Project No. 25-36

IMPACTS OF LAND USE ON TRAVEL BEHAVIOR IN SMALL COMMUNITIES AND RURAL AREAS

FINAL REPORT

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1. Introduction

The final report compiles the technical memoranda prepared for Task 1 (community profiles), Task 2 (data and literature review), and Task 5 (scenario assessment models). The Task 1 technical memorandum is the second chapter below, the Task 2 technical memorandum is the third chapter, and the Task 5 technical memorandum is the fourth chapter.

Chapter 4 (Task 5 technical memorandum) summarizes construction of the integrated land use-transport models that were used in three case studies to (a) assess the impact of land use, development patterns, and the associated economic activities on travel behavior in small communities and rural areas and (b) identify those land use-related conditions and strategies that have the greatest impacts on travel behavior. This chapter is a very technical, high-level summary of the procedures and data used to construct the scenario assessment models. Familiarity with the TRANUS modeling platform is assumed.

Another document, *Close to Home: A Handbook for Transportation-Efficient Growth in Small Communities and Rural Areas*, is intended to convey the research methods and results to the general public.

2. Typology of Small Communities and Rural Areas

Yan Song, Jun Huh, and Brian J. Morton

2.1 Introduction

This chapter presents a new typology of small communities and rural areas in the United States and summarizes the quantitative methods and data that we used. The typology organizes dimensions of the economic, social, and built environments in a representative cross-section of small communities and rural areas so that each type of community has distinctive unifying characteristics. A significant value of the typology is that it classifies rural and small communities on the basis of attributes that affect daily personal travel behavior, thus providing a precise terminology for identifying, within the project's context, the most important similarities and differences among thousands of communities. Our investigation leads us to conclude that a three- or four-part typology captures those similarities and differences, and that an argument can be made in favor of the three-part typology.

In what follows, we document the most important steps that we took to develop the typology including: reviewing definitions of rural communities, reviewing other researchers' typologies of rural communities, creating the variables that are the basis of our typology, and conducting the statistical analyses of the communities' similarities and differences. This document uses GIS-created maps to identify and illustrate the types of communities that we have identified.

2.2 A Review of Definitions of Rural Communities

Although rurality is an elusive concept that defies a rigid definition, it is essential to delineate what is rural for a variety of research and policy purposes. In general, there are three characteristics of rural areas that make them different from urban areas (Deavers 1992). First, rural communities have small scale and low density settlements; second, rural places are peripheral to large urban centers; and third, rurality is also defined by economic specialization, either a few relatively large manufacturers or many farm proprietors.

Different agencies and researchers have developed a range of definitions of rural areas. In this section, we review the most commonly used definitions: the urban/rural distinction developed by the U.S. Bureau of the Census; the metropolitan, micropolitan, and noncore county classifications of the U.S. Office of Management and Budget; and two definitions developed by the Economic Research Service in the U.S. Department of Agriculture.

2.2.1 Definition Developed by the U.S. Bureau of the Census

The U.S Census Bureau defines all territory, population, and housing units located outside of Urbanized Areas and Urban Clusters as rural. It is thus necessary to explain Urbanized Areas and Urban Clusters. According to the Census, Urban Areas must have a core with a population

density of 1,000 persons per square mile and may contain adjoining territory with at least 500 persons per square mile. Two types of Urban Areas are distinguished: the Urbanized Areas which have 50,000 or more people, and the Urban Clusters which have at least 2,500 residents but fewer than 50,000 residents. Thus, rural areas comprise open country and settlements with fewer than 2,500 residents. In addition, areas designated as rural can have vastly different population densities, varying by a factor of 100 or more. It is necessary to note that this definition of rural areas by the U.S. Census is mainly based on population density thresholds and does not necessarily correspond to county boundaries.

2.2.2 Definition Developed by the U.S. Office of Management and Budget

According to the U.S. Office of Management and Budget (OMB), rural areas can be defined as "noncore" counties, which are outside of the "metropolitan" counties and the "micropolitan" counties. Counties are classified as metropolitan if they contain at least one Urbanized Area of at least 50,000 people, or are adjacent to such a core county and linked to the county with significant economic ties. Counties are classified as micropolitan if their largest Urban Area has between 10,000 and 49,999 residents, or are linked to such a core county through significant economic ties. In both cases, outlying counties are economically tied to the core counties if 25% of workers living in an outlying county commute to the core counties, or if 25% of the employment in the outlying county consists of workers coming from the core counties. Rural areas are counties that are neither metropolitan nor micropolitan.

It is important to note that the OMB's definition is not intended to provide an urban/rural dichotomy. Rather, the definition aims to define socially and economically integrated areas, although this definition of noncore/rural areas is mainly based on population density thresholds. Johnson-Webb et al. (1997) provide a rigorous comparison of the designation of rurality used by the Bureau of the Census with the designation of metropolitan/micropolitan statistical areas used by OMB. In essence, the Bureau of the Census divides Americans into the urban and rural populations by block group and block. The OMB splits the population into those who live in metropolitan counties and those who live in nonmetropolitan counties. Nonmetropolitan counties, including both the micropolitan and noncore counties, do not necessarily coincide with the Census-defined rural areas. Some researchers include both micropolitan and noncore counties in the rural category, while others consider only the noncore counties to be rural.

2.2.3 Definitions Developed by the U.S. Department of Agriculture

The Urban Influence Codes (UIC or the Parker-Ghelfi codes) were created by economist Linda Ghelfi and sociologist Tim Parker at the USDA's Economic Research Service (ERS). They allow researchers to break out the standard metropolitan and nonmetropolitan areas into smaller places. Baer et al. (1997) provide the following rationale for this classification scheme.

Beginning with the OMB's designations of metropolitan and micropolitan counties, the codes divide metropolitan counties into two groups: large with at least 1 million residents, and small with fewer than 1 million residents. Nonmetropolitan counties are classified according to whether they are adjacent to a large or small metropolitan area. Nonmetropolitan adjacent counties are further classified in terms of whether or not they contain all of or part of a city of at least 10,000 population. Nonmetropolitan counties that are not adjacent to a metropolitan county are classified in terms of population size: containing all or part of a city of 10,000 residents; containing all or part of a city of 2,500 to 9,999 residents; or containing no part of a city with a population of more than 2,500. Such distinctions based on proximity and population size can be thought of as hierarchies. Table 1 summarizes the Urban Influence Codes.

Table 1: Urban Influence Codes

Metropolitan counties
1. In large metro area of 1 million residents or more
2. In small metro area of less than 1 million residents
Nonmetropolitan counties
3. Micropolitan adjacent to large metro
4. Noncore adjacent to large metro
5. Micropolitan adjacent to small metro
6. Noncore adjacent to small metro with own town
7. Noncore adjacent to small metro no own town
8. Micropolitan not adjacent to a metro area
9. Noncore adjacent to micro with own town
10. Noncore adjacent to micro with no own town
11. Noncore not adjacent to metro or micro with own town
12. Noncore not adjacent to metro or micro with no own town

The Rural-Urban Continuum Codes (RUCC) constitute another urban/rural typology developed by the USDA (Table 2). They also refine the OMB's methodology for classifying metropolitan and nonmetropolitan counties by introducing multiple categories. However, the RUCC differ from the Urban Influence Codes in at least two ways (Baer et al. 1997). First, the former consider urbanized counties to have at least 20,000 residents, and the less urbanized counties to have 2,500 to 19,999 residents. Second, they break down areas into central and fringe metropolitan counties based on commuting patterns.

Table 2: USDA's Rural-Urban Continuum Codes

Metropolitan counties
1. Counties in metro areas of 1 million population or more
2. Counties in metro areas of 250,000 to 1 million population
3. Counties in metro areas of fewer than 250,000 population
Nonmetropolitan counties
4. Urban population of 20,000 or more, adjacent to a metro area
5. Urban population of 20,000 or more, not adjacent to a metro area
6. Urban population of 2,500 to 19,999, adjacent to a metro area
7. Urban population of 2,500 to 19,999, not adjacent to a metro area
8. Completely rural or less than 2,500 urban population, adjacent to a metro area
9. Completely rural or less than 2,500 urban population, not adjacent to a metro area

The Urban Influence Codes and Rural-Urban Continuum Codes have been applied mostly to research areas such as access to health services (Gesler et al. 2006) and rural poverty (Auchincloss and Hadden 2002). We have not identified these definitions being applied to studies on land use and transportation integrations.

2.3 Previous Typologies of Rural Communities

Clearly, there are gradations of geographic rurality. To rank different degrees of rurality, several rural typologies have been developed. We review the most common in this section.

2.3.1 USDA's RUCC Rural Typology

As mentioned above, the Rural-Urban Continuum Codes classify counties on a scale with nine discrete benchmarks. More specifically, they are based on OMB's designations of metropolitan and nonmetropolitan counties but go beyond that dichotomy by further classifying nonmetropolitan areas into six classes based on three aspects of rurality: whether a county is in a metropolitan area; the size of the urban population; and the county's adjacency or nonadjacency to a metropolitan area (Gesler et al. 2006). It is necessary to note that this set of types relies on an arbitrary delineation of population thresholds.

2.3.2 ERS-USDA's 2004 County Typology

The Economic Research Service's County Typology (ERS-USDA, 2004) includes a mixture of economic and social dimensions since an area's economic and social characteristics have significant effects on its development and need for various types of public programs. ERS has developed codes that capture differences in economic and social characteristics for all 3,141 counties, county equivalents, and independent cities in the U.S. They are described with respect to their economic structure, challenges to residents' quality of life, and population change. More specifically, for example, counties are farming dependent, mining dependent, manufacturing dependent, federal/state government dependent, services dependent, or

nonspecialized, and the residents may or may not be experiencing housing stress, persistent poverty, and/or population loss. Here is more information on how dependence is defined:

- Farming-dependent counties—either 15 percent or more of average annual labor and proprietors' earnings derived from farming during 1998-2000 or 15 percent or more of employed residents worked in farm occupations in 2000.
- Mining-dependent counties—15 percent or more of average annual labor and proprietors' earnings derived from mining during 1998-2000.
- Manufacturing-dependent counties—25 percent or more of average annual labor and proprietors' earnings derived from manufacturing during 1998-2000.
- Federal/State government-dependent counties—15 percent or more of average annual labor and proprietors' earnings derived from Federal and State government during 1998-2000.
- Services-dependent counties—45 percent or more of average annual labor and proprietors' earnings derived from services (SIC categories of retail trade; finance, insurance, and real estate; and services) during 1998-2000.
- Nonspecialized counties—did not meet the dependence threshold for any one of the above industries.

It is necessary to note that this method does not include unemployment specifically but it does discuss housing stress and persistent poverty.

2.3.3 Multidimensional and Continuous Typology

The above typologies are mostly based on metropolitan/nonmetropolitan differentiations using a finite number of thresholds. A basic criticism has been raised against threshold approaches in general: all thresholds are arbitrary and lead to artificial categorizations.

Waldorf (2006) introduced the “Index of Relative Rurality (IRR)” to assess counties’ degree of rurality on a truly continuous scale ranging from 0 (most urban) to 1 (most rural). Different from previous approaches, IRR does not rely on arbitrary thresholds to classify different levels of rurality. In addition, IRR employs multiple dimensions to define rurality: population size, density, percentage of urban residents, and distance to the closest metropolitan area. It takes the following steps to develop IRR: selecting and computing variables for each dimension, rescaling variables to a comparable scale, and reducing the multiple dimensions to one single

dimension. IRR makes a valuable contribution to the definition of different levels of rurality by introducing multiple dimensions and continuity into the index.

2.3.4 Summary and Assessment

The existing rural typologies are not ready to be employed for our project for the following reasons: first, these typologies do not include built environment features and hence are less functional for modeling travel behavior because of the lack of information on the land use drivers; second, these typologies do not classify community types conveniently and many classifications rely on arbitrary thresholds. We attempt to address these issues in our typology, which is described in the next section. In addition, another distinction between our typology and the previous typologies is that ours specifically includes an attribute—road density—that helps capture the effect of the transportation system itself on travel behavior.

2.4 Constructing a New Typology of Small Communities and Rural Areas

In this section, we describe the following steps of constructing a typology for our study purpose: (1) defining the unit of analysis, (2) defining our study areas; (3) defining data sources; (4) selecting variables for the construction of the typology; and (5) classifying types of communities through cluster analyses. We explain each step below.

2.4.1 Unit of Analysis

For the purpose of land use and transportation modeling, county boundaries often are not adequate because destinations outside a county exert an influence on the county's residents, inducing many to travel outside the county of residence for work, shopping, health care, and recreation. We use commuting zones as our unit of analysis. Commuting zones were developed by the USDA's Economic Research Service (Tolbert and Sizer 1996). A commuting zone is a multicounty region that conveys the typical pattern of commuting trips in a spatially-defined labor market: a much higher proportion of commuting trips have origins and destinations that are both inside the zone than those trips for which one end is outside (very few commuting zones encompass a single county). Commuting zones account for interrelationships between economic actors, capturing variations in regional economic and labor force activities without regard to a minimum population threshold. It is necessary to note that the commuting zones were developed without regard to a minimum population threshold and were intended to be a spatial measure of the local labor markets across the nation. The developers of commuting zones, Charles Tolbert and Molly Sizer, applied hierarchical cluster analysis to data on commuting flows between counties. For pairs of counties, they first computed a measure of association that expresses the number of persons commuting between two counties as a proportion of the resident labor force in the smaller county. Then they computed a measure of "distance," which is one minus the measure of association. The cluster analysis was conducted using a threshold of 0.98 for the average distance between clusters.

The rationale for developing commuting zones provides us great confidence in using them as our spatial unit of analysis because our purpose is to model travel behavior in part caused by the geographical distribution of land uses and economic activities. In 2000, there were 709 commuting zones delineated for the continental U.S. (ERS-USDA n.d.).

2.4.2 Study Areas

We are interested in modeling transportation activities for small communities and rural areas. To operationally define "small communities and rural areas," we first selected all counties that lie entirely or partially outside of Transportation Management Areas (TMAs), which are designated by the Secretary of Transportation and defined as a Census-designated Urbanized Area with a population of over 200,000 (or an area designated on special request from the Governor and the MPO designated for the area). To gather information on the TMAs, we relied on the FHWA's Metropolitan Planning Organization (MPO) Database (FHWA n.d.) for the designations and obtained GIS boundary data from the National Transportation Atlas Databases 2010 (US DOT 2010).

The results of this step are shown in Map 1. Because commuting zones have been defined only for the contiguous United States, and because of other data limitations pertaining to Alaska and Hawaii (see below), our typology describes only places in the contiguous United States.

In the next step, we overlaid the small community/rural area counties with commuting zones. Then we eliminated the commuting zones that contain large community/urban area counties. Map 2 shows the results: the 546 highlighted commuting zones constitute our universe of study areas.

2.4.3 Additional Data Sources

In this section we summarize the sources of the data used to create the variables that are the basis of our typology. We employed the 2000 Census since crucial results from the 2010 Census were not available. Counts of workers (by industry) for small geographies, counts of worker flows between census tracts, and 2010 commuting zones were unavailable.

(1) U.S. Census 2000 TIGER: boundary files for counties, census tracts, and census block groups, and census blocks;

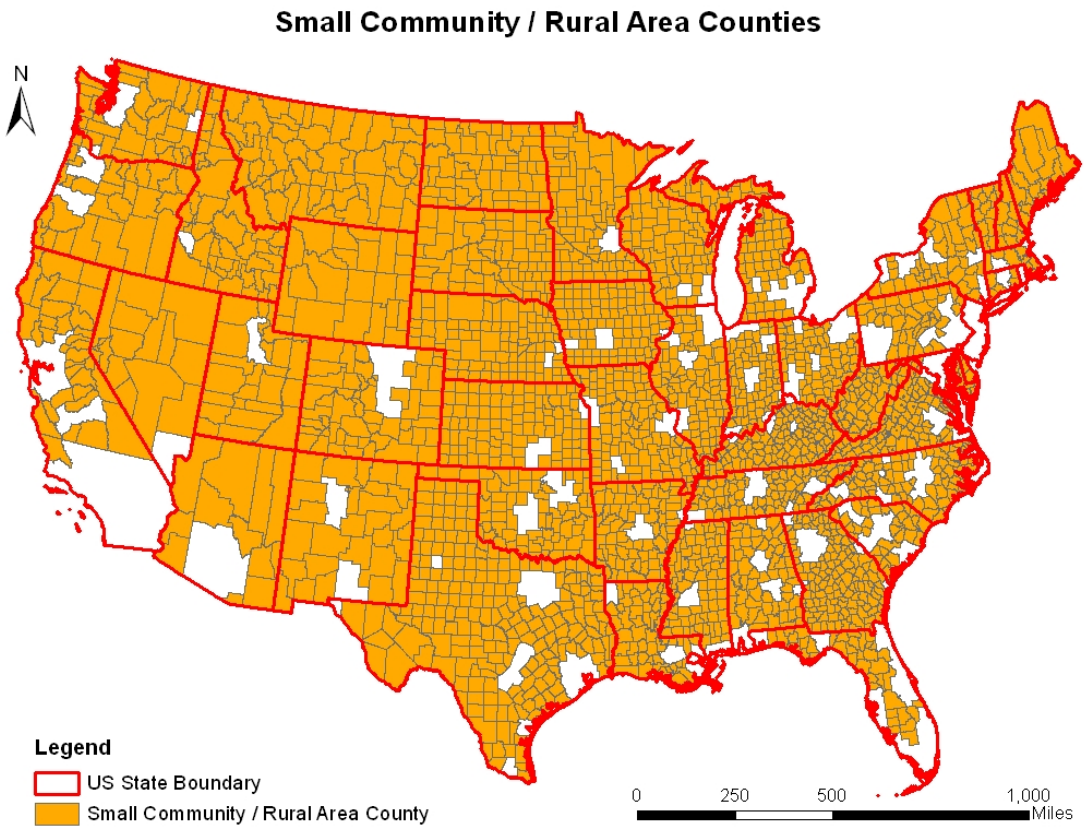
(2) National Historical Geographic Information System (NHGIS): cartographic boundaries with accurate natural boundaries (i.e., coastlines);

(3) Economic Research Service 2000 (ERS-USDA 2000): commuting zone boundaries;

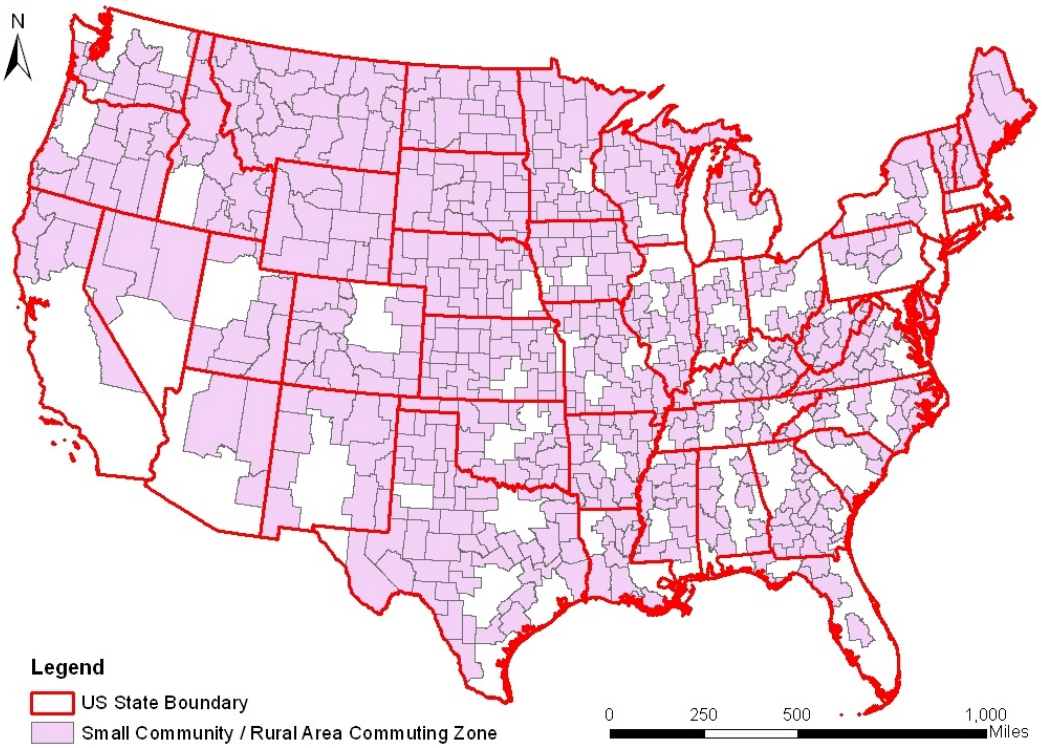
(4) National Transportation Atlas Database 2010 (NTAD 2010): Transportation Management Area (TMA) boundaries;

(5) U.S. Census 2000: information on population, land areas, and water areas;

(6) Census Transportation Planning Package 2000 (CTPP 2000): information on employment at census tract level, especially for sectors including retail trade, health and social assistance, and arts, entertainment, and recreation (see more details below);



Map 1: Counties Entirely or Partially Outside TMAs



Map 2: Study Areas - Commuting Zones Outside TMAs

(7) USGS 2011: information on protected area (national parks, wilderness areas, natural areas managed by land trusts, etc.) to construct a dataset of developed or developable land for the purpose of calculating population density (see more details below). The protected area database that we used appears to be problematic for Hawaii and Alaska. The protected area boundaries frequently do not conform to natural boundaries. We could not resolve the discrepancies by reprojecting the boundaries of the protected areas in those states. Consequently, our universe of study areas excludes the small or rural communities in Hawaii and Alaska;

(8) U.S. Census 2000 TIGER: information on national road networks, 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, and apartment complexes. This revised national road network is then used to calculate road density (see more details below).

2.4.4 Selecting Variables for the Typology

In this section, we provide information on the four variables we use to construct a typology of small or rural areas: population density; road density; land use mixture; and variation in population density. We computed these variables for both commuting zones and counties. For brevity of exposition and because of the significance of commuting zones to explaining travel behavior, we only describe these variables for commuting zones.

- **Population Density**

Density is the most widely used indicator measuring urban form (Gordon and Richardson 1997; Sierra Club 1998; Lockwood 1999; Malpezzi 1999; Galster et al. 2001). While many studies measuring urban density have used the number of residential units for the density calculation, we choose to use population density, which is a more useful indicator for our purpose of examining travel patterns in small or rural areas because of the obvious influence of the number of residents—rather than the number of housing units—on trip generation. In this study, population density is computed as number of people divided by developed or developable land (i.e., excluding water and protected area) for each commuting zone.

Some of the protected areas have a population recorded in the 2000 Census, even when the area is entirely protected. Logically, some portion of those protected areas is developed land, and it is necessary to reduce those areas' protected acreage and to count it as developed land.

