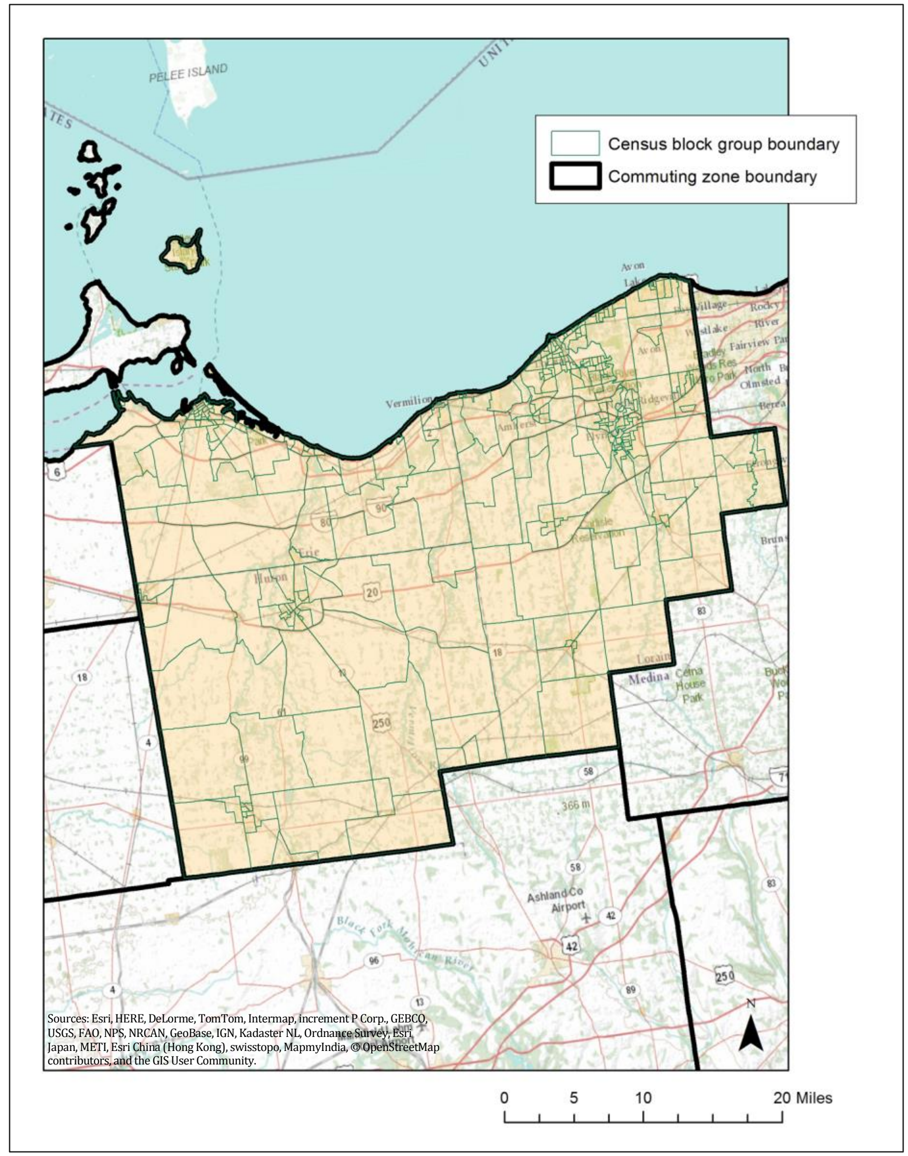


Figure A-15. North Central Ohio commuting zone (Family 3): census block group boundaries.