We first observed this apparent anomaly in protected military land, but we developed an approach to reclassifying protected land that applies to all protected lands. We identified all Census blocks with a population residing in a protected area and considered the land area in those blocks to be developed.

Our characterization of developed or developable land somewhat overstates the situation because not all wetlands have been excluded nor have all floodplains and excessively steep slopes been excluded. The national database of wetlands (U.S. Fish & Wildlife Service's National Wetlands Inventory [2009]) includes large gaps in multiple states, including Arkansas, Louisiana, Montana, New York, and Wisconsin. Consequently the variables in our typology that are based on density somewhat understate density with respect to developed or developable land.

- **Road Density**

Road density is calculated as road length in miles per square mile of developed or developable land in a commuting zone. Differences in road density indicate differences in regional accessibility for trips made via auto, the most frequently used mode of travel in small or rural areas.

- **Land Use Mixture**

Land use mixture has been confirmed as a main contributor to travel behavior. Ideally, one can measure land use mixture by examining how different land uses (such as residential, commercial, industrial, and office land uses) are distributed. However, there is no single dataset of land uses at the national level. Thus it is necessary to resort to a proxy of land use mixture by measuring how residents, jobs, and other activities are distributed in relation to each other, since the main purpose of this study is to evaluate and measure the impacts of transportation and settlement patterns and development strategies on travel behavior, fuel consumption and emissions.

To measure land use mixture, we intend to capture the extent to which residents are exposed to employment such as retail, public service, and entertainment sectors. We choose to use Massey and Denton's interaction index, also known as exposure index, to represent the degree of potential contacts between two different entities within the same area, in this case, the two different entities are population and employment. One advantage of using the interaction index is that it takes account of the relative size of population and employment in determining the degree of possible interaction between them (Massey et al. 1996). The variable is calculated at the commuting zone level by the following equation:

$$Land\_Use\_Mixture\_Index = \sum_{i=1}^{n} \left[\frac{x_i}{X} \right] \times \left[\frac{y_i}{t_i} \right]$$

where x_i and y_i are the numbers of residents and retail and service-oriented employees of geographical unit i, respectively, and t_i is the sum of x_i and y_i. X represents the number of residents in the commuting zone. In our application, i is a census tract, which is the smallest geographical unit available for obtaining employment data for the entire U.S. The land use mixture index varies between 0 and 1, with lower values indicating low potential interaction between population and employment (i.e., low level of land use mixture) and higher values indicating high potential interaction between them (i.e., high level of land use mixture). Note that although manufacturing is not included in the land use mixture attribute, it is represented in the typology. The commuting pattern between residences and manufacturing locations is captured by the use of commuting zones. The land use mixture index is sensitive to the locations of retail businesses and the establishments that provide educational, health, and social services and arts, entertainment, recreation, accommodation, and food services. The index measures the potential for interaction between those places and residents—whether that interaction takes the form of work trips or non-work trips.

- **Variation in Population Density**

We also compute a variable of variation in population density within the commuting zone. Population density, although a very useful measure of settlement intensity, does not reveal the distribution of population across the area. Variation in population density distinguishes commuting zones where most residents are located in a relatively small set of concentrated areas at relatively high densities from commuting zones where residents are spread more evenly. We use the coefficient of variation of population density across census block groups in a commuting zone, which is calculated by dividing the standard deviation of population density by the mean of population density. The coefficient of variation is more useful than the standard deviation of population density because it fairly compares different locales by normalizing the dispersion of population with the mean population density. The equation of the coefficient of variation (CV) is as follows:

$$CV = \frac{\sigma}{\mu}$$

where σ and μ are the standard deviation of population density and the mean, respectively.

It is necessary to note that the four variables are capturing different dimensions of small communities and rural areas, and they are not highly correlated with each other (Table 3).

Table 3: Correlation Matrix of the Variables at the Commuting Zone Level

	Population Density	Road Density	Land Use Mixture	Variation in Pop. Density
Population Density	1.000			
Road Density	0.6330	1.000		
Land Use Mixture	-0.1616	-0.1560	1.000	
Variation in Pop. Density	-0.1593	-0.1478	-0.0218	1.000

2.4.5 Cluster Analyses

It is necessary to classify small communities and rural areas into several types for the following reason: for the purpose of this project, we need to select and conduct modeling exercises for several communities that are most representative of the small communities and rural areas in the whole country. Thus our approach is to classify the small communities and rural areas into several types, and to select one community from each type.

We employ cluster analysis to classify small communities and rural areas. Cluster analysis is a statistical method of grouping observations: the overall difference between groups is maximized while the overall difference within each group is minimized.

We apply cluster analysis to the commuting zones, using the k-means clustering method and the following steps (Aldenderfer and Blashfield 1984): (1) specify the number of clusters (commuting zones) and compute the centroids of the clusters; (2) allocate each data point to the cluster that has the nearest centroid; (3) compute the new centroids of the clusters; and (4) repeat steps 2 and 3 until no data points change across clusters. In our project, all processes for the clustering analyses were executed with Stata. We use four variables: population density, road density, land use mixture, and the coefficient of variation in population density. Since the four variables are measured on different scales, we need to standardize them before performing a cluster analysis. We then use the k-means clustering algorithm to divide the small or rural area commuting zones into 3, 4, 5, or 6 groups.

2.5 Results

In this section, we present the results from the cluster analyses of the commuting zones. Table 4 presents the F statistics for the analyses with 3, 4, 5, and 6 clusters. It is useful to know that in general, smaller numbers of clusters return better F-statistics, suggesting a slightly better

classification. Determining which solution is more appropriate for our purpose warrants a closer investigation of each solution.

Table 4: Calinski and Harabasz Test

Number of Clusters	Calinski / Harabasz Pseudo-F
3	176.05
4	173.81
5	165.46
6	158.82

Table 5 presents the distribution of commuting zones by each cluster or type for 4 solutions. It is evident that for the solutions with 5 clusters and 6 clusters, there is one cluster with only 40 or 27 commuting zones. The small numbers indicate that these two solutions might have captured very small differences in the attributes of the commuting zones.

Table 5: Distribution of Commuting Zones in Each Solution

3 Cluster Solution		4 Cluster Solution		5 Cluster Solution		6 Cluster Solution	
Cluster	Frequency	Cluster	Frequency	Cluster	Frequency	Cluster	Frequency
1	194	1	173	1	152	1	135
2	232	2	65	2	60	2	71
3	120	3	218	3	154	3	27
		4	90	4	140	4	134
				5	40	5	138
						6	41
Total	546	Total	546	Total	546	Total	546

Table 6 further presents cluster means by each cluster for all 4 solutions. These values are the mean standardized scores along each of the four dimensions (i.e., population density, road density, land use mixture, and coefficient of variation in population density). It is quite discernible that the solutions with 5 and 6 clusters have close mean values, for example, the mean values of population density for clusters 3 and 4 are quite close in the 6 cluster solution. This suggests that population densities of these two clusters are very similar although they differ in variation in population density. Because of their similarity in population density, modeling exercises of commuting zones from these two clusters might be less likely to provide new information.

By closely examining and comparing the solutions with 3 and 4 clusters, it is clear that the solution with 4 clusters also makes subtle distinctions for commuting zones with lower densities. The utility of these distinctions for modeling exercises is less clear.

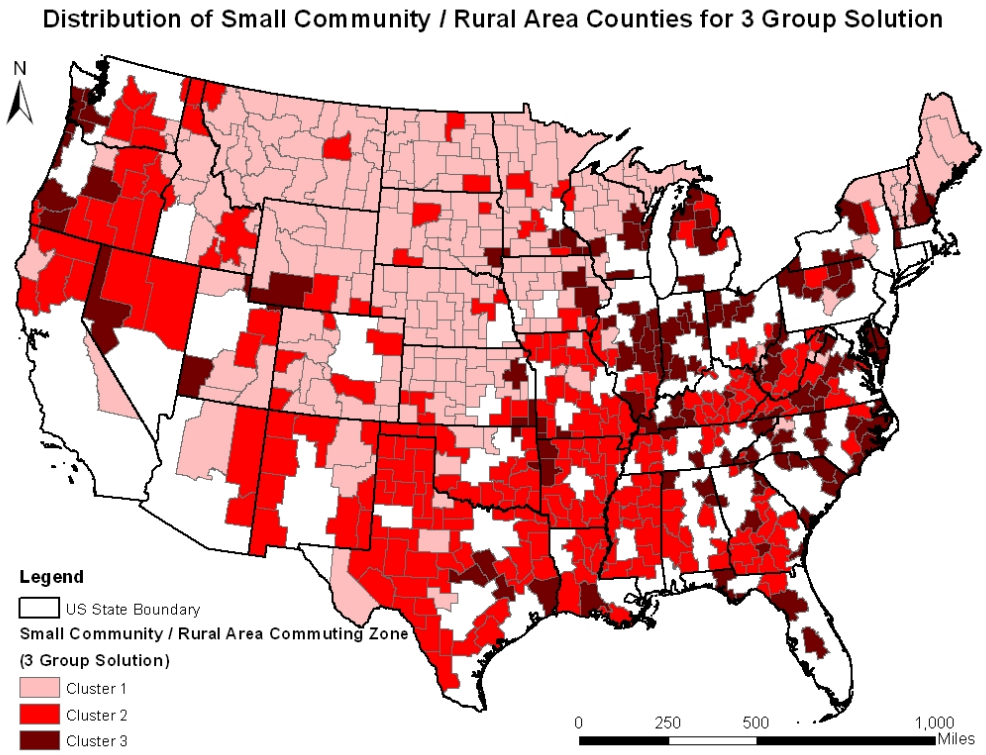
It is also obvious that the solution with three clusters has a well-defined distribution of low, medium, and high densities in both population and road networks, as well as a well-defined distribution of high, medium, and low levels of variation in population density.

Table 6: Cluster Means for the Commuting Zone Typology

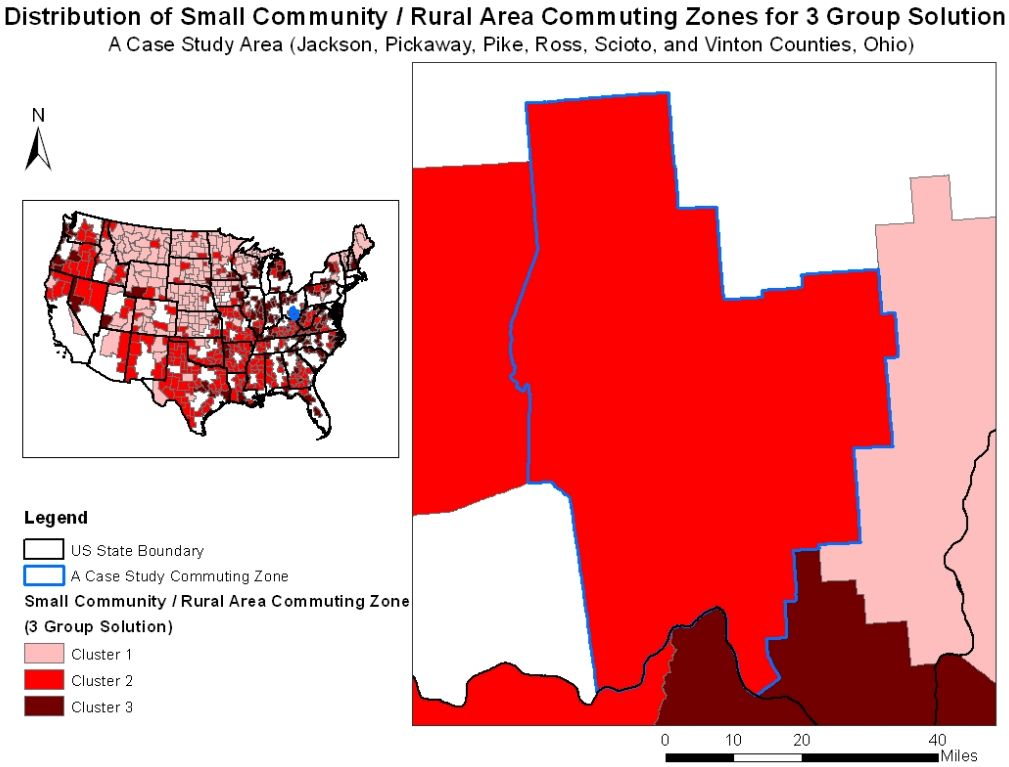
	Cluster	Population Density (persons/square mile)	Road Density (miles per square mile)	Land Use Mixture	Variation in Population Density
3 Cluster Solution	1	18.603	1.681	0.150	1.889
	2	35.432	2.143	0.119	1.653
	3	105.969	2.995	0.133	1.376
4 Cluster Solution	1	18.422	1.672	0.151	1.580
	2	28.020	1.891	0.130	2.838
	3	40.500	2.247	0.120	1.523
	4	118.982	3.119	0.133	1.390
5 Cluster Solution	1	12.786	1.583	0.151	1.593
	2	27.382	1.878	0.131	2.880
	3	34.463	2.114	0.115	1.599
	4	66.813	2.603	0.136	1.446
	5	157.456	3.490	0.128	1.287
6 Cluster Solution	1	13.235	1.639	0.137	1.836
	2	16.276	1.667	0.165	1.460
	3	38.642	2.042	0.129	3.456
	4	38.883	2.151	0.111	1.655
	5	64.680	2.600	0.136	1.418
	6	156.680	3.470	0.128	1.289

Map 3 displays the distribution of clusters for the solution with 3 clusters. Map 4 zooms in on the six-county region in south-central Ohio that is the case-study area for the Task 3 effort to develop the methodology, via a prototypical simulation model, that we will use in the project's Phase II to quantitatively characterize the impacts of land use on travel behavior. Map 5 and Map 6 are the corresponding maps for the 4 cluster solution. In those maps, the color spectrum connotes population density: the darkest color indicates greatest density.

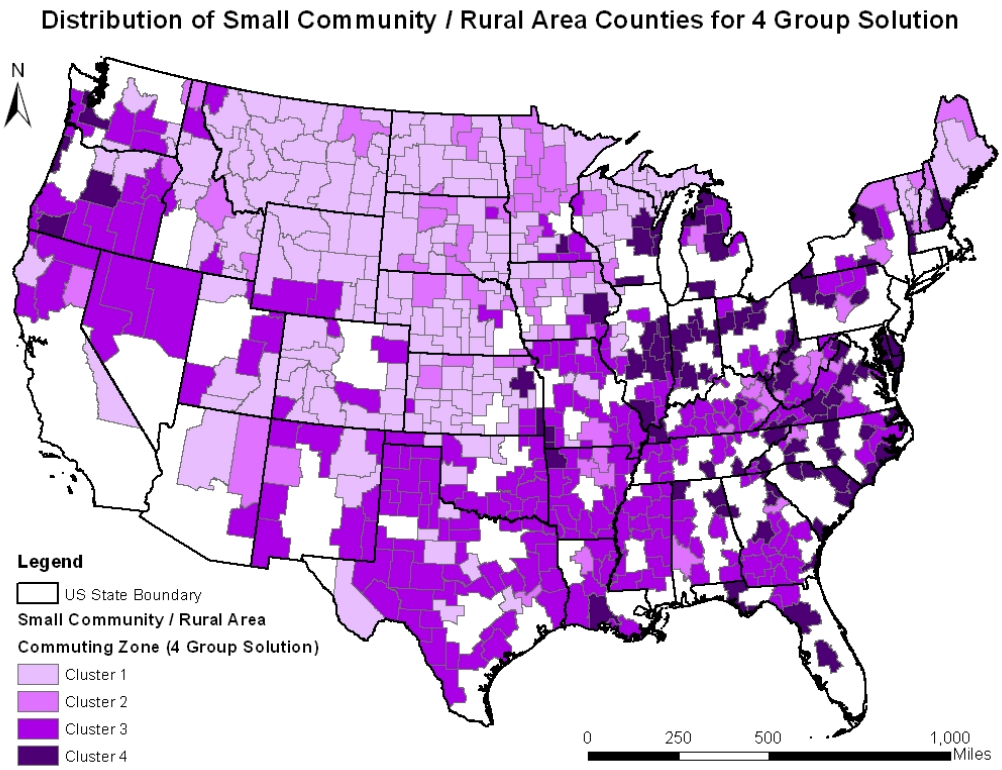
The Midwest and Northeast host most of the commuting zones with lower densities, while the Southeast hosts most of the commuting zones with medium and higher densities. In both the 3- and 4-cluster solutions, the Ohio case-study area is a member of the most frequent type of small community or rural area.



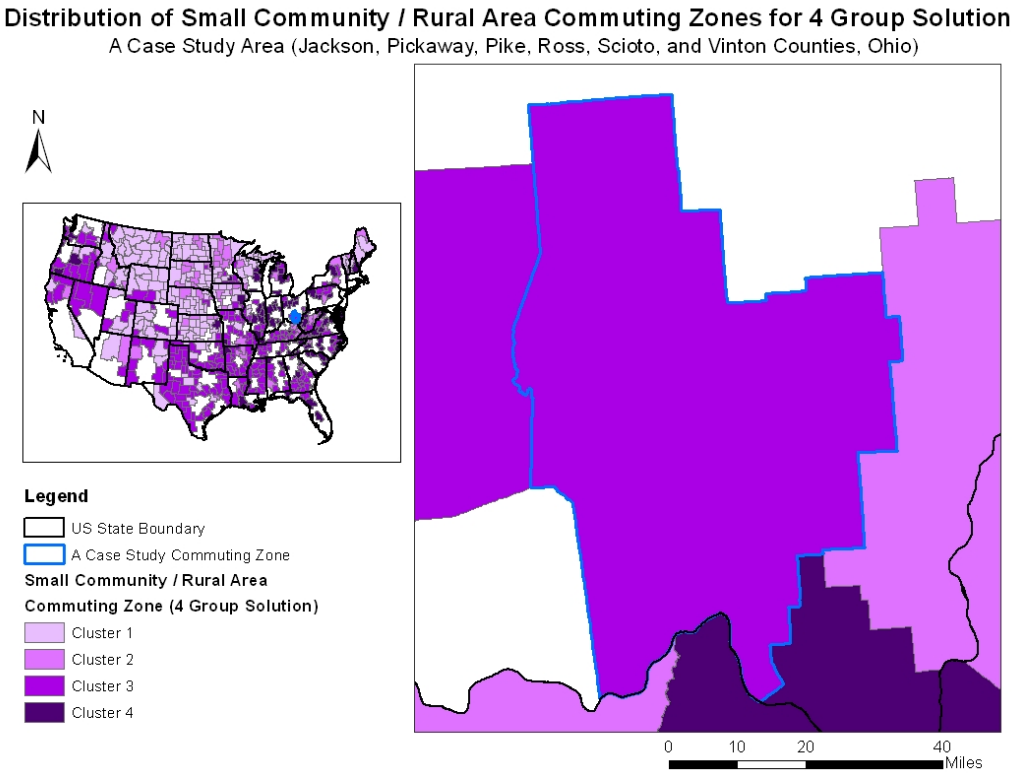
Map 3: Distribution of Small Communities and Rural Areas for the Solution with 3 Clusters



Map 4: A Case Study Area for the Solution with 3 Clusters



Map 5: Distribution of Small Communities and Rural Areas for the Solution with 4 Clusters



Map 6: A Case Study Area for the Solution with 4 Clusters

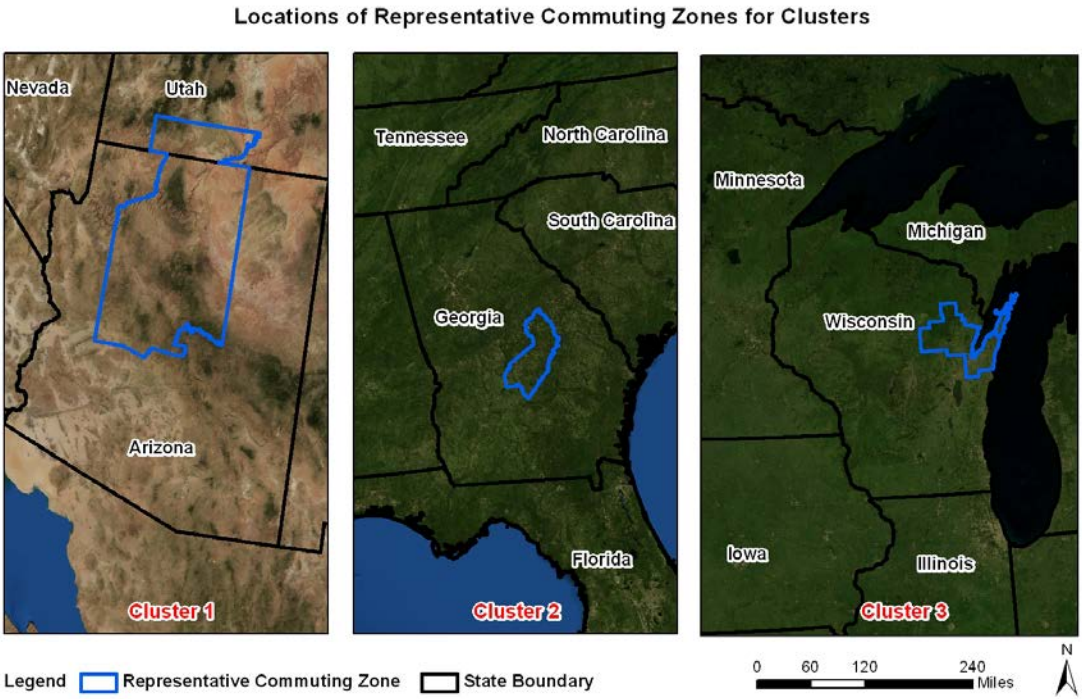
For the above mentioned reasons, we believe that the solution with 3 clusters is the best one for modeling purposes because it has the highest F-statistic and clusters with markedly distinctive attributes.

The next series of maps (Map 7-Map 11) portray the 3-part typology by illustrating the individual attributes of one commuting zone of each type. The left panel in those maps illustrates a type 1 commuting zone, the middle panel illustrates a type 2 commuting zone, and the right panel illustrates a type 3 commuting zone.

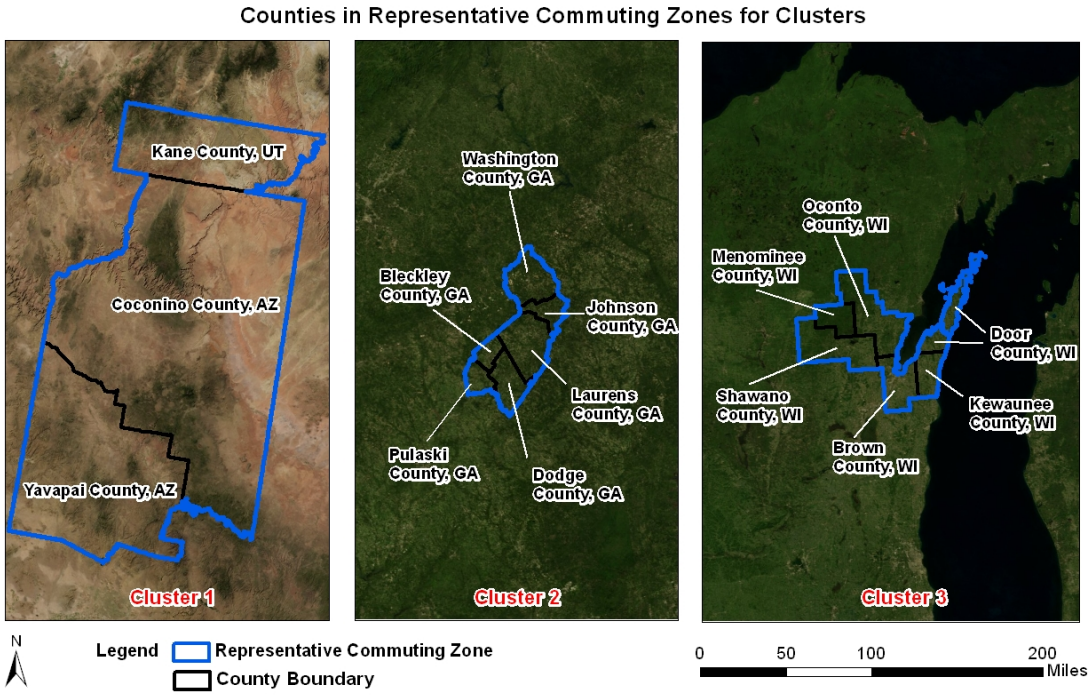
The attributes of each commuting zone have values that are close to the respective cluster means (Table 6). For example, the commuting zone in Georgia (Map 7 middle panel) comprises six counties (Map 8) and belongs to type 2, and its population density, road density, land use mixture, and variation in population density are, respectively, close to the mean values of population density, road density, land use mixture, and variation in population density for all of the type 2 commuting zones.

Map 9 illustrates differences in population density. Map 10 shows the census tracts that have population but not employment and those tracts that have both population and employment;

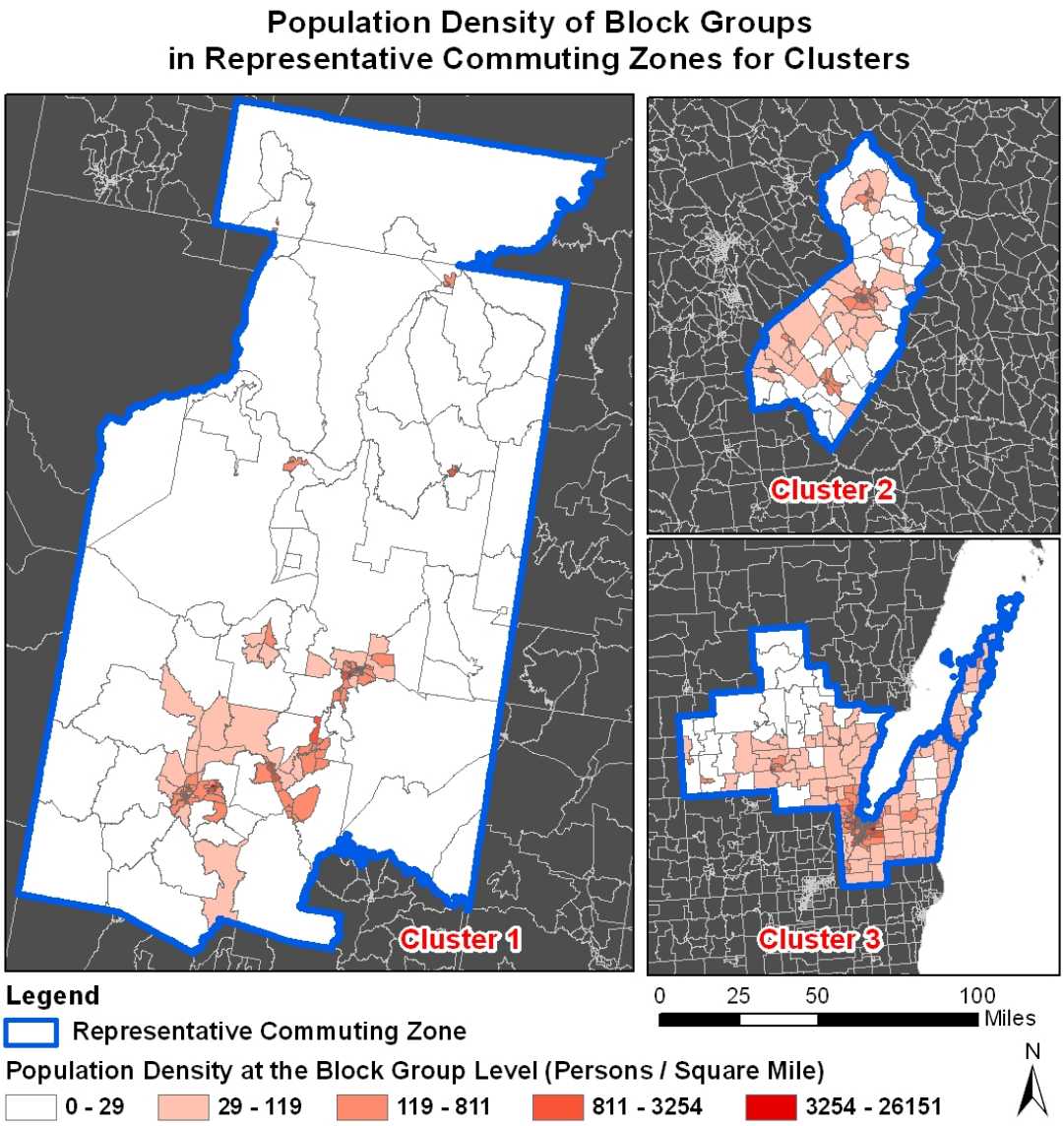
those features help to portray differences in the value of the land use mixture index. The last map illustrates differences in road density.



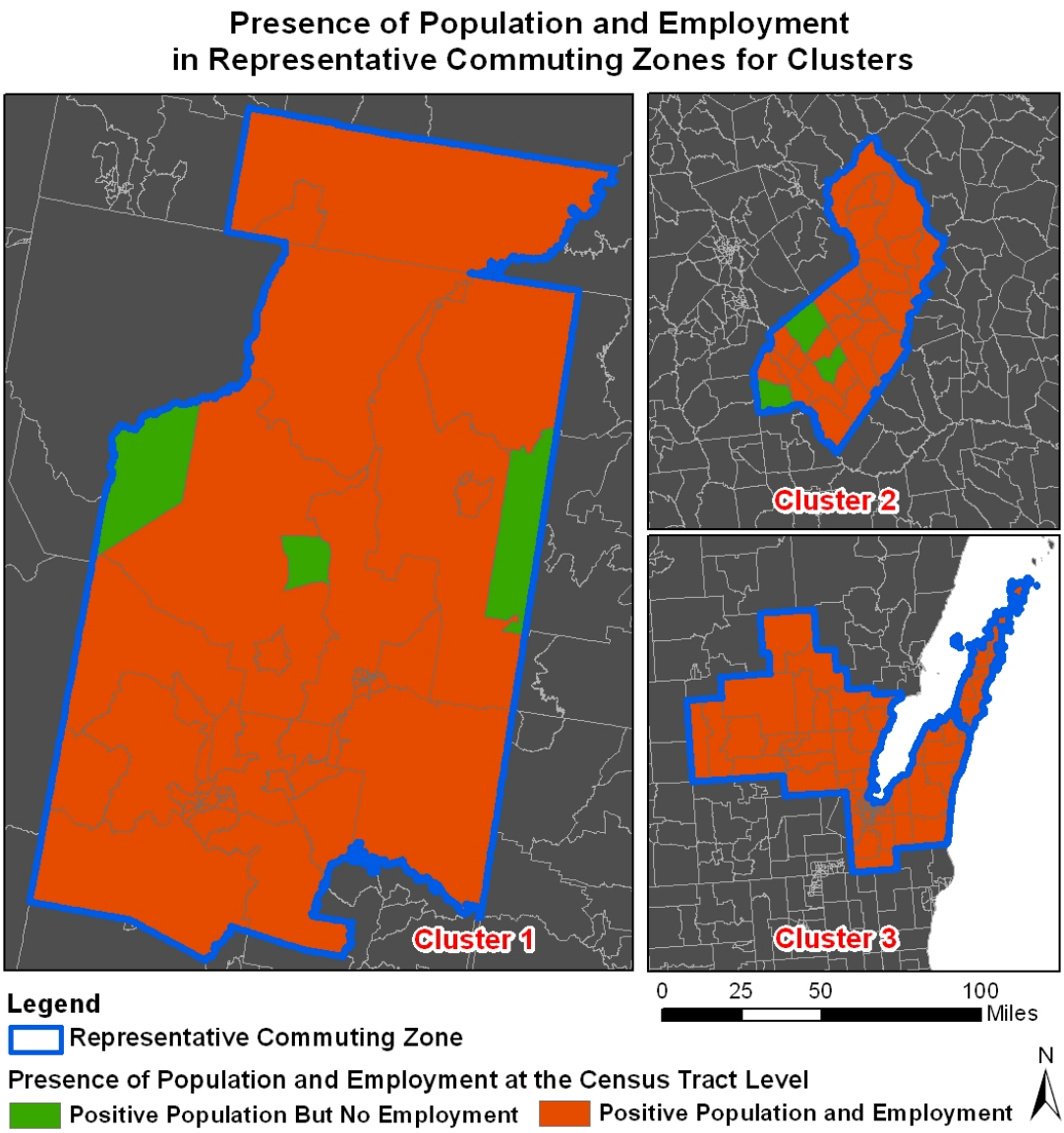
Map 7: Locations of Illustrative Commuting Zones for 3-part Typology



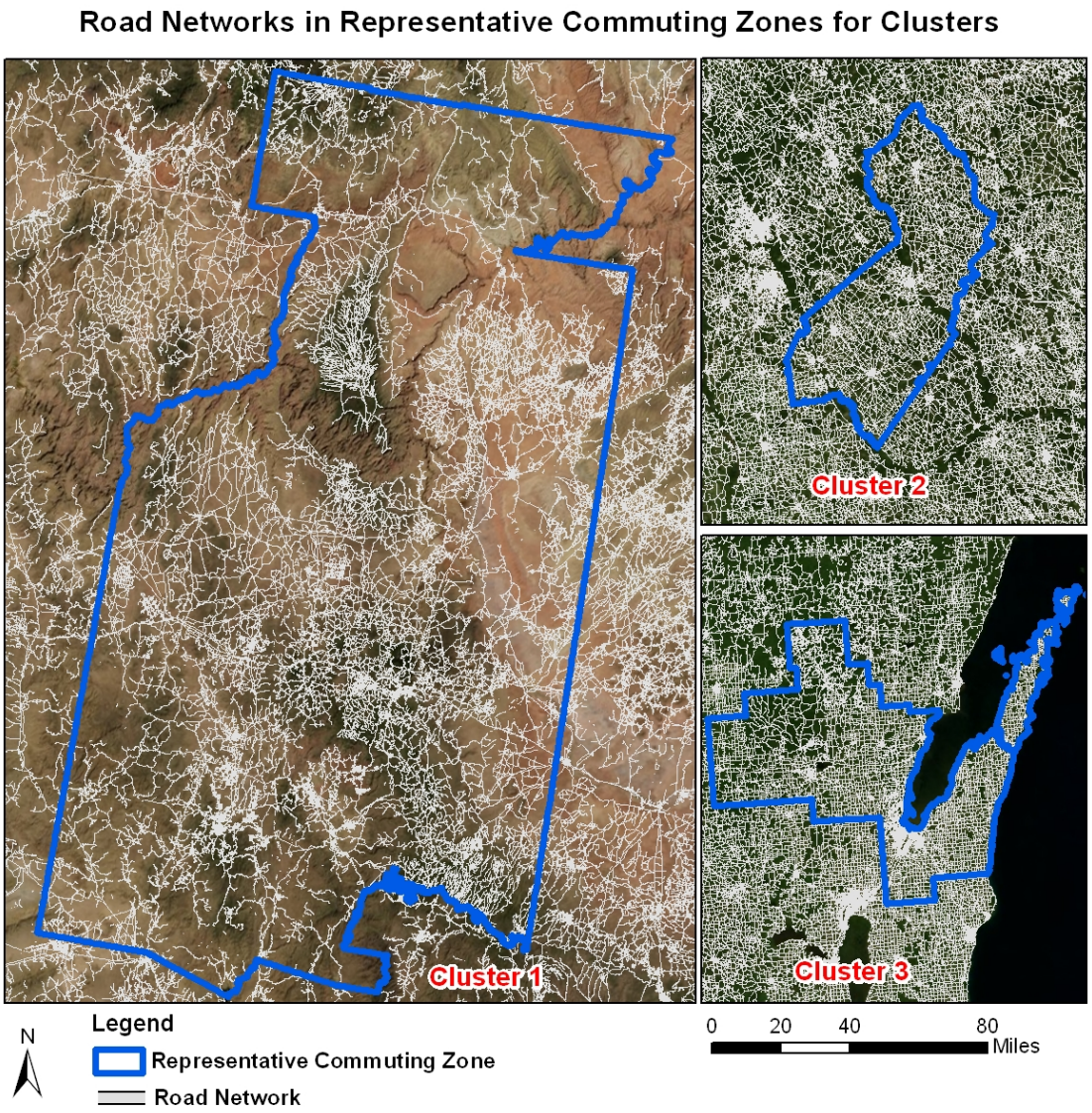
Map 8: Counties in Illustrative Commuting Zones



Map 9: Population Density of Block Groups in Illustrative Commuting Zones



Map 10: Co-location of Population and Employment in Illustrative Commuting Zones



Map 11: Road Networks in Illustrative Commuting Zones

2.6 Brief Narrative Profiles and Illustrative Satellite Photographs of the Three-Part Typology

To further convey the essence of the three-party typology, we have developed a succinct label for each type and short list of distinguishing characteristics. We also obtained satellite photographs of one of the largest towns (if not the largest) in each of the illustrative commuting zones. We formed west-to-east transects by recombining "tiles" selected to portray a town's immediate environs on its western and eastern edges and the relatively higher-density neighborhoods in the town's center.

Due to time constraints, we downloaded the satellite photographs from Google Earth. Google owns the copyright in those photographs. The original source of those photographs is not Google but the U.S. Geological Survey, and the latter's photographs are in the public domain. The satellite photographs that will be in the project documents that the Transportation Research Board will publish will be obtained from the U.S. Geological Survey and hence can be used freely.

The transect photographs that appear below are too wide for standard pages, even when placed in the landscape orientation. We attempt to overcome that limitation by splitting each transect into two parts and placing the first on an even-numbered page and the second on the following page.

2.6.1 Type 1 Community: Open Space with Isolated Settlement

- Sparse population.
- Sparse businesses.
- Many roadless areas.
- Minimum investments in road network and other infrastructure.
- Represented by Flagstaff, Arizona (Figure 1).

Figure 1: Open Space with Isolated Settlement, Represented by Flagstaff, AZ

Figure 2: Flagstaff, AZ, Western Edge and Environs: First Transect

Figure 3: Flagstaff, AZ, Western Edge and Environs: Second Transect

Figure 4: Flagstaff, AZ, Eastern Edge and Environs: First Transect

Figure 5: Flagstaff, AZ, Eastern Edge and Environs: Second Transect

2.6.2 Type 2 Community: Small Towns in a Working Landscape

- Patchy population.
- Patchy businesses.
- Agricultural fields and woodlands are the predominant feature of the landscape.
- Several overlapping but still distinguishable radial road networks are centered on the small towns.
- Represented by Dublin, GA (Figure 6)

Figure 6: Small Towns in a Working Landscape, Represented by Dublin, GA

Figure 7: Dublin, GA, Western Edge and Environs: First Transect

Figure 8: Dublin, GA, Western Edge and Environs: Second Transect

Figure 9: Dublin, GA, Eastern Edge and Environs: First Transect

Figure 10: Dublin, GA, Eastern Edge and Environs: Second Transect

2.6.3 Type 3 Community: Large Towns in a Working Landscape

- Population throughout the commuting zone.
- Businesses throughout the commuting zone.
- Several large towns.
- Almost all land is developed in some way.
- Roads everywhere.
- Represented by Green Bay, WI (Figure 11).

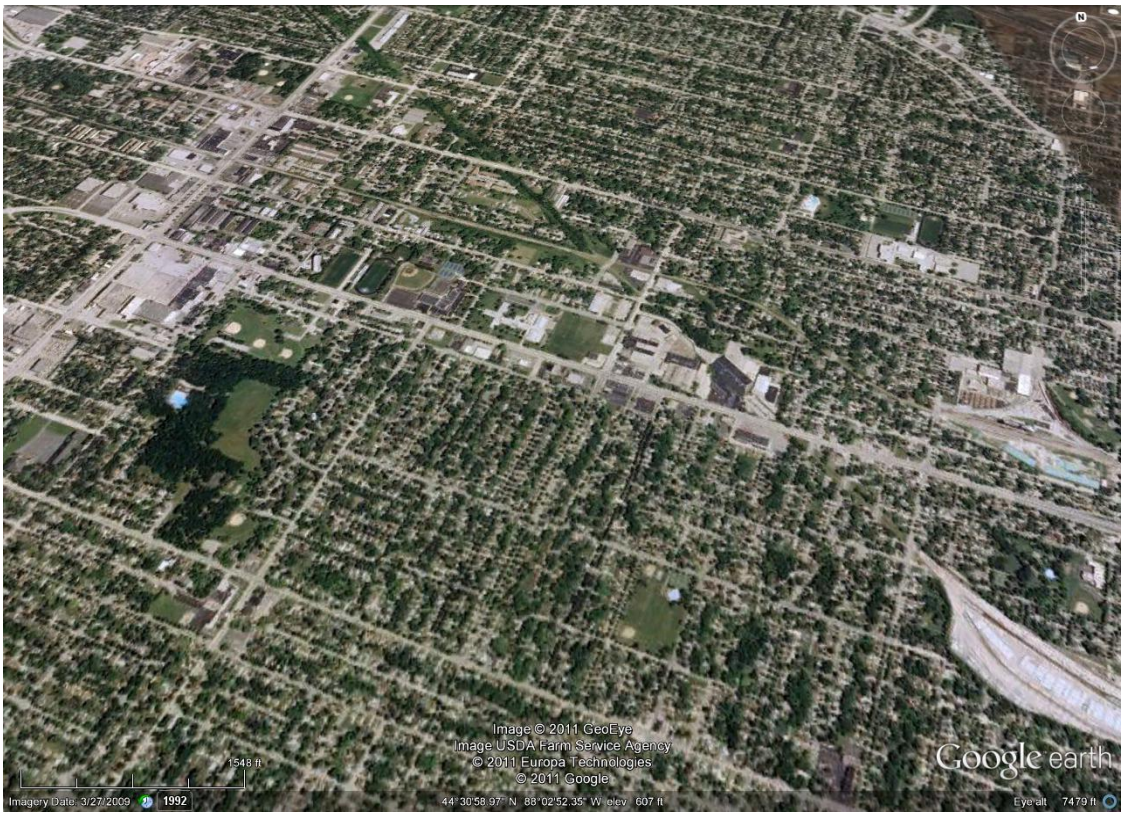


Figure 11: Large Towns in a Working Landscape, Represented by Green Bay, WI

Figure 12: Green Bay, WI, Western Edge and Environs: First Transect

Figure 13: Green Bay, WI, Western Edge and Environs: Second Transect

Figure 14: Green Bay, WI, Eastern Edge and Environs: First Transect

Figure 15: Green Bay, WI, Eastern Edge and Environs: Second Transect

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3. Travel Behavior in Small Communities and Rural Areas: Data and Literature Review

Ann Hartell, Joseph Huegy, Mei Ingram, Eugene Murray, and Chao Wang

3.1 Introduction

This chapter provides a review of relevant literature on the characteristics and influences of land use and the built environment on travel behavior in small communities and rural areas. It also provides a review of data sources related to measuring travel behavior and the physical, economic, and demographic factors that determine travel choices. Detailed information on those resources is provided at the end of the chapter.

The literature and data review conducted for this project began with a substantial collection of studies, reports, and guidance documents collected by the project team. Searches for additional resources were carried out using the TRIS database, general web searches, and through the academic research systems at both UNC and NCSU. The project team also reviewed the cohort of 2010 USDOT TIGER 2 grant recipients to identify any promising new approaches. Data resources evaluated included commonly used datasets known by the research team as well compilations of local, regional or state travel surveys. A review of websites for all 50 states was conducted to identify new data resources and evaluate applicability of a range of publicly available data, including economic, employment, agricultural, and environmental datasets as well as state-level transportation data. The findings of our review provide inputs to the quantitative tasks and inform the development and dissemination of practitioner-oriented materials.

The central concern of the this project is identifying and describing strategies to reduce emissions by reducing overall vehicle miles traveled (VMT) in small communities and rural areas. These strategies need to (a) be supported by empirical evidence from the research and (b) be practical in terms of data needs. The scope of the project is limited to rural areas and small communities, defined as counties outside Transportation Management Areas (TMAs); in other words, any county that does not contain an urbanized area with a population of 200,000 or more.

The literature and data review for this project have substantiated several points that will be useful for the remainder of the project.

- There is little research or data available specifically for rural travel behavior. There are very few datasets constructed from a substantial rural sample, and few local agencies

extensively survey their rural fringe areas. Therefore rural subsamples may need to be drawn from national datasets. There is evidence that data and models can be transferred if an adequate context can be defined for applying them.

- There are many sources of data available to planners in rural areas and small communities that can be used for this project to characterize rural areas and small communities. This includes data on population and economic activity, traffic flow including for trucks; though data is most often only available for large geographic areas such as counties.
- There is an extensive literature on land use and transportation interaction, but it covers mostly urban areas and the conclusions should be transferred to rural areas and small communities with caution. However, this literature does suggest promising approaches such as clustering nonresidential uses including jobs destinations.
- Small communities and rural areas have unique transportation needs including good intercity connections to improve regional accessibility from small centers that can also serve rural populations, improving the specificity and attention to freight movement, and understanding the needs of special populations such as the elderly and low-income workers.
- For rural residents, distance from urban areas is an important factor in the frequency of trips and for overall miles traveled by rural residents. It is hypothesized that distance from urban areas is a major influence on the greater length and lower frequency of trips by rural residents compared to urban residents.
- While rural areas may focus on economic development, the form that development takes can provide economic benefits and consensus can be built for improved development form through visioning processes. Interestingly, policies applied in non-attainment areas can reduce VMT and might be successfully applied in rural areas to reduce VMT.