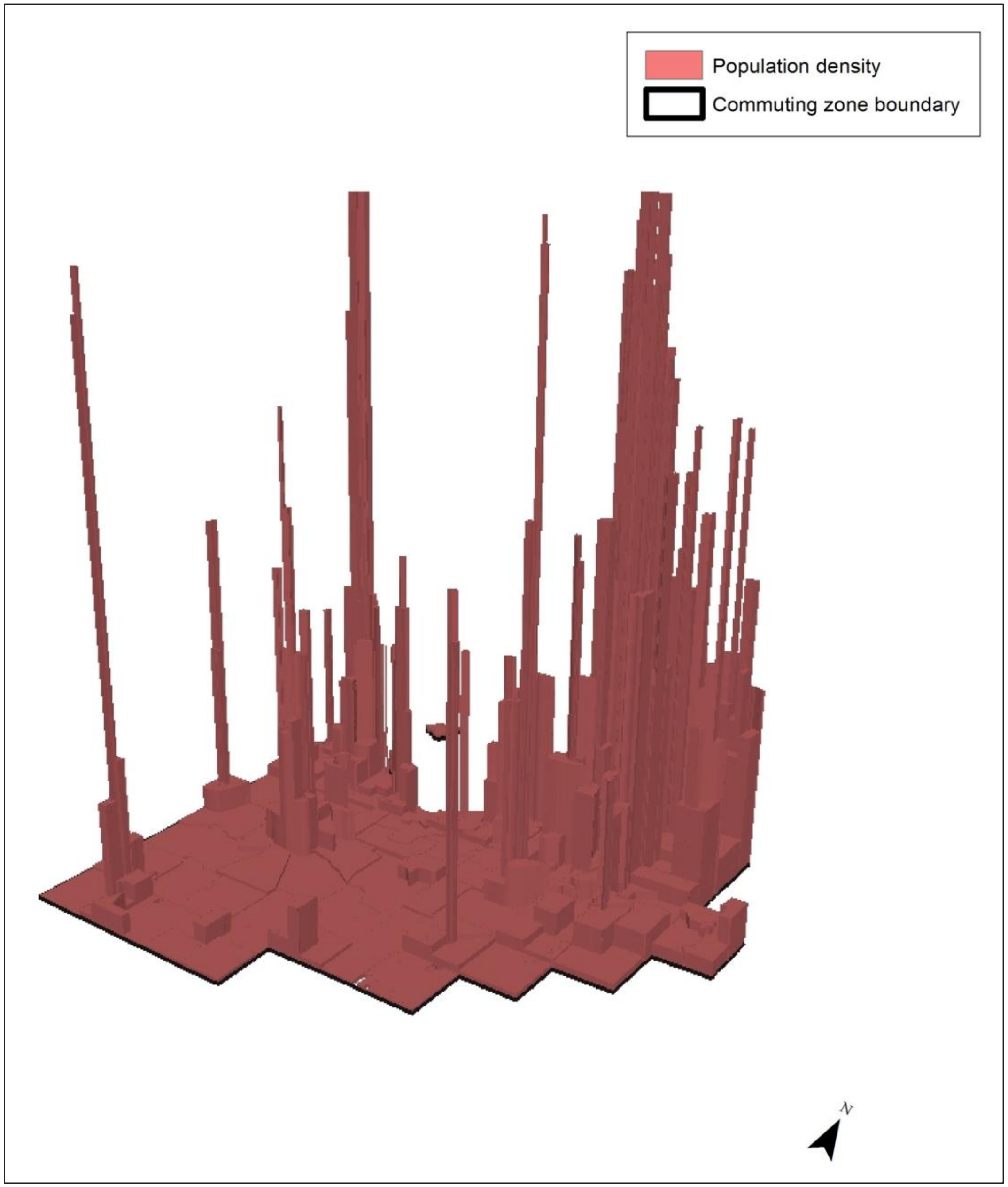


Figure A-16. North Central Ohio commuting zone (Family 3): population density.

More Information about Accessibility Measures

This section explains more fully how "access to commercial establishments" and "access to households" were measured, which was reviewed briefly in the earlier section, Project Overview: The Computer Models.

Quantifying commercial establishments

Census data do not include direct information about the number, size, or hours of operation of commercial establishments, so the number of commercial jobs was used as an indicator of the availability of commercial establishments. A grocery store with 50 jobs is likely to provide a greater range of goods than a store with two jobs. A grocery store that is open 24 hours a day seven days a week will employ more workers than an identical grocery store open only 12 hours a day. Consequently, number of jobs is an approximate but easily calculated indicator of the volume, range, and availability of goods and services on offer.

Quantifying households

The total number of households for each of the analysis zones was obtained from census data. Number of households affects the volume of the demand for commercial goods and services. Because households typically have members who are employed, the total number of households also affects the supply of labor available to the study area's employers.

Quantifying nearness / farness

Generalized travel cost was used as an indicator of nearness or farness. Generalized travel cost includes all of the expense and inconvenience of travel, including travel time, waiting time (when the bus is taken), bus fares, gasoline and maintenance. All of these expenditures, with the exception of waiting time, vary directly with distance.

Quantifying economic factors

For each analysis zone and each resource (floor space, households, and commercial goods and services, i.e., commercial jobs), the computer models estimate the average cost of producing one unit of the resource. The estimates of those costs consider the cost of housing, households' consumption of floor space and commercial goods and services, and businesses' consumption of labor. The computer models also estimate the cost incurred by workers when commuting and the costs incurred by households when traveling to and from commercial establishments, yielding estimates of the costs of transporting one unit of labor and one unit of commercial goods and services from the zone in which the resource is produced to the zone in which it is consumed. The full cost is the sum of the unit production cost and unit transportation cost. In the models, consumers are sensitive only to the full cost, not to an increase in only production cost or only unit transportation cost.

Everything else being equal, households that are the source of inexpensive labor (that is, lower wages, which reflect a lower cost of living, especially housing) result in a higher measure of "access to households" than households that are the source of expensive labor (higher wages). Because commercial jobs are a proxy for commercial goods and services, employees' wages are a proxy for the cost of those goods and services. Consequently, less expensive commercial labor (lower wages) results in a higher measure of "access to commercial establishments."

Calculating the accessibility index

Although the calculation of accessibility indices is complex, the basic idea may be conveyed by comparing two zones on the basis of access to commercial jobs (which was used to indicate the size, number, and availability of commercial establishments). For example, in the North Carolina-Tennessee study area, the zone with the least accessibility to commercial jobs is zone 4009; the zone with the greatest accessibility to commercial jobs is zone 5010.

Zone 4009 itself has 127 commercial jobs. Thinking of zone 4009 as the center of several concentric circles in which a circle's radius corresponds to travel time, and the center corresponds to an effective travel time of "zero" minutes, 127 jobs are present at the center of zone 4009's circles. Table A-2 compares the number of commercial jobs within various travel times from the center of zone 4009 and from the center of zone 5010. Zone 5010's circles always have more jobs. That's why its index of accessibility to commercial establishments is higher than zone 4009's index.

Table A-2. Comparing access to commercial jobs in two analysis zones.

	Zone 4009 (NC-TN)	Zone 5010 (NC-TN)
Travel Time from Zone in Minutes	Commercial Jobs (indicating size/# of Commercial Establishments)	Commercial Jobs (indicating size/# of Commercial Establishments)
0	127	2,739
0-45	14,192	15,859
0-90	27,104	32,983
0-120	30,908	39,302