3.2 Data Review

A substantial number of data resources were reviewed to document data accessible to practitioners and to evaluate specific datasets for use in this research project and for inclusion

in guidance for practitioners. The resources include household travel surveys drawing from national, regional, and local samples; transportation system datasets; land use data; and economic and employment data. In addition to the discussion provided in this section, descriptive summaries and basic documentation of relevant data resources focusing on variables in the datasets that could be used specifically in the study relating to rural and small areas and identifying limitations of reporting (data suppression) where appropriate are provided in the first appendix.

3.2.1 Travel Behavior Data

National datasets provide an important resource to researchers and practitioners. They support analyses of travel behavior trends and overall system performance. Generally speaking, travel behavior data will have to be paired with land use and other socio-economic data to be useful for understanding travel choices and influences. Although national datasets have large samples, at the local level most travel survey samples are sparse, which affects accuracy at fine spatial scales. Several national data resources were reviewed for this project and the most relevant are discussed below.

The National Household Travel Survey (NHTS) is a national scale household travel survey sponsored by the Federal Highway Administration (FHWA) (*1*). The 2009 sample covers 150,000 households across the country; data from the 2001 and 2009 surveys are available. The survey collects similar information to any regional household travel survey including travel characteristics of residents, demographic data, and information about trips and schedules. County summary information of average mode share, and journey-to-work flows are publicly available. In addition to the usual travel behavior information, NHTS also includes certain land use and socio-economic information for the location of the surveyed household such as Metropolitan Statistical Area (MSA), area population, population density, and employment density, with some variables derived from US Census. It also includes estimates of annual VMT or person miles traveled. Geographic resolution for public use data is census block group (sometimes tract), but researchers can request traffic analysis zone (TAZ)-level detail.

The American Community Survey (ACS) is a national, rolling-sample survey, conducted annually by the US Census Bureau, each time covering a different part of the country (*2*). In 2009, ACS sampled about 1.9 million housing units and about 147,000 persons in group quarters; since 2000, 12.5 million housing units have been surveyed; although for any given region and survey, samples are sparse. ACS data are provided as averages across consecutive years, e.g. a 2005-2009 average. The ACS collects information on the journey to work and demographic information but not information on other trip purposes. Spatial resolution for the ACS has the same caveats as the NHTS.

Aside from the national data collection initiatives, many regions and states conduct their own travel behavior surveys. These household surveys gather travel characteristics of residents in an area. They also collect demographic and other transportation-related data. Planning agencies usually rely on household travel surveys to develop and calibrate transportation planning models, which support transportation decisions for projects and policies.

The Metropolitan Travel Survey Archive (MTSA) project is a funded effort to collect travel survey data from various agencies across the United States (*3*). This project collected 85 surveys from 44 metropolitan agencies, and provides easy online access to survey data spanning 44 years (1965 – 2008). They include 281,981 household records, and 3,576,329 trip records (*4*). This clearinghouse of surveys provides an overview of the history and current status of household travel surveys as well as a set of surveys relevant for other project tasks.

The surveys collected by the MTSA project were conducted by different agencies in different geographic areas using different survey methods. Therefore the data are in different formats and contain different information. However, as household travel surveys, most of them gather basic travel behavior, demographic, and other transportation-related data. For example, they usually collect travel behavior data, such as trip frequency, duration, mode, and trip purpose. The common demographic data collected are household size, type of dwelling unit, age of each family member, number of workers, and number of students. Other data include number of vehicles, possession of a driver's license, parking costs, and toll costs. Also collected are spatial data including household locations and trip origins and destinations.

The surveys archived by the MTSA project represent a range of place types. Some surveys are from large cities like New York, Dallas, and Seattle. Others are from smaller cities like Daytona Beach, Salt Lake City, and Fort Collins. Although most of the surveys were conducted in metropolitan areas, they include the household samples from small communities or rural areas on the urban fringe. For example, the survey conducted in the Raleigh-Durham (NC) area includes households living in small communities like Cary, and rural areas like Chatham County. In addition, four statewide household travel surveys were collected in the MTSA project. These surveys provide ample information of travel behavior in small communities and rural areas. For example, the Ohio statewide household travel survey sampled 2,223 households in 57 rural counties in Ohio.

It is worth noting that some data sets or documentations were missing for some of the surveys collected by the MTSA project. Lack of some important files, such as a data dictionary, prevents full understanding and analysis of the data sets. To protect the privacy of the respondents, some agencies removed the longitude and latitude information of household locations and trip ends, or replaced them with a coarser spatial resolution such as census tract number or county FIPS. Consequently, the spatial analysis based on these surveys will be constrained, and deriving

accurate trip length information will be impossible. There are other household travel surveys that were not collected by the MTSA project that may be available on request from local or regional agencies in selected pilot locations. These surveys are expected to contain similar information and to have similar limitations.

There are several data resources that focus on transit. Many MPOs conduct on-board surveys of transit users, especially in regions where an extensive transit system exists. The information collected is used by transit service planners and may also be used to develop traffic forecasting models. Travelers' household location, boarding/alighting location, and trip origin/destination locations are collected and are often geocoded to TAZs for MPOs using the information to develop a travel demand model. Other information commonly collected includes transit mode (local bus, express bus, and commuter rail), access/egress mode to/from transit (walk, park-and-ride), access/egress time and distance, fare paid, number and duration of any transfers, and trip purpose. Demographic data are also collected including household income, age of traveler, vehicles owned, and employment status. These data may be available to the research team on request.

Because travel surveys have limitations with respect to how current they may be (infrequently administered) and sample size, especially outside urban areas, practitioners and researchers often find they must consider transferring data or model results from other locations to analyze the area of interest. There is an extensive literature on transferring models either temporally or spatially, though most studies compare large urban area data. Models transferred temporally are estimated using existing data and are applied to a forecast. Models transferred spatially are estimated using data for one place and are applied in another place. Karasmaa points out that the usual test for transferability has been to test statistically the equivalence of the model coefficients between two places (*5*). The coefficients could only be expected to be equivalent if the context for the two models is the same and the original model was correctly specified. Differences can be caused by differences in the transportation system, in travel behavior, or in urban form. In general it should be possible to transfer models if it is done with care and consideration of the context for both models (*5*).

Everett suggests that including a measure of spatial context in models of how much people travel can improve results for transferred models (*6*). Here context means socioeconomic distributions and life cycle distributions. These affect, for example, whether households travel at all on a given day as shown in a comparison of travel surveys for two small areas in Tennessee. The more the context differs between two areas the more difficult it will be to transfer models. This is why relying only on size, as quick-response tools do, is not sufficient. Presumably if one can include a measure(s) of context it will improve transferability. Everett tested a surrogate measure for spatial context using one-mile grid cells and dividing the

population within the cell by the area of the cell (population density) and then grouping the results into urban, suburban, and rural area types (*6*). The results of the investigation showed that including a measure of this type can improve models transferred spatially. This would seem to be a useful finding, because the measure could be calculated by analysts in rural and small urban areas. The research is useful for this study because it compares data across small urban areas in Tennessee and Ohio.

In general it appears from the literature that the more context can be included in models, the more they can be transferred from one place to another. A key challenge is to develop models that improve transferability while relying on measures that are available and easily calculated by rural and small urban practitioners.

3.2.2 Transportation System Data

Transportation system data describes the location, configuration, and the capacity, speed and operational characteristics of transportation infrastructure. All fifty states have both a state web site and state DOT web site that serve as portals to state data resources and contacts. Of more use to local and small area planners are sites at forty-nine of fifty states that make traffic counts available including thirty-eight that provide at least limited count histories that are useful for analyzing trends in traffic volumes. Twenty-three states make classification or truck counts available online and a few more offer classification counts on request. Only twenty states do not appear to have classification counts available online in some form. Twenty-seven states provide road GIS mapping with some providing an extensive set of attributes (number of lanes, posted speeds, functional classification, access control). Forty-three states have state GIS mapping available, though the amount available varies. Some states are getting efforts under way to provide clearinghouse functions for GIS data and this appears to be an emerging approach for leveraging GIS investments made at different levels of government.

Because information about freight can provide important insights into economic activity and potential conflicts with other modes and users, this review included a search specifically for applicable freight data. Freight data are collected by federal agencies and by other public and private entities on a regional, state, or national level. There are many sources of freight data; a review of available freight data in the US identified 32 data sources (*7*). However, these data collection efforts are not coordinated, and the resulting data sets contain varying aspects of freight movements. See the first appendix for additional details on the freight datasets described below.

The Commodity Flow Survey (CFS) is the primary public source of national and state level data on domestic freight shipments in the United States. It is a joint effort by the Research and Innovative Technology Administration, the Bureau of Transportation Statistics, the US Census Bureau, and the US Department of Commerce. It has been conducted every five years since

1993, most recently in 2007. Freight transportation characteristics are collected, such as commodity types, origins and destinations, values, weights, modes of transport, distance shipped, and ton-miles of commodities shipped. The CFS is the only publicly available source of commodity flow data for the highway mode. The limitation of this data set is that it only samples establishments in mining, manufacturing, wholesale, auxiliaries, and selected retail industries. Establishments classified in transportation, construction, agriculture, and most retail and service industries are excluded from the survey. Another limitation is that CFS only provides data at national, state, or MSA level; therefore it does not provide much information for a regional or local freight analysis.

Some examples of other public freight databases include the rail Carload Waybill Sample from the Surface Transportation Board (STB), the Vehicle Inventory and Use Survey (discontinued after 2002) from the US Census Bureau and the Transportation Annual Survey (also known as the Motor Freight Transportation and Warehousing Survey) from the US Census Bureau.

One of the most widely used freight data resources is the proprietary database TRANSEARCH INSIGHT (also known as Reebie TRANSEARCH database). The database was created by combining information from public sources (including CFS) and private sources (primary shipment data from major freight carriers). It has been updated on an annual basis since 1980. Compared to CFS, the TRANSEARCH INSIGHT database contains freight data from more industries, and it can provide freight movement data at the county level. The limitation of this database is that its accuracy and reliability cannot be verified and it can be obtained only at cost. However, some state DOTs purchase TRANSEARCH and local planning agencies or researchers may be able to acquire the data by requesting it from their DOT.

Some metropolitan areas also collect their own freight data through commercial vehicle surveys, such as Atlanta, Denver, and the Triangle region (Raleigh-Durham-Chapel Hill). Such surveys usually collect trip rate, trip length, origin, and destination for commercial freight vehicles. Some state DOTs and local planning agencies intermittently collect traffic counts by FHWA vehicle classification, which can yield regional or local freight data.

For data on transit systems, the most extensive is the National Transit Database (NTD) where transit agency and ridership statistics from over 660 transit providers are compiled from mandatory reporting requirements for transit agencies that are supported by Federal Transit Administration grants (both rural and urban grant programs included; *8*). Data include service area statistics, type of service provided, transit fleet characteristics, and cost and service effectiveness measures. The data are updated annually and are publicly available. The American Public Transportation Association also releases data about transit systems, including detailed information about individual systems that do not report to the NTD (*9*). These data include

passenger miles, number of passenger trips, annual vehicle revenue miles and hours, and the size and characteristics of the agency fleet.

Unfortunately, a national archive of all fixed route transit service was not found. However, state DOTs and MPOs are likely to have current route maps readily available; although for local agencies these maps may not be in a format that is easy to use in analysis (e.g. GIS).

3.3 Economic and Land Use Data

The data review searched for datasets that collect economic data, employment data, and land use data. There are a number of data resources that provide information about economic activity including productivity, employment, and participation in targeted economic development programs. For example Longitudinal Employer-Household Dynamics (LEHD) provides quarterly longitudinal workforce information by industry, including work force residential location and work location, and industry employment gain and loss (*10*). However, agriculture sector activity is frequently not included, making this resource less useful for rural areas. Of more applicability for rural areas is the US Department of Agriculture's (USDA) Atlas of Rural and Small-Town America. This resource was developed as part of the USDA Economic Research Service and "promotes the well-being of rural America through research and analysis to better understand the economic, demographic, environmental, and social forces affecting rural regions and communities" (*11*). The atlas provides county-level data on demographics, agriculture, flows of labor and commodities between counties and rural characteristics, such as percent of the workforce engaged in agriculture, and amount of land under agricultural production.

Detailed information about nonfarm employment is available from the federal Bureau of Labor Statistics (BLS) through their monthly releases of current employment statistics, which cover some 140,000 businesses and government agencies nationwide (*12*). BLS also reports prices, living conditions, and employer costs through its Consumer Expenditure Survey and the Employment Cost Index. Consumer Expenditure Survey data, used by the research team to develop the project's analytical methodology (see below), are available for the nation, the four U.S. census regions, and certain Metropolitan Statistical Areas; public-use microdata are also available. The US Census Bureau also collects detailed information on the US economy every five years and reports the data on multiple scales, to as fine as Census Place, making it applicable to small communities, although because this survey has frequently not collected agricultural sector data, it may not be useful for rural areas (*13*). The Economic Census reports number of business establishments, sales and receipts, annual payroll, and number of employees. The National Association of Counties (NACO) collects information about county-level economic conditions and local government activities; however data are available only to NACO members (*14*).

Employment and wage data are collected by state employment security agencies as part of the Quarterly Census of Employment and Wages (formerly the ES-202 program) in all fifty states (*15*). Employers subject to state and federal unemployment compensation laws are required to file reports providing a rich data source for states covering 99.7% of all wage and salary civilian employment. The reports filed by employers are confidential, but the information in the reports can be combined with information filed by other employers to give a profile of employment by county. Some states provide information on employment by two- or three-digit North American Industry Classification System (NAICS) codes by county. It is important to note that data reporting is suppressed if there are only a few establishments in a class (less than three for example) or if one establishment has most of the employment in a class (greater than eighty percent for example). Data provided by states can include current and historic total wages and number of employees by NAICS two-digit categories at the county level. States may provide employment projections by state and some aggregation of counties such as economic development regions. Data are available from both the federal Bureau of Labor Statistics and also frequently from state employment security agencies. It should be noted that information is not available for individual employers.

Population data for non-census years at the county level is frequently available through state administrative departments or economic development departments. When available, these sites may provide information on migration and other helpful data beyond tabulations of population counts. Some states prepare population projections based on demographic analysis including births, deaths, and migration that can be used as a basis for transportation forecasts. For example, Ohio provides population projections by county from 2008 to 2018 for five-year age cohorts. The US Census Bureau also provides population estimates for counties including demographic components of change (births, deaths, migration) and by demographic characteristics (age, sex, race, and Hispanic origin). The US Census Bureau maintains an online clearinghouse of information from states participating in the Federal State Cooperative Program for Population Estimates (*16*).

Finally, there are some data resources that document the digital economy. The US Census Bureau collects information on e-commerce in a series of manufacturer, retail, wholesale and service sector surveys (*17*). The e-Stats program reports the value of goods and services sold online, but excludes agricultural products. While not technically a dataset, The US Department of Labor Employment and Training Administration oversees an economic development program called Workforce Innovation in Regional Economic Development (WIRED). WIRED is designed to provide a framework for coordinating regional economic development that includes benchmarking and tracking progress over time (*18*). Participating regions develop a data collection tool that "incorporates economic, research and development, investment and real-time job information to provide a current and accurate picture of the regional economy and its

assets" (*18*). With nearly 40 regions across the country participating, this program may yield additional data relevant for this project.

3.4 Literature Review

In addition to data resources, the project team sought out empirical research and qualitative analyses that can shed light on the relationship between travel behavior and land use in small communities and rural areas. The review adds to the data review by describing the direction, strength, and size of effects, thus providing insights for later tasks. The literature review also sought examples of approaches used by other researchers that may inform practitioners.

The research literature on land use and transportation is extensive, and a great number of researchers have studied this relationship, yet their work has been largely focused on urban areas, where traditional transportation issues such as congestion, air quality, and transit planning are high priorities. Because of metropolitan planning requirements and greater institutional and funding capacity, metropolitan areas enjoy much greater data availability, frequently at high levels of quality and detail, allowing for robust empirical studies. As this study is focused on developing methodologies for small communities and rural areas, findings from studies of metropolitan regions must be approached with some caution, both because they may utilize data unavailable outside metro areas, and because the characteristics of metro areas and metro area residents may be different.

3.4.1 Land Use and Travel Behavior

Because a transportation network is the only possible way to physically connect locations and the persons embedded in their constituent social and economic networks, the built environment shapes daily personal travel behavior in a number of ways. The built environment has been represented in statistically-oriented travel studies through the five "D variables" (*19*): density (of population or employment), diversity (of land uses), design (of the road network), destination accessibility (separation between selected origins and destinations), and distance to public transit (or the intensity of public transit provision).

What can we learn from those studies that is convincingly applicable to small communities and rural areas? We will briefly examine methodology and results, drawing primarily on the critical overviews prepared by the National Research Council's Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption (*19*), Antonio Bento and colleagues (*20*), and Reid Ewing and Robert Cervero (*21*).

The methodological feature that is most significant to our own study is the way in which the built environment is analyzed. Implicit in any particular study is a typology of urbanized areas, metropolitan statistical areas, or urban or suburban neighborhoods, i.e., the locales in which a study is grounded. Therefore the issue for our study is whether the five D's are generalizable to

our universe of study areas. The issue is one of appropriate application, not relevance: travel behavior—vehicle miles traveled, trip frequency, trip length, and mode choice—can hardly not be influenced by density, diversity, design, destination accessibility, and distance to public transit.

Our typology of small communities and rural areas reflect density, diversity, design, and destination accessibility. The measurements of those attributes are adapted to the conditions that are unique to such locales. (The section in this report on the typology provides details.)

- *Population density*. Our density variable is population density, measured with respect to developed or developable land. In a study of national extent, the calculation of density must use a denominator that is developed or developable land, not total area nor even total area less water. To meaningfully convey density, the denominator must exclude not only water but also protected lands such as parks, wilderness areas, private nature preserves, wildlife refuges, weapon testing grounds, etc. Those exclusions are necessary for unbiased comparisons of the density of settlement no matter which counties are being compared. Thus a fair comparison may be made of a gateway to a national park and a working landscape comprising town and village, industry and agriculture, and shopping mall and main street. (Looking ahead, it will be important to make sure that physical constraints on community growth are incorporated into the scenario designs.)
- *Diversity and destination accessibility*. We use land-use mixture to represent diversity and destination accessibility. The land-use mixture variable that we use measures the extent to which an area's residents live near commercial or service-*oriented* establishments.
- *Design*. Our design variable is road density: center-line miles per unit of developed or developable land.

As noted above, we did not find a comprehensive catalogue of fixed-route transit service (see below). Therefore, constructing a measure of transit provision would prove a difficult task. Further, to properly measure transit provision, we would have to either obtain the locations of all bus stops and calculate the shortest network distance from residences and business establishments to bus stops, or obtain the locations of every route and calculate route density (route miles per unit area of developed or developable land)—a daunting task for a nationwide

analysis encompassing more than 2,600 counties. What can be said about transit in rural areas and small communities, is that some degree of transit is provided, if only demand-response, social services transit. Therefore, where appropriate, transit will be considered as a potential influence for changes in travel behavior in our study areas.

While recognizing the hundreds of empirical investigations of the built environment's influence and multiple literature reviews, the study by Bento et al. (*20*) represents the literature sufficiently for our purposes. Theirs is a signature study because the Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, in *Driving and the Built Environment*, cites it as the source of their upper-bound estimate of the change in travel that may be achieved by a substantial alteration of a region's built environment, a 25% reduction in vehicle miles traveled (*19*, p. 89); the built environment is defined by road density, supply of public transit, population centrality, jobs-housing balance, city shape, and population density. It is important to observe that the study investigates 114 urbanized areas within Metropolitan Statistical Areas, not small communities or rural areas. We hesitate to extrapolate the results of their investigation to our study areas, but we believe that there is merit in asking whether similar changes in the built environment in small communities and rural areas could have a similar or greater effect.

As travel is essentially the way that locations are connected, land use patterns shape travel behavior in a number of ways. Ewing and Cervero note there is an empirically observed relationship between the built environment, and among the commonly studied relationships is the influence of density on travel behavior (*21*). One such study, found that high density and a higher degree of mixed land uses increase nonmotorized travel (*22*). Concentrations of activities can be an effective strategy for reducing driving in downtown districts or small town Main streets, sometimes referred to a 'park once' districts (*23*). Researchers surveyed suburban and smaller urban areas in Northern California and found that proximity to destinations such as a library, theater, or post office was negatively associated with non-motorized travel, reflecting an overall quality of accessibility in the study locations (*24)*.

Refocusing development into small-scale districts that do not require driving faces significant challenges stemming from the regionalization and increasing scale of shopping and services destinations, including medical services and industrial parks that has redirected travel and increased overall driving especially for fast-growing rural areas at the metropolitan fringe (*23*). This is reinforced by one of the previously mentioned Canadian studies that found medical trips an important destination, and that 72% of trips for medical purposes were to urban locations, while a similarly large share of work trips (60%) were to urban locations (*24*).

As for land use characteristics that reduce driving, Ewing and Cervero's meta-analysis found that high densities of destinations had the greatest effect on reducing driving to jobs, although

the effect is relatively small (an elasticity of -0.20; *20*). Similarly, Brownstone offers a critical review of the literature and concludes that land use changes can have "negligible impacts" on reducing VMT, and suggests fuel taxes, congestion pricing, parking restrictions, and socioeconomic factors are more effective than increasing density (*25*).

Driving and the Built Environment points out some of the challenges to making substantial changes to existing development patterns, including the longevity of housing stock, zoning and other regulatory constraints, and real estate loan and financing structures that favor segregated uses and dispersed structures (*19*). Still this study found density, especially at employment destinations, to be significant for increasing walking and transit use.

While analyses find important relationships between settlement patterns and travel behavior, the effects of changes in individual attributes of the built environment tend to be small, and creating large-scale change in settlement patterns that will deliver appreciable changes in travel behavior is unlikely in the near term. This crucial point is made in *Driving and the Built Environment*: "significant increases in more compact, mixed-use development will result in modest short-term reductions in energy consumption and CO_2 emissions, but these reductions will grow over time" (*19*, p. 6). The built environment in growing small communities and rural areas is changing incrementally, and plausible changes in the pattern of new development can support simultaneous incremental improvements in accessibility and per-capita air pollutant emission rates.

3.4.2 Travel Behavior and the Transportation System

It seems reasonable that many of the system factors shown to have an effect on travel behavior in urban areas also applies, at least generally, in small communities. Rural areas, however, present a particular challenge. By definition, they are unlikely to have appreciable levels of density of housing, jobs, or street networks, or to have robust transit systems. So what can the research tell us about rural households' travel choices? How do rural households differ from urban households and in what ways are they similar?

As discussed above, transportation system characteristics are understood to have an important relationship with travel behavior. Aside from density of the roadway network, studies have investigated this relationship by analyzing large scale system characteristics which illustrate broad trends in rural areas and small communities. For example, using NHTS data Zhang et al. found that holding location types constant (large urban, small urban, rural), households living at greater distances from urban centers had lower rates of VMT (*26*). These authors conclude that households further from urban centers make fewer trips to the center. Similarly Pucher and Renne found (*27*) rural households make 5% fewer trips, but cover 38% more miles per person per day than their urban counterparts. Focusing on rural areas, a paper using FHWA's Highway Performance Measurement System data found race, gender, and per-capita income important

factors for forecasting VMT, and that telecommuting does decrease VMT in rural areas (*28*). There seems clear evidence that distance has an effect on decisions people make of how often and even whether to travel. This has important implications for understanding broad patterns for rural areas and for small communities that interact with urban areas.

Another important strand of research is related to accessibility. While accessibility is defined in many different ways, both quantitative and qualitative, it essentially means the ease and ability of people to connect places and activities, and is included in our project through our Diversity and Destination Accessibility variable. Illustrating the strength of this measure for non-motorized travel in urban areas, Ewing and Cervero found providing pedestrian connections between where people live and where they work to be important in the choice to use a mode other than auto (*19*). In fact, these connections were found to be more important than land use mix, which is considered an important driver of the choice to walk or cycle. Kwan offers some criticism of accessibility measures that are based on network or built environment characteristics because these fail to capture personal accessibility, making the valid point that it is a fallacy to assign an accessibility score for a spatial unit (Census tract, TAZ, etc.) to the people who reside in that unit because it assumes demand matches the available destinations (*29*).

In considering accessibility at a regional scale, the Rural Policy Research Institute evaluated priorities for rural areas and small communities: communities on the urban fringe want access to jobs in the adjacent cities, tourism destinations want access to their attractive assets and amenities, while resource-based places (agriculture or resource extraction) want market access and economic diversification (*30*). Guidance for rural transportation planners similarly suggests that very different demand management approaches are needed for different types of rural places (*31*). Planners must address these local concerns with tools that allow them to construct scenarios and options that fit with a range of community needs.

Household demand is shaped by many factors, and a considerable amount of research has been carried out to understand these factors. Demographics and income are well established as important determinants of travel behavior. Yet again, studies focusing on small communities and rural areas are sparse and, especially for rural areas, are quite limited in scope. They are mentioned here because they offer some insights into transportation concerns that are unique to rural areas and may offer insights for later project tasks.

Comparing rural to urban residents, Pucher and Renne found the rural poor covering 59% more miles and the rural affluent traveling 31% more miles than their urban counterparts; rural elderly residents also cover more distance than the urban elderly (*27*). A series of studies using Canadian data focus on rural elderly residents' transportation decision-making processes. One such study asked if rural elderly residents face mobility challenges when they can no longer

drive to determine the need for alternatives for this special population (*32*). Based on travel diary information and GPS data, the study found most trips would still be taken with a friend or family member, although most respondents preferred a solution that would not involve depending on friends and family (*32*). The most difficult trips to continue to make when driving was no longer an option were medical trips—the most critical life maintenance trips—pointing up the importance of providing transportation choices in rural areas. Saenz describes differences between temporal differences between rural and urban areas because of variation in work schedules (*33*): Rural workers are more likely to work shifts other than the traditional 9.00 AM to 5.00 PM shift; they are far more likely to report to work between noon and midnight. This difference is particularly evident among black, Latino, and low-income workers, raising questions about whether work schedules may promote greater social isolation for these groups by creating scheduling conflicts with child care, school activities, and health care appointments and suggesting that these groups may have particular transportation needs such as for greater span of transit service (*33*).

While transit is often a reflex response to questions of how to reduce driving and provide mobility options for elderly non-drivers, a recent paper by Thakuriah using data from employment access programs offers an important caveat on costs of transit services: combining costs and subsidies, demand response transit services are expensive (*34*). Still, a TCRP report on the economic impacts of rural public transportation found the greatest benefits returned from transit trips in these areas stem from trips for employment, education or training, medical services (especially dialysis), and trips that keep people with disabilities and the elderly independent (*35*). Despite these benefits, transit is difficult to effectively operate in low density, low population areas. Illustrating the impact of this fact, in 2005, the Bureau of Transportation Statistics reports almost 40% of rural residents nationwide had no local transit service in their communities (*36*). Transit service connecting rural areas to regional destinations is similarly limited. Amtrak currently serves only 200 non metropolitan stops on its routes nationwide, and few of those stops have local transit connections (*30*). Although in recent years, intercity bus is staging a comeback, service is offered only in a handful of markets.

Coupled with and related to cost, non-urban and low-density settlement patterns are clearly an important factor in the general lack of transit options outside metropolitan areas. The important early work of Pushkarev and Zupan evaluated a range of transit service types to identify the development patterns needed to make them cost-effective and provides some empirically derived 'rules of thumb' for considering transit (*37*). In general, they calculate a density of approximately 6 dwelling units per acre is needed to make even low-volume, dial-a-ride service feasible. These authors make an important point with respect to planning and policy to build potential for transit: policies that cluster *nonresidential* floor space are most effective for creating a transit-ready land use pattern, even more effective than increasing

residential densities. This is especially relevant for this study, because small communities and rural areas are likely to resist policies to substantially increase residential densities to levels that will support fixed route transit.

Several reports document concerns about truck traffic in rural areas and small communities. There are a number of factors that have changed truck movement in ways that impact these communities. Rural stakeholders and planners reported concerns about trucks including the increase in truck volumes on rural highways as a result of the North American Free Trade Agreement (NAFTA; *31*). Areas with concentrated animal feeding operations (CAFOs) have also seen increased truck traffic to serve the livestock and feed hauling needs of this recent form of agricultural production. An additional change has been the deregulation of the trucking industry itself, which has led to an increase in the number of small trucking firms, many of which are located outside metropolitan areas (*31*). Twaddell and Emerine also note that the broad shift away from rail to trucks has increased truck volumes through rural areas and small communities (*36*). While it is unlikely that small communities and rural areas will see congestion at a level that significantly affects truck movement, Wheeler and Figliozzi found that congestion greatly increases pollution from trucks posing a risk to human health, and levies additional costs from delay and unreliability. Although this was an urban study, it does suggest the importance of preserving freight operations for economic and human health reasons (*38*).

3.4.3 Attitudes and Ideologies

Because one of the goals of this project is to develop guidance for practitioners, and because the guidance will suggest changes in transportation systems and land use patterns, the literature review also included studies on the perceptions, preferences, and choices about transportation and land use. This literature can inform scenarios and plans that are meaningful and implementable for small communities and rural areas. The attitudes that underlie travel choices are important factors for transportation planning as they provide insights into how to design projects and programs that will best fit with preferences of the community and therefore have the greatest likelihood of successful implementation.

Several studies offer insight into the attitudes that affect mode choice, especially choices for modes other than driving. These studies suggest potential opportunities to influence travel behavior that may not be evident from traditional studies that analyze only the influence of travel time and economic cost. Some studies are finding other elements at play in mode choice decisions. For example, Chao et al. found that pro-transit and pro-bike/walk attitudes were associated with using transit and non-motorized travel, which indicates a degree of self-selection at work; residents who prefer non-auto modes select residential locations that allow them to satisfy that preference (*24*). A recent paper points out that the assumption that individuals' choice sets include the full range of modes available in their communities, lack of

information or attitudes may mean that they do not in fact consider all modes (*39*). This assumption may underestimate the potential for awareness and information campaigns and overestimate modal shifts based on model projections.

The willingness to walk was examined in an urban-area study; findings include a need to increase the assumed threshold for length of a walk trip from the commonly accepted ¼ mile to 1/3 mile (*40*). This result has important implications for local planners working to increase walk share or plan transit routes. A willingness-to-pay survey that asked about the value of various attributes of proposed transit projects found high value placed on transit projects that incorporated placemaking (plazas, streetscaping, quality built environments), especially among middle and high-income respondents (*41*). Still the most valued transit system attribute was reliability. While these studies are in urban contexts, they offer some insights to transit planners working in small communities and rural areas.

Attitudes are similarly important for local planners proposing changes in development patterns. Several recent analyses are encouraging in this regard, and offer evidence of the value of integrating transportation and land use planning for greater efficiency. A 2011 national survey by the National Association of Realtors found 12% prefer suburbs with only houses, 19% prefer mixed use suburbs, 22% prefer rural, 18% small towns (*42*). This survey also found that preserving farms and open areas was a high or extremely high priority for 53% of Americans, suggesting that planning for those outcomes is valued, even by those who do not live in rural areas. Similar support for rural lands conservation was found in a attitudinal survey on population growth, land use and the environment in California (*43*). A more targeted survey in a California community that had recently held a vote on a farmland preservation measure found strong support for a governmental role in growth management, and that this support was not limited to higher educated and high income groups (*44*).

Further support for land use policy tools was found in a 2010 study survey of two regions (California and the US southwest) and found that places where rapid growth is considered a problem are more likely to support infill development, and that while people generally were content with driving for local trips, a substantial number of respondents preferred a small house with a small back yard and a short commute to a large house with a large backyard and a long commute (*45*). The analysis also found general political ideology to be a factor in whether or not smart growth is favored. The researchers suggest that describing smart growth as an extension of the environmental movement will not resonate with conservatives. This is particularly relevant for planners working in rural areas, where political orientation is likely to be more conservative. For these communities, explaining compact development and efficient transportation systems as a way to greater energy independence, expand consumer choice, design good rental projects for low income people, and provide marketable development are

more likely to be effective (*45*). As a further caution, the USDOT found rural stakeholders skeptical about the livability agenda, which emphasizes greater mode choice and a focus on integrating community, land use, and transportation planning, so particular attention to rural values and concerns are needed to effectively plan in rural areas (*31*). One North Carolina survey found residents and decision makers in small towns in North Carolina supported Main Street projects that improve streetscapes and sidewalks and credit these improvements with generating economic benefits (*46*).

3.5 Implementation Windows: Policy and Practice

In identifying the opportunities for greater integration of land use and transportation planning to promote greater system efficiency and lower emissions, the review considered a range of plans, policy reports, current initiatives at the federal and state level, and typologies that have been applied to rural and small communities. These ideas are documented here as potential inputs to future project tasks, including practitioner guidance.

One of the clear messages from the federal level is that policies and planning for transportation and land use planning need to be aligned as evidenced by the formation and activity of the Sustainable Communities Partnership between HUD, EPA, USDOT, and the USDA. FHWA is also supporting the livability agenda through various programs (*23*). This policy direction is being implemented by the distribution of grants to communities who are forming a peer group who are planning, designing, and building projects that connect transportation, land use, and economic development. While not enough time has passed for the results from the first cohort of grantees to be assessed as to the success or failure of plan or project outcomes, it is likely that this group will generate a substantial number of exemplary projects in the coming years.

In the interim, good examples are available in the report *Noteworthy MPO Practices in Transportation-Land Use Planning Interaction*, where an evaluation found willingness for the transportation agency to take the lead while recognizing that land use decisions are made by a diverse set of actors largely outside the traditional transportation planning arena as a critical factor for success (*34*). A similar review of best practices by Bartholomew (*49*) found local land use authorities only rarely used scenario planning, perhaps because they take a conservative approach to land use controls or because they view the issues as regional in nature, and not for local planning. Still, Dalbey recommends visioning for rural communities; to avoid overreaction to rapid growth or to overcome misplaced concern about land use planning in places who are seeking to grow, both of which can have unintended and negative consequences for the community over the long term (*48*).

In addition to scenario planning, several resources suggest additional tools to integrate land use and transportation planning or bring about shifts that reduce driving. Zhang el al. reports an interesting relationship between VMT and locations with non-attainment status under the

Clean Air Act; this study concluded that the various policies and programs implemented in response to receiving a designation as a nonattainment area and implementing air quality improvement projects and programs (e.g. CMAQ programs including ridesharing, vehicle inspection and maintenance, special fuels programs, transit, telecommuting, etc.) result in household VMT reductions (*26*). This result suggests that similar programs could reduce VMT, perhaps even in small communities and rural areas even though attaining air quality compliance is not a concern.

Another approach, also within the purview of transportation agencies, is access management. A report for AASHTO describes access management as a tool to integrate land use into transportation projects to reduce induced growth, and is especially appropriate for rural areas and small communities (*49*). Still, most reviews of effective policy instruments focuses on land use elements such as incentives for infill or redevelopment, linking natural resource conservation with processes, and coordinating development at the regional level (see e.g. *36*, *50*, *51*, and *52*). California and Vermont have exemplary efforts to integrate transportation and land use planning through designating not only areas that should remain rural, but also locations where the favored strategy is growth (*53*, *54*).

It is worth noting the large number of policy documents and studies that offer typologies of rural areas and small communities, which provide different lenses for evaluating these communities or different priorities for planning, although they do not include transportation characteristics. Some typologies are based on amount of development and proximity to an urban area (*23*). Other typologies have included economic factors, growth patterns, and transportation concerns which point out the heterogeneity among rural places. Residents, too, recognize the unique concerns of their communities. In Hamilton et al., results from a survey of rural residents identified a range of concerns, many of which are related to economic transition, and resulting in out- or in-migration (*55*). Other planning challenges these authors identify include a lack of cohesion or strong civic institutions in poor areas, outdated funding mechanisms that provide inadequate support for rural infrastructure. This diversity of contexts indicates a range of planning approaches and tools are required to successfully address local needs.

Very few studies use land use data to define types of rural areas. One exception is Hartter and Colocousis, who used the National Land-Cover Dataset to identify change in land cover (deforestation to development) in three US regions (*56*). The land-cover analysis was compared with residents' attitudes about growth, decline, and future prospects. The study found that regions with similar land use change were quite heterogeneous with respect to the forces driving change; in the Pacific Northwest, rapid land-cover change is associated with sprawl and rapid growth while land-cover change in Appalachia is attributable to mining and the

population is in decline with few economic prospects. This study demonstrates the need to understand the economic forces underlying land use change if the goal is to provide meaningful policy tools and options for local practitioners and decision makers.

3.6 Data Resource Summaries

3.6.1 American Community Survey (ACS)

Collected by census bureau, ACS is a national continuous rolling sample. Each survey covers different parts of the country; state or local can request add-on samples for specific areas that routine sample plans have not yet covered.

It has similar information as a regional household survey. For any survey year, the samples are sparse. Thus an average of consecutive years is provided, such as a 2006-2008 average, 2005-2009 average, and so on.

The spatial data are provided at high resolution on request: latitude/longitude coordinates for household and trip end locations can be obtained by researchers.

Census Transportation Planning Products (CTPP) will now be prepared using the ACS data instead of the decennial census. The last time the CTPP was prepared using decennial census data was in 2000. Please refer to the data review summary of CTPP for details.

1. Data category: Travel behavior
2. Data collection time frame: 2000, 2005 – present
3. Data collection frequency: Continuous rolling
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/acs/www/)
5. Date of access: July 11, 2011
6. Organization that collected the data: US Census Bureau
7. Availability: Public
8. Smallest level of geography available: Same as NHTS. Generally to census tract (if not block group) but researchers may obtain further detailed geo-information via special request.
9. Small urban or rural: Both, variables can be used to select either
10. National or local coverage:

- National
- PUMS summary data available for areas with Population ≥ 100K only

- Many information summaries are available at state, county, place, township, village, city CDP, or tract level/block group level (have to work together with other census data for a complete picture)

11. List of variables of interest:

In addition to the usual household travel survey information collected, ACS also collects the following additional information:

- Household: Cost of utilities for electricity, gas, water and sewer; food stamps used; household composition and employment status (local economic environment); family income and household income; householder and spouse work status
- Person: Disability (can be associated with mobility difficulty, demand for special transportation service); health insurance coverage; poverty status
- Workers: Employment status (laid off, looking for a job, hours/days worked); occupation and duty detail; earnings (in addition to household total income)
- Employer of the worker: Industry details (NAICS, can be used to identify if agricultural industry or local dominant industry); business type (non-profit, etc.)
- Housing unit: Size of the lot; annual agricultural product sale (a measurement of rural economy); existence of business/medical office on site; if farm residence; physical structure details (number of rooms); plumbing facilities; phone service available; rent; property value; real estate tax; mortgage (if there is one and if so the amount paid monthly); fire/hazard/flood insurance
- Land use (aggregated level to the geography resolution of choice, e.g. state, county, place, tract or block group): Median and mean household income by household size; per capita income; poverty status; place of work – census designated places and/or Minor Civil Divisions (MCDs), number of housing units; number of occupied and vacant dwelling units; means of transportation to work by a) vehicles available, b) time leaving home to work, c) travel time to work; aggregate travel time to work (by place of work-state and county level); aggregate number of vehicles used in commuting; time leaving home to work; travel time to work (and for workplace geography); median earnings by

a) work experience, b) means of transportation to work for workplace geography; mean usual hours worked

12. Detailed information:

Sample size: From 2000-2009, it sampled 12.5 million housing units and 435,000 persons in group quarters. Sampling of persons in group quarters did not start until 2007. Sample of group quarter persons did not start till year 2007. In 2009, ACS sampled about 1.9 million housing units and about 147,000 persons in group quarters (Table 7).

Table 7: ACS – Sampled Units 2000-2009

Year	Housing Units (NOT persons)	Group Quarters Population (Persons)
2009	1,917,748	146,716
2008	1,931,955	145,974
2007	1,937,659	142,468
2006	1,968,362	N/A
2005	1,924,527	N/A
2004	568,966	N/A
2003	572,447	N/A
2002	512,768	N/A
2001	601,875	N/A
2000	587,519	N/A
10-Year Total	12,523,826	435,158

Table 8: ACS – Key Information at the Aggregated Level

Potential Useful Info	Table Title	Availability of data for Geographies other than Block Groups		Availability of data for Block Groups Only in Summary File
		In Summary File AND American FactFinder	Only in Summary File	
Land use	Total population	x		x
Land use: Income	Household income in the past 12 months	x		x
Land use: Income	Median HH income in the past 12 months by HH size		x	
Land use: Income	Median household income in the past 12 months	x		x
Land use: Income	Per Capita Income In The Past 12 Months	x		x
Land use: Income	Poverty status	x		
Land use: Commute Work place	Place Of Work For Workers 16 Years And Over-Not Metropolitan Or Micropolitan Statistical Area Level	x		x
Land use: Housing	Housing Units	x		x
Land use: Housing	Occupancy Status	x		x
Land use: Housing	Vacancy Status	x		x
Travel: Commute mode	Means Of Transportation To Work By Age		x	
Travel: Commute total travel time	Aggregate Travel Time To Work Of Workers By Sex	x		
Travel: Commute total travel time at work place	Aggregate Travel Time To Work Of Workers By Place Of Work-State And County Level		x	

Potential Useful Info	Table Title	Availability of data for Geographies other than Block Groups		Availability of data for Block Groups Only in Summary File
		In Summary File AND American FactFinder	Only in Summary File	
Travel: Commute total vehicles used	Aggregate Number Of Vehicles Used In Commuting By Workers 16 Years And Over By Sex		x	
Travel: Commute Mode	Means Of Transportation To Work	x	x	x
Travel: Commute Mode by vehicle available	Means Of Transportation To Work By Vehicles Available	x		
Travel: Commute Mode by time period	Means Of Transportation To Work By Time Leaving Home To Go To Work	x		
Travel: Commute Mode by trip time length	Means Of Transportation To Work By Travel Time To Work	x		x
Travel: Commute time period	Time Leaving Home To Go To Work	x	x	
Travel: Commute trip time length	Travel Time To Work	x	x	
Travel: Commute time	Aggregate Travel Time To Work Of Workers By Means Of Transportation To Work For Workplace Geography		x	
Travel: Commute	Time Arriving At Work From Home For Workplace Geography		x	

Potential Useful Info	Table Title	Availability of data for Geographies other than Block Groups		Availability of data for Block Groups Only in Summary File
		In Summary File AND American FactFinder	Only in Summary File	
time period				
Travel: commute travel time	Travel Time To Work For Workplace Geography		x	
Worker: Earning	Median Earnings In The Past 12 Months	x		
Worker: earnings by commute mode	Median Earnings In The Past 12 Months By Means Of Transportation To Work For Workplace Geography		x	
Worker: Work hours	Mean Usual Hours Worked In The Past 12 Months For Workers 16 To 64 Years		x	

3.6.2 American Public Transportation Association (APTA)

APTA produces numerous public transit system data products based on the information provided from its members: the vehicle database, fare report, and infrastructure report, and most importantly to the research project: the annual Fact Book. The Fact Book states that it provides information for "all public transportation systems, including those that do not report to the National Transit Database." Summary information at the state, local and national level is available to the public, as is detailed information for some transit systems.

The 2011 edition of the Fact Book reports 2009 statistics from transit agencies serving a Urbanized Zone Area (UZA) population of at least 50,000. As a result, many small communities and most rural area transit providers will not be included in the database. University transit systems also do not appear in the database (e.g., Duke, NCSU, and UNC).

1. Data category: Transit system
2. Data collection time frame: Longitudinal
3. Data collection frequency: Annual
4. Source for data set: American Public Transportation Association

   (http://www.apta.com/resources/links/Pages/default.aspx)
5. Date of access: July 21, 2011
6. Organization that collected the data: American Public Transportation Association
7. Availability: Public
8. Smallest level of geography available: Urbanized area (minimum population 50,000)
9. Small urban or rural: None reported below 50,000 population
10. National or local: National
11. List of variables of interest:

APTA data include the following operating statistics of for all transit agencies, in categories of 1) agency total (all modes combined); 2) by mode; and 3) by urbanized area:

- Vehicles Operated under Maximum Service
- Vehicles Available for Maximum Service
- Annual Vehicle Revenue Miles
- Annual Vehicle Revenue Hours

- Unlinked Passenger Trips
- Passenger Miles

12. Detailed information:

Table 9 displays an example of the data.

Table 9: APTA 2011 Fact Book - Agency Modal Totals – Example: NC (Extracted)

Agency	City	UZA Name	UZA Population	Mode
Asheville Transit System(ATS)	Asheville	Asheville, NC	221,570	DR, MB
Cape Fear Public Transportation Authority(Wave)	Wilmington	Wilmington, NC	161,149	DR, MB
Capital Area Transit(CAT)	Raleigh	Raleigh, NC	541,527	DR, MB
Chapel Hill Transit(CHT)	Chapel Hill	Durham, NC	287,796	DR, MB, VP
Charlotte Area Transit System(CATS)	Charlotte	Charlotte, NC-SC	758,927	DR, LR, MB, VP
Durham Area Transit Authority(DATA)	Durham	Durham, NC	287,796	DR, MB
Fayetteville Area System of Transit(FAST)	Fayetteville	Fayetteville, NC	276,368	DR, MB
Greensboro Transit Authority(GTA)	Greensboro	Greensboro, NC	267,884	DR, MB, VP
Guildford County Transportation(GCTAMS)	Greensboro	Greensboro, NC	267,884	DR
High Point Transit(Hi Tran)	High Point	High Point, NC	132,844	DR, MB
North Carolina State University Transportation Department(NCSU)	Raleigh	Raleigh, NC	541,527	MB
Piedmont Authority for Regional Transportation(PART)	Greensboro	Greensboro, NC	267,884	MB, VP
Research Triangle Regional Public Transportation Authority(TTA)	Research Triangle Park	Durham, NC	287,796	DR, MB, VP
Town of Cary(CTRAN)	Cary	Raleigh, NC	541,527	DR, MB
Western Piedmont Regional Transit Authority(WPRTA)	Conover	Hickory, NC	187,808	DR, MB
Winston-Salem Transit Authority - Trans-Aid of Forsyth County(WSTA)	Winston-Salem	Winston-Salem, NC	299,290	DR, MB

Notes:

1) Mode: DR: Demand response; MB: bus; LR: light rail; VP: van pool
2) Missing: at least Duke, NCSU, and UNC buses

3.6.3 Atlas of Rural and Small-Town America

The US Department of Agriculture/Economic Research Service (ERS) collects and provides comprehensive economic, demographic, and environmental information on rural areas through a spatial interpretation of county-level, economic, and social conditions along four dimensions: people, jobs, agriculture, and county classifications. ERS also provides additional information, based on their research, at the county or census tract level: Economic Type, Policy Type, and Population Interaction Zones for Agriculture (PIZA).

Perhaps the most useful information for this project is a set of spatial measures ERS developed to show the inter-dependency between a rural community (county or place) and the surrounding region, either rural or metropolitan. These measures include: Commuting Zones, Urban-Rural Continuum Codes, and Urban Influence Codes. These indicators measure the relationship between a rural community and the larger region where it is located. This is quite unlike the simple urban/rural definition that the US Census uses to describe an area.

The Atlas supports the interactive analysis and interpretation of the various measures (see details in later section) and products ERS has developed. Any of the measures may be mapped for types of counties, including (but not limited to) those defined as:

- Nonmetro, Noncore, Micropolitan
- Economic base such as if dependent on farming or manufacturing
- High natural amenities
- Persistent poverty

1. Data category: Economic and Land Use
2. Data collection time frame: Longitudinal (1980, 1993 - latest: 2003 based on 2000 census)
3. Data collection frequency: Decennial
4. Source for data set: The U.S. Department of Agriculture – Economic Research Service (http://www.ers.usda.gov/Data/)
5. Date of access: July 19, 2011
6. Organization that collected the data: The US Department of Agriculture - Economic Research Service (ERS)
7. Availability: Public
8. Smallest level of geography available: County

9. Small urban or rural: Rural oriented but at county level (some information at census tract level)
10. National or local: National
11. List of variables of interest:

The following are from the ERS official website:

- People: Demographic data from the American Community Survey, including age, race and ethnicity; migration and immigration; educational attainment; household size and composition
- Jobs: Economic data from the Bureau of Labor Statistics and other sources, including information on employment trends, unemployment, industrial composition, and household income
- Agriculture: Measures from the latest Census of Agriculture, including number and size of farms, operator characteristics, off-farm income, and government payments
- County classifications: the rural-urban continuum; dependence on any economic sector or activity; persistent poverty; population loss; measures for a county's economic interaction with its surrounding region including commuting zones, codes for location on the rural-urban continuum and for the degree of urban influence
    - Economy: dominant economic activity, e.g. farming, manufacture, service, government, etc.
    - Policy Type: housing stress; low educational attainment; low employment; persistent poverty; population loss; economic dependency on recreation; retirement destination community
    - Population Interaction Zones for Agriculture (PIZA): measures the degree of influence that nearby urban-related population exerts on agricultural land

12. Detailed information:

Economic Type—Codes and definitions of the categories are as follows:

- Farming-dependent (440 total, 403 non-metro) counties—either 15 percent or more of average annual labor and proprietors' earnings derived from farming during 1998-2000 or 15 percent or more of employed residents worked in farm occupations in 2000.
- Mining-dependent (128 total, 113 non-metro) counties—15 percent or more of average annual labor and proprietors' earnings derived from mining during 1998-2000.
- Manufacturing-dependent (905 total, 585 non-metro) counties—25 percent or more of average annual labor and proprietors' earnings derived from manufacturing during 1998-2000.
- Federal/State government-dependent (381 total, 222 non-metro) counties—15 percent or more of average annual labor and proprietors' earnings derived from Federal and State government during 1998-2000.
- Services-dependent (340 total, 114 non-metro) counties—45 percent or more of average annual labor and proprietors' earnings derived from services (SIC categories of retail trade; finance, insurance, and real estate; and services) during 1998-2000.
- Non-specialized (948 total, 615 non-metro) counties—did not meet the dependence threshold for any one of the above industries.

Policy Types—These indicators are not mutually exclusive; definitions of the types are as follows:

- Housing stress (537 total, 302 nonmetro) counties—30 percent or more of households had one or more of these housing conditions in 2000: lacked complete plumbing, lacked complete kitchen, paid 30 percent or more of income for owner costs or rent, or had more than 1 person per room.
- Low education (622 total, 499 nonmetro) counties—25 percent or more of residents 25-64 years old had neither a high school diploma nor GED in 2000.
- Low employment (460 total, 396 nonmetro) counties—less than 65 percent of residents 21-64 years old were employed in 2000.
- Persistent poverty (386 total, 340 nonmetro) counties—20 percent or more of residents were poor as measured by each of the last 4 censuses, 1970, 1980, 1990, and 2000.

- Population loss (601 total, 532 nonmetro) counties—decline in number of residents between the 1980 and 1990 censuses and between the 1990 and 2000 censuses.
- Nonmetro recreation (334 designated nonmetro in either 1993 or 2003, 34 were designated metro in 2003) counties—classified using a combination of factors, including share of employment or share of earnings in recreation-related industries in 1999, share of seasonal or occasional use housing units in 2000, and per capita receipts from motels and hotels in 1997.
- Retirement destination (440 total, 277 nonmetro) counties—number of residents 60 and older grew by 15 percent or more between 1990 and 2000 due to in-migration.
- Population-Interaction Zones for Agriculture (PIZA): From http://www.ers.usda.gov/Data/PopulationInteractionZones/overview.htm:

Widespread conversion of rural lands to urban uses has drawn attention at all levels of government. To provide information useful for projections of future changes in land use, ERS has created a system to classify remaining farmland into "population-interaction zones for agriculture" (PIZA). These zones represent areas of agricultural land use in which urban-related activities (residential, commercial, and industrial) affect the economic and social environment of agriculture. In these zones, interactions between urban-related population and farm production activities tend to increase the value of farmland, change the production practices and enterprises of farm operators, and elevate the probability that farmland will be converted to urban-related uses.

For an increasing number of applications, however, classifications for even smaller spatial areas and spatial points (specific latitudes and longitudes) would be useful. The increasing availability of geo-located data, and Geographic Information Systems (GIS) software for its analysis, motivates an additional system. Ideally, that system is complementary to the county-level and census-tract schemes cited above, but capable of classifying even smaller sub-county spatial areas according to the amount of urban-related population interaction to which they are subject. The PIZA codes are a newly available measure that attempts to satisfy that need while providing a bridge to county level measures. In addition, the PIZA codes provide a continuous measure of population interaction, which is more useful for some applications than are the existing ordinal measures.

Commuter Zone (CZ, county level): Each county has a designated commuting zone ID based on the commuting flow exchanges from decennial census. It shows county-to-county exchanges of commuters (going to and/or attracting from) for counties where at least 25% of work trips are

exchanges with a metropolitan or micropolitan area. This information helps define the economic relationship between one county and another. CZ data are available for 1980, 1990 and 2000. Trends in these data can illustrate how a rural, ex-urban community developed in relation to nearby urban areas.

Table 10 shows an example of Commuting Zones in the Raleigh-Durham, NC, region, defined in 2003 using 2000 census information and commuting interaction changes for Vance and Warren counties. In 1980 and 1990 Vance and Warren counties interacted with each other, but by 2000 they show increased interaction with the Durham-Raleigh Commuting Zone. Person County was in the same CZ with Halifax County, VA in 1980, but in 1990, it is shown to have more commuting interaction with the Durham-Raleigh Commuting Zone.

The table also lists micropolitan areas such as Dunn in Harnett County, Sanford in Lee County, and Henderson in Vance County (all census defined non-metro counties). Warren and Granville counties do not have any micropolitan areas based on the 2000 census.

Table 10: 2003 Commuting Zone – Example: 87 - Durham-Raleigh, NC [Extracted]

FIPS (County)	CZ ID 1980	CZ ID 1990	CZ ID 2000	County Name	Metropolitan Area, 2003 (Null means Non-Metro, or 'Rural')	County Population 2000	Commuting Zone Population 2000
37037	34601	01701	87	Chatham	Durham, NC Metropolitan Statistical Area	49,329	1,475,053
37063	34601	01701	87	Durham	Durham, NC Metropolitan Statistical Area	223,314	1,475,053
37069	34601	01701	87	Franklin	Raleigh-Cary, NC Metropolitan Statistical Area	47,260	1,475,053
37077	34601	01701	87	Granville		48,498	1,475,053
37085	34601	01701	87	Harnett	Dunn, NC Micropolitan Statistical Area	91,025	1,475,053
37101	34601	01701	87	Johnston	Raleigh-Cary, NC Metropolitan Statistical Area	121,965	1,475,053
37105	34601	01701	87	Lee	Sanford, NC Micropolitan Statistical Area	49,040	1,475,053
37135	34601	01701	87	Orange	Durham, NC Metropolitan Statistical Area	118,227	1,475,053
37145	32901 Person, NC Halifax, VA	01701	87	Person	Durham, NC Metropolitan Statistical Area	35,623	1,475,053
37181	34602 Vance, Warren, NC	01702 Vance, Warren, NC	87	Vance	Henderson, NC Micropolitan Statistical Area	42,954	1,475,053
37183	34601	01701	87	Wake	Raleigh-Cary, NC Metropolitan Statistical Area	627,846	1,475,053
37185	34602	01702	87	Warren		19,972	1,475,053

Rural-Urban Continuum Code (RUCC, county level): describes the economic relationship between a county and a metropolitan area by population size and adjacency to a metro area.

Table 11: Rural Urban Continuum Codes (2003)

Rural Urban Continuum Codes (2003)
1 = County in metro area, population =(more than 1 million)
2 = County in metro area, population =(250K, 1 million)
3 = County in metro area, population =(0, 250K)
4 = Nonmetro county with urban population = (20K, ∞), adjacent to a metro area
5 = Nonmetro county with urban population = (20K, ∞), NOT adjacent to a metro area
6 = Nonmetro county with urban population = (2.5K, 20K), adjacent to a metro area
7 = Nonmetro county with urban population = (2.5K, 20K), NOT adjacent to a metro area
8 = Nonmetro county completely rural or urban population = (0, 2.5K), adjacent to metro area
9 = Nonmetro county completely rural or urban population = (0, 2.5K), NOT adjacent to metro area

Urban Influence Code (UIC, county level): similar to the RUCC, this measure defines the economic relationship between a county based on population, presence of towns of various sizes, and adjacency to a metropolitan or micropolitan area.

Table 12: Rurality Measurement – Urban Influence Codes (2003)

Urban Influence Codes
1 = Large, in Metro, residents = (1M, ∞)
2 = Small, in Metro, residents = (1, 1M)
3 = Micropolitan, Adjacent to a Large metro area
4 = Noncore, Adjacent to a Large metro area
5 = Micropolitan, Adjacent to a Small metro area
6 = Noncore, Adjacent to a Small metro area w/ a town of residents = (2.5K, ∞)
7 = Noncore, Adjacent to a Small metro and w/ NO town of residents = (2.5K ∞)
8 = Micropolitan, NOT adjacent to a Metro area
9 = Noncore, Adjacent to Micro area and w/ a town of residents = (2.5K, ∞)
10 = Noncore, Adjacent to Micro area and w/ NO town of residents = (2.5K ∞)
11 = Noncore, NOT adjacent to a Metro/Micro area and w/ a town of residents = (2.5K, ∞)
12 = Noncore, NOT adjacent to a Metro/Micro area and w/ NO town of residents = (2.5K ∞)

Table 13 displays a comparison of the RUCC, the UIC, and the US Census designation.

Table 13: ERS Rurality Measures and Census Metropolitan/Micropolitan Statistical Area Designations

NC County	2000 Census Population	2000 Persons per Square Mile	2000 Census % of Com-mute[1]	2003 Metropolitan / Micropolitan Statistical Area Null = Non-Metro	Rural Urban Continuum Codes (RUCC) 2003	Urban Influence Code (UIC) 2003
Chatham	49,329	72.2	0.0	Durham Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M
Durham	223,314	769.2	0.0	Durham Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M
Franklin	47,260	96.1	0.0	Raleigh-Cary Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M
Granville	48,498	91.3	36.2		6 = Nonmetro county w/ urban pop [2.5K,20K), adjacent to a metro area	6 = Noncore, ADJACENT to a small metro w/ town residents ≥ 2.5K
Harnett	91,025	153.0	44.9	Dunn Micropolitan	4 = Nonmetro county w/ urban pop = [20K, ∞), adjacent to a metro area	5 = Micropolitan area ADJACENT to a small metro area
Johnston	121,965	154.0	0.0	Raleigh-Cary Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M

NC County	2000 Census Population	2000 Persons per Square Mile	2000 Census % of Com-mute[1]	2003 Metropolitan / Micropolitan Statistical Area Null = Non-Metro	Rural Urban Continuum Codes (RUCC) 2003	Urban Influence Code (UIC) 2003
Lee	49,040	190.6	2.7	Sanford, Micropolitan	4 = Nonmetro county w/ urban pop = [20K, ∞), adjacent to a metro area	5 = Micropolitan area ADJACENT to a small metro area
Nash	87,420	161.8	0.0	Rocky Mount Metropolitan	3 = County in metro area, pop =[0, 250K)	2 = Small, IN a metro area w/ residents < 1 M
Orange	118,227	295.7	0.0	Durham Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M
Person	35,623	90.8	0.0	Durham Metropolitan	2 = County in Metro area, pop =[250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M
Vance	42,954	169.4	6.7	Henderson Micropolitan	4 = Nonmetro county w/ urban pop = [20K, ∞), adjacent to a metro area	5 = Micropolitan area ADJACENT to a small metro area
Wake	627,846	754.7	0.0	Raleigh-Cary Metropolitan	2 = County in Metro area, pop = [250K, 1 M)	2 = Small, IN a metro area w/ residents < 1 M

[1] % of Commute: Percent of workers in nonmetro counties commuting to central counties of adjacent metro areas.

3.6.4 California Statewide Household Travel Survey

The 2000-2001 California Statewide Household Travel Survey was conducted between October 2000 and December 2001 among households located in each of the 58 counties throughout the State of California. A total of 17,040 households participated in the survey.

Rural counties included in the survey are: Humboldt, Madera, Nevada, Sierra, Kings, Mendocino, Lake, Tehama, Siskiyou, Inyo, Mono, Alpine, Lassen, Modoc, Del Norte, Glenn, Plumas, Colusa, and Trinity. The year 2000 estimated households in all rural counties are 330,095, among which 2,437 households participated in the survey.

1. Data category: Travel behavior
2. Data collection time frame: 2000-2001
3. Data collection frequency: One time
4. Source for data set: Minnesota Metropolitan Travel Survey Archive (http://www.surveyarchive.org/archive.html)
5. Date of access: July 14, 2011
6. Organization that collected the data: California Department of Transportation
7. Availability: Public
8. Smallest level of geography available: latitude/longitude
9. Small urban or rural: Include both small urban and rural communities
10. National or local: Local (statewide)
11. List of variables of interest:

    All the variables listed below were directly collected.

    - Household variables: household size; number of vehicles (bikes); type of dwelling unit (SFH, condo etc.); owner/renter status; household income; household location; number of workers; and number of students
    - Person variables: age; gender; possession of a valid driver's license; employment status; ethnicity; disability status; education; student status; occupation; employment type; and flexibility of work schedule
    - Vehicle variables: vehicle body type (auto, van, RV etc.); whether vehicle is owned or leased; fuel type

- Trip variables: trip purpose; trip mode; transit usage; walking/biking distance to transit stop (in blocks); vehicle occupancy; parking cost; toll cost; departure time; arrival time; departure location; and arrival location
- Place variables: latitude/longitude coordinates

All of the following variables can be derived from the directly collected variables: trip rate (frequency); trip travel time; trip length; journey-to-work trip length; mode share; and VMT.

3.6.5 Census Transportation Planning Package (CTPP)

The Federal Highway Administration provides the CTPP, a set of special tabulations designed for transportation planners and extracted from the decennial census. The data were originally from the decennial census long form (1970-2000). Because of its large sample size (about 16% of households nationwide), the data are considered reliable and accurate; if the 16% sample rate were applied evenly across the country, it should provide good coverage of rural areas. Certainly the CTPP has better coverage for rural areas than any general household travel survey unless a survey specifically targeted rural households. For comparison, the overall household sample rate for the 2006 Greater Triangle (Raleigh-Durham) Household Travel Survey was only 0.9%. Starting in 2005, the CTPP data are drawn from the monthly rolling American Community Survey, and includes similar products.

CTPP travel behavior data are summarized at an aggregated level (e.g., TAZ, or county) into three parts, the so-called "Transportation Profile":

- Part 1: Residence end data summarizing worker and household characteristics
- Part 2: Place of work data summarizing worker characteristics
- Part 3: Journey-to-work flow data (including mode, mean travel time etc.)

1. Data category: Travel behavior
2. Data collection time frame: Longitudinal (previous 1970 – 2000, present)
3. Data collection frequency: Annual summary and average for average of consecutive years from monthly rolling data (e.g., average of 2005-2007, average of 2006-2008, average of 2006-2010)
4. Source for data set: The U.S. Department of Transportation – Federal Highway Administration: (http://www.fhwa.dot.gov/planning/census_issues/ctpp/)
5. Date of access: August 17, 2011
6. Organization that collected the data: Census Bureau
7. Availability: Public
8. Smallest level of geography available: National
9. Small urban or rural: Same as NHTS
10. National or local: National
11. List of variables of interest:

Same as ACS and NHTS; travel-related information including:

- Households: Number of households and persons in the area (by urban and rural); average household size; total workers; employment status; household mean and median income; total workers in households; vehicles available; poverty status; life cycle of household; housing units; vacancy status
- Persons: Age; class of worker; industry of worker; occupation by industry
- Trips: Mode to work; mean and median travel time to work; departure time to work; percent mode share and comparison (e.g., between years 2000 and 2005)

3.6.6 Commodity Flow Survey (CFS)

The Commodity Flow Survey (CFS) is the primary public source of national and state level data on domestic freight shipments in the US. It has been conducted every five years since 1993; the most recent survey was conducted in 2007. The 2007 CFS samples approximately 100,000 establishments from a universe of about 754,000 establishments. The CFS is the only publicly available source of commodity flow data for the highway mode. The limitation of this data set is that it only samples the establishments in mining, manufacturing, wholesale, auxiliaries, and selected retail industries. Establishments classified in transportation, construction, farms and most retail and service industries are excluded from the survey. Another limitation is that CFS only provides data at national, state, or Metropolitan Statistical Area (MSA) level; therefore it does not provide much information for a regional or local freight analysis.

1. Data category: Freight
2. Data collection time frame: Since 1993
3. Data collection frequency: Every 5 years
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/econ/cfs/)
5. Date of access: August 10, 2011
6. Organization that collected the data: Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS), the U.S. Census Bureau, and the U.S. Department of Commerce
7. Availability: Public
8. Smallest level of geography available: CFS geographic areas (there are 123 CFS geographic areas for the whole United States in the 2007 CFS)
9. Small urban or rural: Include both small urban and rural communities
10. National or local: National
11. List of variables of interest:

    All the following variables were directly collected: shipment value; shipment weight in pounds; commodity code from Standard Classification of Transported Goods (SCTG) list; commodity description, origin, and destination; and mode of transportation.

    All the following variables can be derived: trip rate (frequency); distance shipped; mode share and ton-miles of commodities shipped.

All these variables can be derived by geography, commodity type, and modes of transportation.

3.6.7 Economic Census

The economic census provides detailed economic information from the national to the local level. The 2007 data cover most of the U.S. economy in its basic collection of establishment statistics. Other related programs include statistics on minority- and women-owned businesses. Censuses of agriculture and governments are also conducted at the same time.

With surveyed industry employment (by NAICS), the data can be used for identifying typology. However, many industries, especially agriculture (one indicator for rural community), were not surveyed; thus, the data may not be useful for choosing study scenarios.

1. Data category: Economic and land use
2. Data collection time frame: Longitudinal (1997 – latest 2007)
3. Data collection frequency: Every 5 year
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/econ/census07/)
5. Date of access: July 12, 2011
6. Organization that collected the data: The U.S. Census Bureau
7. Availability: Public
8. Smallest level of geography available: Census Place
9. Small urban or rural: Covers small urban area but not rural (or non-metro/non-micropolitan within a county all together).
10. National or local: National
11. List of variables of interest:

Economic data for other industry sectors (by 2007 NAICS, list from 2-digit to 6-digit) could be useful. However, agricultural sector often was not surveyed and data are not available. The 2007 Economic Fact sheet (based on the 2007 Economic Census and the 2007 Nonemployer Statistics) covers the following info:

- Number of establishments
- Sales, receipts, revenue, shipments, or business done
- Annual payroll
- Number of employees

12. Detailed information:

2007 Economic data sets by related survey: Commodity Flow Survey, Economic Census, Economic Census of Island Areas, Survey of Business Owners.

Related Annual Economic Surveys: Annual Survey of Manufacturers, Business Patterns, Nonemployer Statistics.

3.6.8 Economic Indicators

Various national economic indicators such as trade data, product data, new home sales, and so on. Data for small urban/rural areas are not available.

1. Data category: Economic and land use
2. Data collection time frame: Longitudinal (various years – present)
3. Data collection frequency: Monthly mostly, some quarterly
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/cgi-bin/briefroom/BriefRm)
5. Date of access: July 13, 2011
6. Organization that collected the data: The U.S. Census Bureau
7. Availability: Public
8. Smallest level of geography available: National
9. Small urban or rural: Covered but cannot be distinguished
10. National or local: National
11. List of variables of interest:
    - US International Trade in Goods and Services
    - US Trade Data
    - Country & Product Data
    - Wholesale Trade: Sales and Inventories (1990 – present)
    - Manufacturer's Shipments, Inventories, and Orders (1996 – present)
    - Construction Spending (1958 – present)
    - Advance Report on Durable Goods Manufacturers' Shipments, Inventories and Order (by NAICS) (monthly, 1958- present)
    - New Home Sales (monthly, 1958-present)
    - Quarterly Financial Report - Retail Trade (1993-present)
    - New Residential Construction (monthly, 1959-present)
    - Manufacturing and Trade Inventories and Sales
    - Advance Monthly Sales for Retail and Food Services (1953 – present)

- Quarterly Financial Report-Manufacturing, Mining, Wholesale Trade, and Selected Service industries (1993-present)
- Housing Vacancies and Home Ownership (Quarterly, 1956 – present)
- Quarterly Service Survey (2004-present)

3.6.9 E-Stats

The U.S. Census Bureau offers E-commerce information collected from four separate Census Bureau surveys:

- Annual Survey of Manufactures (ASM)
- Annual Retail Trade Survey (ARTS)
- Annual Wholesale Trade Survey (AWTS)
- Service Annual Survey (SAS)

These surveys use different measures of economic activity such as shipments for manufacturing, sales for wholesale and retail trade, and revenues for service industries. Consequently, measures of total economic and e-commerce activity vary by economic sector, are conceptually and definitionally different, and therefore, are not additive. The Census Bureau's e-commerce measures report the value of goods and services sold online whether over open networks such as the Internet, or over proprietary networks running systems such as Electronic Data Interchange (EDI).

Although E-Stats does not cover the entire U.S. economy, the report "Measuring the Electronic Economy" covers NAICS industries that accounted for approximately 77 percent of economic activity measured in the 2002 Economic Census. The report does not cover agriculture**,** mining, utilities, construction, agents, brokers, electronic markets in wholesale trade, and approximately one-third of service-related industries.

1. Data category: Economic and land use
2. Data collection time frame: Longitudinal (1999 – present)
3. Data collection frequency: Annual
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/econ/estats/index.html)
5. Date of access: July 13, 2011
6. Organization that collected the data: The U.S. Census Bureau
7. Availability: Public
8. Smallest level of geography available: National
9. Small urban or rural: Cannot be identified
10. National or local: National
11. List of variables of interest:

Shipments, sales, revenue (total and e-commerce) by NAICS for selected industry.

3.6.10 Greater Triangle (Raleigh-Durham-Chapel Hill) Household Travel Survey

The 2006 Greater Triangle Household Travel Survey was conducted between January 2006 and June 2006. This survey sampled 5,107 households from 12 counties in the Triangle region of North Carolina. The twelve counties are Wake, Durham, Orange, Chatham, Lee, Harnett, Johnston, Nash, Franklin, Vance, Granville and Person. Although many of the households included were located in three major cities in the surveyed area (Raleigh, Durham, and Chapel Hill), this survey also sampled from rural and small communities.

1. Data category: Travel behavior
2. Data collection time frame: 2006
3. Data collection frequency: One time
4. Source for data set: Minnesota Metropolitan Travel Survey Archive (http://www.surveyarchive.org/archive.html)
5. Date of access: July 19, 2011
6. Organization that collected the data: Capital Area Metropolitan Planning Organization (CAMPO), Durham-Chapel Hill-Carrboro Metropolitan Planning Organization (DCHC), North Carolina Department of Transportation (NCDOT), Triangle Transit Authority (TTA)
7. Availability: Public
8. Smallest level of geography available: census tract (latitude/longitude information could be available upon request)
9. Small urban or rural: Include both small urban and rural communities
10. National or local: Local
11. List of variables of interest:

    All the variables listed below were directly collected.

    - Household variables: Household size; number of vehicles; number of bikes; household location; type of dwelling unit (SFH, condo etc.); owner/renter status; length lived at current address; factors influencing home location choice; household income; number of drivers; number of workers; and number of students
    - Persons: Age, gender, possession of a valid driver's license; ethnicity; disability status; education; occupation; work status; work location; length worked at current location; factors influencing home location choice, flexibility of working hours; and student status

- Vehicles: Vehicle body type (auto, van, RV etc.) and fuel type
- Trips: Trip purpose; trip end location; trip mode; vehicle occupancy; parking cost; transit usage; walking/biking distance to transit stop (in blocks); departure time; and arrival time
- Places: census tract and FIPS code for census place

All the following variables can be derived from the directly collected variables: trip rate (frequency); trip travel time; trip length; journey-to-work trip length; mode share and VMT.

3.6.11 Labor Statistics

The U.S. Department of Labor's Current Employment Statistics program surveys each month about 140,000 businesses and government agencies nationwide (including 400 metropolitan areas and divisions), representing approximately 410,000 individual worksites, to collect detailed industry labor statistics on employment, hours, and earnings of workers on nonfarm payrolls. The data are available at the metropolitan area and county level.

1. Data category: Economic and land use
2. Data collection time frame: Longitudinal (1997 – present, May 2010)
3. Data collection frequency: Monthly/Quarterly/Annually
4. Source for data set: The U.S. Department of Labor (http://www.bls.gov/data/)
5. Date of access: July 25, 2011
6. Organization that collected the data: The U.S. Department of Labor - Bureau of Labor Statistics
7. Availability: Public
8. Smallest level of geography available: County, metropolitan area, largest 50 cities
9. Small urban or rural: County level/metropolitan area (possible within)
10. National or local: National
11. List of variables of interest:

BLS provides the following geographically based survey data:

- Employment & Unemployment: Monthly occupational employment; hours; earnings from the Current Employment Statistics survey (monthly, State and Metro Area); total non-farm employment; civilian labor force; mass layoff statistics; local area unemployment statistics
- Cross-industry estimates: by national, State, Metropolitan area, non-Metropolitan Area (started from Year 2007) and by NAICS.
- Productivity: Nonfarm business unit labor costs; output per hour for non-farm business productivity
- Prices & Living Conditions: from the Consumer Expenditure Survey

- Compensation & Working Conditions: from the National Compensation Survey and the Employment Cost Index

3.6.12 Longitudinal Employer-Household Dynamics (LEHD)

The LEHD data are provided by the U.S. Census Bureau each quarter. The LEHD provides longitudinal workforce indicator information by industry, work force living location and work location, industry employment gain and loss. LEHD combines federal and state administrative data on employers and employees with core Census Bureau censuses and surveys. Also part of the LEHD program is the Local Employment Dynamics (LED): a voluntary partnership between state labor market information agencies and the U.S. Census Bureau to develop new information about local labor market conditions at low cost, with no added respondent burden, and with the same confidentiality protections afforded census and survey data. It offers tools for creating work force residential location maps. LEHD also offers online interactive tools to analysis for areas as small as census place (such as Chapel Hill, NC).

LEHD provides the following data tools:

- Community Economic Development (CED) HotReport: information tailored to economic development decision-making, a multi-faceted view of local and regional conditions. Topics include the economy, transportation, housing, schools, top industries, occupations, and more.
- QWI Online: The Quarterly Workforce Indicators (QWI) are a set of economic indicators -- including employment, job creation, wages, and worker turnover. The QWI are built upon wage records in the Unemployment Insurance (UI) system and information from state ES-202 data. The universe of QWI data is UI-covered earnings. UI coverage is broad, covering over 90% of total wage and salary civilian jobs. NAICS- (or SIC)-based QWI by state, geographic grouping, industry, year and quarter, sex, age group, and ownership. Also includes net job gains and losses from 2007Q4 onward.
- OnTheMap: An online mapping and reporting application showing where workers are employed and where they live with companion reports on worker characteristics and optional filtering by age, earnings, or industry groups. A total of 48 states are currently featured showing data for seven years (2002 through 2008).
    - Area Profile Analysis - shows the location and characteristics of workers living or working inside the selected study area.
    - Area Comparison Analysis - shows the count and characteristics of workers employed or living in locations contained by the selected study area.

    - Distance/Direction Analysis - shows the distance and direction totals between residence and employment locations for workers employed or living in the selected study area.
    - Destination Analysis - shows the home or work destinations of workers employed or living in the selected study area.
    - Inflow/Outflow Analysis - shows the count and characteristics of worker flows in to, out of, and within the selected study area.
    - Paired Area Analysis - shows the location and characteristics of workers that share the selected home and work areas.
  - Industry Focus: Determine the top industries for a local area and local workers, focus in on a particular industry to see how it ranks among top industries, and also look at the characteristics of those who work in that industry

1. Data category: Economic and Land Use
2. Data collection time frame: Longitudinal (latest: May 16, 2011)
3. Data collection frequency: Quarterly
4. Source for data set: The U.S. Census Bureau (http://lehd.did.census.gov/led/datatools/datatools.html)
5. Date of access: July18, 2011
6. Organization that collected the data: The U.S. Census Bureau (and federal and state administrative)
7. Availability: Public
8. Smallest level of geography available (from small to large): workforce investment area, place, metro, county, state
9. Small urban or rural: Metropolitan or Micropolitan areas
10. National or local: National but some states have not passed through the experimental production phase
11. List of variables of interest: (variables listed in the summary descriptions above)
12. Detailed information:

Data source: the employment data used in this application are derived from Unemployment Insurance Wage Records reported by employers and maintained by each state for the purpose of administering its unemployment insurance system. The states assign employer locations, while workers' residence locations are assigned by the U.S. Census Bureau using data from multiple federal agencies. Age, earnings, and industry profiles are compiled by the Census Bureau from a state's records and are supplemented with other Census Bureau source data. Final compilations and confidentiality protection are performed by the Census Bureau.

Job Data: the LED Partnership defines a job as a link between a worker and a firm at which the worker has been employed during the reference quarter and during the quarter prior to the reference quarter (Quarter 2 (April-June) of the year of interest). The definition is sometimes called a "Beginning of Quarter" job because it is assumed that the worker was employed at that firm on the first day of the reference quarter. If a worker is employed at more than one job during the referenced period and those jobs are covered by the core datasets, then all of those jobs will be captured in the dataset. A primary job is defined as the one job for each worker that provides the most earnings. By analyzing primary jobs, you are seeing "one job per worker," whereas analyzing "All Jobs" you are seeing all the jobs held by the workers selected through your spatial query.

Exclusions: When QWI private industry employment numbers are compared with other employment data, exclusions to UI coverage should be taken into account. Federal government employment is not generally included. Exempted employment varies slightly from state to state due to variations in state unemployment laws, but generally also excludes many farmers and agricultural employees, domestic workers, self-employed non-agricultural workers, members of the Armed Services, some state and local government employees as well as certain types of nonprofit employers and religious organizations (which are given a choice of coverage or non-coverage in a number of states).

3.6.13 Michigan Statewide Household Travel Survey

The 2004-2005 Michigan Statewide Household Travel Survey was conducted between March 2004 and January 2005. The State of Michigan was divided into seven geographic areas in the survey, and a total of 14,996 households were sampled. The seven areas and the number of households surveyed for each area are: 2,249 households from SEMCOG (Seven counties of Detroit Area), 2,369 from Small Cities (Population of 5,000-50,000 outside small urban and TMA areas), 2,044 from Upper Peninsula Rural, 2,090 from Northern Lower Peninsula Rural, 2,084 from Southern Lower Peninsula Rural, 2,098 from Transportation Management Areas (TMAs, Population over 200,000), and 2,062 from Small Urban Modeled Areas (Population between 50,000-200,000).

1. Data category: Travel behavior
2. Data collection time frame: 2004-2005
3. Data collection frequency: One time
4. Source for data set: Minnesota Metropolitan Travel Survey Archive (http://www.surveyarchive.org/archive.html)
5. Date of access: July 18, 2011
6. Organization that collected the data: Michigan Department of Transportation
7. Availability: Public. Only the survey documentation is currently available. Data set can be obtained by contacting Michigan DOT.
8. Smallest level of geography available: latitude/longitude
9. Small urban or rural: Include both small urban and rural communities. All counties in Ohio were surveyed.
10. National or local: Local (statewide)
11. List of variables of interest:

    All the variables listed below were directly collected.

    - Household variables: household size; number of vehicles (bikes); type of dwelling unit (SFH, condo etc.); owner/renter status; household income; household location; number of workers; and number of students
    - Person variables: age; gender; possession of a valid driver's license; employment status; ethnicity; disability status; education; student status; occupation; employment type; and flexibility of work schedule

- Vehicle variables: vehicle body type (auto, van, RV etc.); whether vehicle is owned or leased; fuel type
- Trip variables: trip purpose; trip mode; transit usage; walking/biking distance to transit stop (in blocks); vehicle occupancy; parking cost; toll cost; departure time; arrival time; departure location; and arrival location
- Place variables: latitude/longitude coordinates

All the following variables can be derived from the directly collected variables: trip rate (frequency); trip travel time; trip length; journey-to-work trip length; mode share; and VMT.

3.6.14 National Agricultural Statistics Service (NASS)

The NASS is provided by the U.S. Department of Agriculture, covering virtually every aspect of U.S. agriculture with information on production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of U.S. producers. Data are provided at the county level.

1. Data category: Economic and Land Use
2. Data collection time frame: Longitudinal (1997-2007)
3. Data collection frequency: Every 5 years
4. Source for data set: The U.S. Department of Agriculture (http://www.nass.usda.gov/Data_and_Statistics/index.asp)
5. Date of access: July13, 2011
6. Organization that collected the data: The U.S. Department of Agriculture
7. Availability: Public
8. Smallest level of geography available: County and Agriculture District (larger than county)
9. Small urban or rural: Covers but difficult to distinguish
10. National or local: National
11. List of variables of interest:
    - Agriculture: number of farms; farm computer ownership and use
    - Economics: expenses; land and assets; income; labor; prices paid
    - Environmental: agricultural chemical usage by product
    - Education and Outreach: data quality and methodology; FAQs

3.6.15 National Household Travel Survey (NHTS)

The NHTS is a national scale household travel survey, which covers the entire country, collected by Federal Highway Administration (FHWA). In 2009, the NHTS covered 150,000 households surveyed from March, 2008, through May, 2009, including all weekdays and holidays. It collects information similar to any household travel survey. In addition to the usual travel behavior info, NHTS also attaches selected census based land use and socio-economic information associated with the surveyed household location. Currently, only 2001 and 2009 data are available. Geographic location resolution for public use data is census block group. Paired with surveyed community economic and land use data, the dataset is a rich source of information. Note: NHTS-2009 eliminates the retrospective collection of long distance trip data. Detailed travel information was collected for only the survey day. This means the so-called dual commute trips that happened in rural/small communities could be missed.

1. Data category: Travel Behavior
2. Data collection time frame: 2001 and 2009 (March 2008 - May 2009)
3. Data collection frequency: Occasional
4. Source for data set: The U.S. Department of Transportation – National Household Travel Survey (http://nhts.ornl.gov/)
5. Date of access: July 6, 2011
6. Organization that collected the data: The U.S. Department of Transportation - Federal Highway Administration (FHWA)
7. Availability: Public
8. Smallest level of geography available:
    - Households and population (and density): census block group
    - Employment: census tract
    - Household and trip ends location: Public dataset available at block group level;

    Researcher special request dataset available at regional TAZ (or even latitude/longitude)
9. Small urban or rural: Both; variables can be used to select either
10. National or local: National
11. List of variables of interest: Refers to Table 14 below
12. Detailed information:

The NHTS excludes: Group quarters (e.g., nursing home, hospital, military bases, living quarters with 10 or more unrelated roommates); dorm/fraternity and sorority houses included so long as no more than 10 people shared the same phone number; persons under age 5.

Table 14: NHTS - Potentially Useful Variables

Potential Use	Variable	Description	In Data File
AQ: fuel consumption	GSYRGAL	Annual fuel consumption in gasoline-equivalent gallons	Vehicle
AQ: vehicle fleet	FUELTYPE	Type of fuel	Vehicle
AQ: vehicle fleet	VEHAGE	Age of vehicle in years	Vehicle
AQ: vehicle fleet	VEHOWNMO	How long vehicle owned (in months)	Vehicle
AQ: vehicle fleet	VEHTYPE	Vehicle type	Day trip, Vehicle
AQ: vehicle fleet	VEHYEAR	Vehicle Model year	Vehicle
HH: # of persons	HHSIZE	Count of HH members	All
HH: # of vehicles	HHVEHCNT	Count of HH vehicles	All
HH: # of workers	WRKCOUNT	Number of workers in HH	All
HH: if related	HHRELATD	At least some HHMs are related	Household
HH: income	HHFAMINC	Derived total HH income	All
HH: internet use - economic development?	WEBUSE	Frequency of internet use in past month	Person
HH: licensed driver	DRVRCNT	Number of drivers in HH	Person, day trip, vehicle
HH: life cycle	LIF_CYC	Life Cycle classification for the HH	All

Potential Use	Variable	Description	In Data File
Land use: Census area types	HBHUR	Urban / Rural indicator - Block group **Urban** • Urban areas have highest population density scores based on density centiles • 94% of block groups designated Urban have a density centile score between 75 and 99 • Downtown areas of major cities and surrounding neighborhoods are usually classified as urban **Suburban** • Suburban areas are not population centers of their surrounding communities • 99% of block groups designated Suburban have a density centile score between 40 and 90 • Areas surrounding urban areas are usually classified as suburban **Second City** • Second Cities are population centers of their surrounding communities • 96% of block groups designated Second City have a density centile score between 40 and 90 • Satellite cities surrounding major metropolitan areas are frequently classified as Second Cities **Town/Rural** • Town/Rural areas include exurbs, farming communities, and various rural areas • 100% of block groups designated Rural have a density centile between 0 and 20 • 98% of block groups designated Town have a density centile between 20 and 40 • Exurban towns have slightly denser populations than rural areas	All

Potential Use	Variable	Description	In Data File
Land use: Area type	URBRUR	Household in urban/rural area	All
Land use: econ development, use of internet	PURCHASE	Number of times purchased via internet in past month	Person
Land use: MSA category where HH is	MSACAT	MSA category for the HH home address	All
Land use: MSA has rail - HH location	RAIL	MSA heavy rail status for HH	All
Land use: MSA population - where HH is	MSASIZE	MSA population size for the HH home address	All
Land use: Selection of rural, small urban	URBANSIZE	Size of urban area in which home address is located	All
Land use: Selection of rural, small urban	HBPPOPDN	Population per sq. mile - Block group	All
Land use: Selection of rural, small urban	HBRESDN	Housing units per sq. mile - Block group	All
Land use: Selection of rural, small urban	URBAN	Home address in urbanized area	All
Land use-tract: employment density	HTEEMPDN	Workers per square mile living in Tract	All
Land use-tract: housing unit density	HTRESDN	Housing units per sq. mile - Tract level	All
Land use-tract: population	HTPPOPDN	Population per sq. mile - Tract level	All

Potential Use	Variable	Description	In Data File
density			
Person: > 1 job	GT1JBLWK	Have more than one job	Person
Person: employment detail	OCCAT	Job category	Person
Person: employment detail	SELF_EMP	Self-employed	Person
Person: employment detail	WKFTPT	Work full or part-time	Person
Person: if a worker	WORKER	Subject worker status	Person, day trip
Person: worked	PAYPROF	Worked for pay or profit last week	Person
Travel: accessibility	ISSUE	Most important transportation issue (e.g. highway congestion, access to transit, lack of sidewalks, price of travel)	Person
Travel: activity	WHYFROM	Trip purpose for previous trip	Day trip
Travel: activity duration	DWELTIME	Calculated Time (minutes) at destination	Day trip
Travel: capture dual commute and/or irregular work place	FXDWKPL	No fixed workplace	Person
Travel: capture dual commute/Interaction with other region	AWAYHOME	Travel day reason was away from home	Day trip
Travel: capture dual commute?	FRSTHM	Did Person Start Travel Day at Home?	Person, day trip
Travel: capture dual	OUTOFTWN	Was out of town the entire travel day?	Person,

Potential Use	Variable	Description	In Data File
commute?			day trip
Travel: commute distance	DISTTOWK	One-way distance to workplace (miles)	Person
Travel: commute mode	WRKTRANS	Transportation mode to work last week	Person
Travel: cost	GASPRICE	Price of gasoline (cents) on respondent's travel day	Day trip
Travel: cost	GSCOST	Fuel cost in nominal US dollars per gasoline-equivalent gallon	Vehicle
Travel: cost	GSTOTCST	Annual fuel expenditures in nominal US dollars	Vehicle
Travel: cost	PAYTOLL	Toll paid on this interstate?	Day trip
Travel: distance to school	DISTTOSC	Distance home to school	Person
Travel: education vs. behavior	EDUC	Highest grade completed	Person, day trip
Travel: end time	ENDTIME	Trip end time in military	Day trip
Travel: limit	CONDNIGH	Medical condition results in limiting driving to daytime	Person
Travel: limit	CONDPUB	Medical condition results in using bus/subway less frequently	Person
Travel: limit	CONDRIDE	Medical condition results in asking others for rides	Person
Travel: limit	CONDRIVE	Medical condition results in giving up driving	Person
Travel: limit	CONDTRAV	Medical condition results in reduced day-to-day travel	Person
Travel: limit	MEDCOND	Have medical condition making it hard to travel	Person
Travel: limit	MOROFTEN	Would like to get out more often	Person
Travel: mode	CARRODE	Number of people in vehicle last week	Person
Travel: mode	PSGR_FLG	Was passenger on trip that only used Privately Owned Vehicle	Day trip

Potential Use	Variable	Description	In Data File
Travel: mode	PUBTRANS	Respondent Used Public Transportation on trip	Day trip
Travel: mode	SCHTRN1	Mode to school	Person
Travel: mode	SCHTRN2	Mode from school	Person
Travel: mode	TRPTRANS	Transportation mode used on trip	Day trip
Travel: multiple laces	SAMEPLC	Stayed at same place all day	Person
Travel: no trip	WKRMHM	Has option to work at home	Person
Travel: non-motorized trip	NBIKETRP	Number of bike trips in past week	Person
Travel: non-motorized trip	NWALKTRP	Number of walk trips in past week	Person
Travel: non-motorized trip	SCHCRIM	Walk/Bike issue: violence/crime along route	Person
Travel: non-motorized trip	SCHDIST	Walk/Bike issue: distance between home & school	Person
Travel: non-motorized trip	SCHSPD	Walk/Bike issue: speed of traffic along route	Person
Travel: non-motorized trip	SCHTRAF	Walk/Bike issue: amount of traffic along route	Person
Travel: non-motorized trip	WKFMHMXX	Frequency of working from home in past month	Person
Travel: number of trips	CNTTDHH	Category of number of household trips	HH
Travel: number of trips	CNTTDTR	Count of travel day trips for this respondent	Person
Travel: out of area	OUTCNTRY	Out of country entire travel day	Person
Travel: paratransit needed	CONDSPEC	Medical condition results in using special transit services	Person
Travel: paratransit needed	CONDTAX	Medical condition results in using a reduced fare taxi	Person
Travel: path	INTSTATE	A part of this trip was on interstate	Day trip

Potential Use	Variable	Description	In Data File
Travel: path	USEINTST	Interstate used for any trips	Person, day trip
Travel: purpose	TRIPPURP	General Trip Purpose (Home-Based Purpose types)	Day trip
Travel: time period	STRTTIME	Trip start time in military	Day trip
Travel: time period	TDWKND	Travel day trip was on weekend	Day trip
Travel: time period	TRAVDAY	Travel day - day of week	All
Travel: time period	WRKTIME	Usual arrival time at work	Person
Travel: transit - wait time	TRWAITTM	Derived length of wait for public transit - minutes	Day trip
Travel: transit access	TRACC1 – TRACC4	1st-4th mode used to get to public transit	Day trip
Travel: transit access time	TRACCTM	Derived time to get to public transit - minutes	Day trip
Travel: transit drive access mode	DROP_PRK	Parked or dropped off at public transit	Day trip
Travel: transit egress mode	TREGR1 – TREGR5	1st – 5th mode used from public transit to destination	Day trip
Travel: transit time	TREGRTM	How long to destination from transit - converted to minutes	Day trip
Travel: transit use	PTUSED	How often S used public transit in past month	Person
Travel: transit use	USEPUBTR	Use public transit on travel day	Person, day trip
Travel: travel time	TIMETOSC	Minutes to get to school	Person
Travel: travel time	TIMETOWK	Minutes to go from home to work last week	Person
Travel: trip distance	TRPMILES	Calculated Trip distance converted into miles	Day trip
Travel: trip distance	VMT_MILE	Calculated Trip distance (miles) for Driver Trips	Day trip
Travel: trip length	TRVL_MIN	Derived trip time - minutes	Day trip

Potential Use	Variable	Description	In Data File
Travel: trip length	TRVLCMIN	Calculated travel time	Day trip
Travel: trip purpose	WHYTO	Travel day purpose of trip (User's Guide: Why the traveler went to the trip destination)	Day trip
Travel: trip purpose	WHYTRP1S	Trip purpose summary	Day trip
Travel: trip purpose	WHYTRP90	1990 Trip Purpose (User's Guide: round-trip purpose (focus on the main reason)	Day trip
Travel: vehicle occupancy	NUMONTRP	Count of total people on trip	Day trip
Travel: VMT	ANNMILES	Self-reported annualized mile estimate	
Travel: VMT	BESTMILE	Best estimate of annual miles	Vehicle
Travel: VMT	OD_READ	Odometer reading	Vehicle
Travel: VMT	YEARMILE	Miles respondent drove last 12 months	Person
Travel: work distance Relation with other area	GCDWORK	Great circle distance (miles) between home and work	Person
Travel: work schedule	FLEXTIME	Respondent can set or change start time of work day	Person

3.6.16 National Transit Database (NTD)

NTD is provided by the Federal Transit Administration which describes it as "the Nation's primary source for information and statistics on the transit systems of the United States. Recipients or beneficiaries of grants from the Federal Transit Administration (FTA) under the Urbanized Area Formula Program or Other than Urbanized Area (Rural) Formula Program are required by statute to submit data to the NTD. Over 660 transit providers in urbanized areas currently report to the NTD through the Internet-based reporting system" (http://www.ntdprogram.gov/ntdprogram/ntd.htm). NTD covers aspects of transit agency operations including service use, modal characteristics, service area statistics, agency financial information, and some composite measures such as service efficiency and cost- and service-effectiveness.

1. Data category: Travel Behavior
2. Data collection time frame: 1978 Section 15 data - present
3. Data collection frequency: Longitudinal (Monthly and Annual)
4. Source for data set: http://www.ntdprogram.gov/ntdprogram/
5. Date of access: July 28, 2011
6. Organization that collected the data: The U.S. Department of Transportation - Federal Transit Administration (FTA)
7. Availability: Public
8. Smallest level of geography available: Census place
9. Small urban or rural: Possible if community name known
10. National or local: National
11. List of variables of interest:
    - Urbanized Area (UZA) Statistics - 2000 Census: Square Miles and Population
    - Service area: Square miles and population
    - Service: Annual passenger miles; annual unlinked trips: average weekday/Saturday/Sunday unlinked trips; vehicles operated in maximum service; and vehicles available for maximum service; percent vehicle spares; annual passenger miles; annual vehicle revenue miles; annual unlinked trips; annual vehicle revenue hours; fixed guideway directional route miles; average fleet age in years

3.6.17 2001-2003 Ohio Statewide Household Travel Survey

The 2001-2003 Ohio Statewide Household Travel Survey was conducted between August 2001 and May 2003. The study area consists of all counties in the State of Ohio with the exception of those that are within the MPO boundaries of Cincinnati, Cleveland, and Columbus. A total of 16,112 households participated in the survey, among which 2,223 were in rural counties. Rural counties defined in the survey are: Ashtabula, Auglaize, Belmont, Brown, Carroll, Columbiana, Crawford, Fulton, Lawrence, Washington, Adams, Ashland, Athens, Champaign, Clinton, Coshocton, Darke, Defiance, Erie, Fayette, Gallia, Guernsey, Hancock, Hardin, Harrison, Henry, Highland, Hocking, Jackson, Knox, Logan, Marion, Meigs, Mercer, Monroe, Morgan, Morrow, Muskingum, Noble, Ottawa, Paulding, Perry, Pike, Preble, Putnam, Ross, Sandusky, Scioto, Seneca, Shelby, Tuscarawas, Union, Van Wert, Vinton, Wayne, Williams, and Wyandot.

1. Data category: Travel Behavior
2. Data collection time frame: 2001-2003
3. Data collection frequency: One time
4. Source for data set: Minnesota Metropolitan Travel Survey Archive (http://www.surveyarchive.org/archive.html)
5. Date of access: July 15, 2011
6. Organization that collected the data: Ohio Department of Transportation
7. Availability: Public
8. Smallest level of geography available: latitude/longitude. Unfortunately, they are not available to the public. Special request for address geocoding information can be sent to the Ohio DOT.
9. Small urban or rural: Include both small urban and rural communities. All counties in Ohio were surveyed with the exception of those that are within the MPO boundaries of Cincinnati, Cleveland, and Columbus.
10. National or local: Local (statewide)
11. List of variables of interest:

    All the variables listed below were directly collected. All locations were geocoded to latitude/longitude, but they are not available to the public although geocoded address information can be requested from the Ohio DOT.

- Household variables: household size; number of vehicles (bikes); type of dwelling unit (SFH, condo etc.); owner/renter status; household income; household location; number of workers; and number of students
- Person variables: Age; gender; possession of a valid driver's license; employment status; student status; employment type; and occupation
- Trip variables: trip purpose; trip mode; transit usage; walking/biking distance to transit stop (in blocks); vehicle occupancy; parking cost; toll cost; departure time; arrival time

All the following variables can be derived from the directly collected variables: trip rate (frequency); trip travel time (reported by respondents); and trip mode share. If latitude/longitude are available, trip length; journey-to-work trip length; and VMT can also be derived.

3.6.18 Quarterly Census of Employment and Wages (ES202)

This program used to be called the ES 202 program. Data are also available through state employment security agency web sites. Data will be suppressed if there are a small number of establishments (<3) or if one establishment has more than 80% of total employment for the NAICS category. While data for individual establishments are not available, historic data are available for the industry category, so trends and county profiles can be constructed. Also the data can be used for control totals if commercial employment databases are available (purchased).

1. Data category: Economic and Land Use
2. Data collection time frame: Longitudinal
3. Data collection frequency: Quarterly
4. Source for data set: (http://www.bls.gov/cew/data.htm)
5. Date of access: August 11, 2011
6. Organization that collected the data: State Employment Security Agencies/Bureau of Labor Statistics
7. Availability: public
8. Smallest level of geography available: county
9. Small urban or rural: yes
10. National or local: local
11. List of variables of interest:
    - Number of employees by NAICS 2 plus codes
    - Number of establishments
    - Total wages
    - Average weekly wage
    - Average annual pay

3.6.19 Survey of Business Owners (SBO)

The U.S. Department of Labor – Bureau of Labor Statistics (BLS) provides the Survey of Business Owners (SBO). The SBO is the only comprehensive, regularly collected source of information on selected economic and demographic characteristics for businesses (by NAICS, 2- through 6-digit) and business owners (by gender, ethnicity, race, and veteran status). The information can be presented/summarized to census place (e.g., Apex, NC) via American FactFinder.

The SBO covers only nonfarm businesses and excludes: Crop and Animal Production; Scheduled Passenger Air Transportation; Rail Transportation; Postal Service; Funds, Trusts, and Other Financial Vehicles; Religious, Grant making, Civic, Professional, and Similar Organizations; Private Households; Public Administration.

1. Data category: Economic and Land Use
2. Data collection time frame: Longitudinal (1972 - 2007)
3. Data collection frequency: Every 5 years
4. Source for data set: The U.S. Census Bureau (http://www.census.gov/econ/sbo/)
5. Date of access: July13, 2011
6. Organization that collected the data: The U.S. Census Bureau – Bureau of Labor Statistics
7. Availability: Public
8. Smallest level of geography available: Census place
9. Small urban or rural: Rural or small urban need to be identified somewhere else first
10. National or local: National
11. List of variables of interest:

    Data on American FactFinder (by gender, ethnicity, race, and veteran status):

    - Business Ownership: Jointly owned or operated by spouses; majority of business family-owned; number of owners of business
    - Business Characteristics: Year business originally established; home-based business; operated as a franchise; owned by a franchise; language(s) used in transactions; type(s) of workers employed; e-commerce as a percentage of total sales; company made purchases online; company had a web site; full or part-time business; business operating or reason ceased; type(s) of customer categories; percent of total sales exported; operations established outside the US; outsourced business function outside US; employer-paid benefits offered

- Financing: Sources of start-up or acquisition capital; amount of start-up or acquisition capital; sources of capital to expand business
- Characteristics of Business Owners: How business initially acquired; year of acquisition; primary functions in business; average hours per week spent working; if this business is primary source of income; prior experience owning a business; educational attainment; age of owner; owner US born; owner service-disabled or veteran

3.6.20 TRANSEARCH INSIGHT

TRANSEARCH INSIGHT is one of the most widely used commercial freight databases. The database was created by combining information from public sources (including Commodity Flow Survey, CFS) and private sources (primary shipment data from major freight carriers). It has been compiled and produced on an annual basis since 1980. Compared to CFS, the TRANSEARCH INSIGHT database contains freight data from more industries, and it can provide freight movement data at the county level. This database is proprietary so its accuracy and reliability cannot be verified.

1. Data category: Freight
2. Data collection time frame: Longitudinal (1980 – present)
3. Data collection frequency: Annual
4. Source for data set: IHS Global Insight
   http://www.ihs.com/products/global-insight/industry-analysis/commerce-transport/database.aspx
5. Date of access: August 10, 2011
6. Organization that collected the data: Reebie Associates, Inc. before 2005 and IHS Global Insight after 2005
7. Availability: Proprietary for purchase
8. Smallest level of geography available: county
9. Small urban or rural: Include both small urban and rural communities
10. National or local: National
11. List of variables of interest:
    Freight movement in tonnage by geography, commodity group and mode of transportation at national, state, business economic area, and county levels. Includes 38 commodities by two-digit Standard Transportation Commodity Classification (STCC), and covers truck, rail, waterborne, and air shipments.

3.6.21 Workforce Innovation in Regional Economic Development (WIRED) Regions

WIRED is a workforce training and economic development initiative from the US Department of Labor. WIRED "model regions integrate economic and workforce development activities and demonstrate that talent development can drive economic transformation in regional economics across the US ….WIRED goes beyond traditional strategies for worker preparation by bringing together state, local and federal entities; academic institutions (including K-12, community colleges and universities); investment groups; foundations; and business and industry to address the challenges associated with building a globally competitive and prepared workforce" (http://www.doleta.gov/wired/regions/).

WIRED is not a database; WIRED counties are participants in the program and have identified specific target industries for the program.

1. Data category: Economic and Land Use
2. Data collection time frame: NA
3. Data collection frequency: Information collected for program planning purposes
4. Source for data set: The U.S. Department of Labor – Employment and Training Administration (http://www.doleta.gov/wired/regions/)
5. Date of access: August 12, 2011
6. Organization that collected the data: U.S. Dept. of Labor - Employment & Training Administration
7. Availability: Public
8. Smallest level of geography available (from small to large): County
9. Small urban or rural: County only
10. National or local: National
11. List of variables of interest: NA

12. Detailed information:

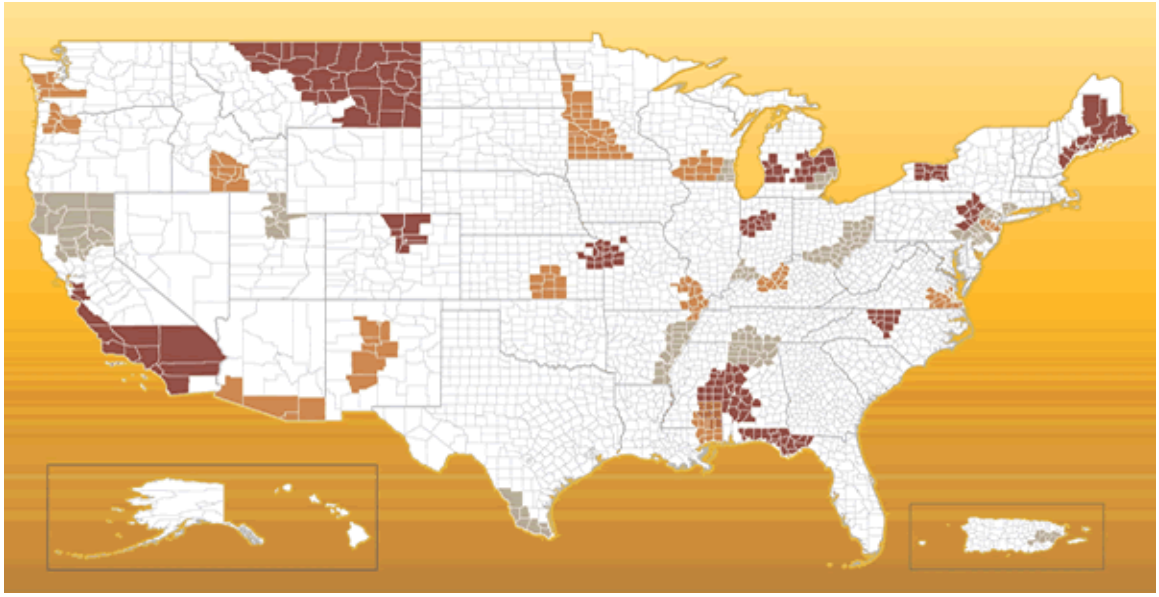

Figure 16: Workforce Innovation in Regional Economic Development (WIRED) Regions

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4. Scenario Assessment Models

The primary analytical engines that the research team used to investigate the influences of land use on travel behavior are three integrated land use-transport models, one for each case-study area, that were built using the TRANUS modeling platform.[1] The models' primary purpose is to predict how travel behavior, specifically vehicle-miles traveled and per capita vehicle-miles traveled, might change in response to hypothetical changes in employment, population, and development pattern. Thus the models' primary purpose is scenario assessment; they are not intended to forecast an area's most-likely development pattern and the consequent travel behavior. This chapter summarizes the research team's model building process: data acquisition and processing, calibration, and model validation.

For a defined study area, each model assembles databases that describe the area's economy, population, consumption of space, transportation infrastructure, and public transit. In addition to those activities and transportation databases, the other parts of a model are the behavioral parameters that represent the demands of business and government for civilian labor; demands of the population for the goods and services provided locally by commercial enterprises; demands of the population for housing units; and demands of the population for the transportation services consumed on a daily (weekday) basis.

Each scenario assessment tool is a machine for coordinating production and consumption in space. It is also a sophisticated calculator of the cost of producing things and the cost of transporting them.

Coordination has two fundamental aspects. First, all markets clear. For each good or service traded in a market, total production equals total consumption.

Second, both production and consumption occur at defined and interrelated places. The places of production and places of consumption are explicitly connected by a transportation network. The volume of exchange between a place of production and a place of consumption depends upon transportation cost and production cost.

Production has a broad meaning. It has the usual meaning: businesses produce goods and services by combining labor with other inputs.

Production also has distinctive meanings derived from the simulation modeling context. Households are produced with floor space and the goods and services provided by grocery

[1] 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.

stores, health care providers, and many other commercial establishments. An increase in employment produces an increase in households. An increase in households increases employment in the businesses that make the goods and services that households consume.

The scenario assessment tool predicts changes in daily travel behavior in response to employment and population growth and changes in development patterns. Predicted travel reflects realistic adaptations to new circumstances: changes in travel modes, trip origins, and trip destinations induced by changes in locations of businesses and households and changes in travel cost and travel time.

4.1 Case-Study Model Structure

The three scenario-assessment models have identical structures, and the models' parameters were estimated or calibrated using identical procedures. As the term is used here, "model structure" refers to the following foundational characteristics.

- A study area's core geography is a Commuting Zone, which is a spatial expression of local labor markets. The significance of Commuting Zones for the scenario assessment models is that their sub-models of locational choice attempt to explain choice only among the zones that are in a Commuting Zone, and the transportation network and any public transit routes are explicitly described only in the Commuting Zone.
- A study area also includes the core geography's environs, which are the external census tracts that are the origins of external-internal work commute trips or the destinations of internal-external work commute trips.
- Employees and households are located at the geographic centers of zones that are either census tracts or census block groups. The employment data in the 2000 Census Transportation Planning Package determines whether a county's zones would be tracts or block groups. If employment is reported for block groups, a county's zones are block groups; otherwise, the zones are census tracts.
- Employees are classified according to a single three-part typology of industries, which is based on two-digit NAICS codes.
    1. Agriculture, forestry, fishing and hunting, and mining (AFFHM).
    2. Commercial: retail trade; finance, insurance, and real estate; etc.
    3. Other industries: transportation and warehousing and utilities, construction; etc.
- The population is represented by households. Thus persons living in group quarters, as defined by the U.S. Bureau of the Census, are not included.
- Households are classified according to a single six-part typology that reflects family structure and size and age of householder, as defined by the U.S. Bureau of the Census.
    1. Single-persons aged 15-64.
    2. Married couples with children of which the householder is aged 15-64.

    3. Married couples without children of which the householder is aged 15-64.
    4. Other families with children of which the householder is aged 15-64.
    5. Households in which the householder is 65 or older.
    6. All other households.
- Consumption of space is represented as residential floor space and is classified according to a three-part typology.
    1. Single-unit housing units, including duplexes.
    2. Multiunit housing units.
    3. Manufactured (mobile) homes, including all other housing units, such as recreational vehicles, included in the 2000 decennial census.
- Roads and highways are represented abstractly with respect to geometry, and only the highways (freeways and arterials) that provide regional accessibility are completely represented. Local roads and collectors are represented with medium-low detail. Park-and-ride lots are included.
- Roads and highways (or, more precisely, "links") are classified according to a single typology based on the free-flow (posted) speed; whether pedestrians are allowed access; the motorized vehicles that are allowed access; and the volume-delay function. Centroid connectors have infinite capacity and a de minimis length of 0.1 mile.
- Public transit routes are represented only for fixed-route service.
- A single set of travel demand categories (trip purposes) is used: home-based work, home-based commercial, external commute, and home-based all other.
- Home-based work, home-based commercial, and home-based all other trips are endogenous to the model.
- External commute trips are exogenous to the model, i.e., they are included via a fixed origin-destination trip table.
- All models include private vehicle, walk, and bus.
- Movement across the boundaries of a study area's core occurs at gateways or external stations located on or near its perimeter, at roads or highways that provide regional access.
- The simulation period is a 16-hour weekday, which begins at 6:00 AM (06:00) and ends at 9:59 PM (21:59).
- The base scenario—the one used for calibrating parameters—represents conditions in the year 2000, which is the vintage of the employment and population data.

4.2 A Detailed Look at the Geography of One Study Area: the North Carolina - Tennessee Case Study

4.2.1 Overview

The study area comprises three different geographies. First, the core study area comprises the internal zones, which are the containers for households, employees, housing units and the transportation network. Second, the environs of the core study area are delineated by a buffer drawn around the core study area. Third, external zones located on or near the core study area's perimeter are gateways or nodes in the transportation network that allow (commuting) trips to enter or leave the core study area.

Decisions made during this phase of model construction immediately determine the model's spatial resolution and the number and distribution of external commuting trips that are loaded onto the transportation network. This phase also influences subsequent phases of model construction. The most important of those downstream effects is the classification of employees and households as exogenous or endogenous; details are provided in the following section on employment, households, and floor space.

4.2.3 Core Study Area and Internal Zones

The core study area comprises four counties in North Carolina and one in Tennessee ("NCT"). They are: Ashe, Avery, Watauga, and Wilkes counties in North Carolina and Johnson County in Tennessee. All 38 internal zones are census tracts.

4.2.4 Environs, External Zones, and External Commuting Trips

The environs comprise the census tracts of which the centroid lies in a 50-mile buffer drawn around the perimeter of the core study area. Those external tracts are the origins of the external-internal commuting trips that are included in the model, and they are the destinations of the internal-external commuting trips that are also included. Twenty three external zones, located on roads that provide regional accessibility, serve as the gateways between the core study area and the environs.

The process that leads to determination of the preferred buffer and simultaneously to identification of the external commuting trips that are included has the following major components.

1. Create buffers of various sizes around the core study area and identify the census tracts in each buffer.

2. Using a geographical information system, determine the external zone that is nearest (measured as airline distance) to each census tract in a buffer. A "residual tract" in one

of the buffers is assigned the external station that is nearest the centroid of the tract's parent county.[2]

3. Download and merge Census Transportation Planning Package 2000 Table 3-001 for NC and the same table for TN and remove one-half of the flows that are common to both tables. The latter step is necessary to avoid double-counting the flows into NC and out of TN and vice versa, which are present in both states' tables.

4. For as many buffers as desired, create lists of the internal-external commuting trips and external-internal commuting trips.

5. Select the buffer that represents the core study area's environs.

6. For the selected buffer, create the I-E and E-I home-to-work flow tables in origin-destination format, and allocate the "residual" flows to either an external zone (I-E flows) or a census tract in the core study area (E-I flows).

7. Construct the work-to-home flow tables by transposing the I-E and E-I home-to-work flow tables.

8. Remove the flows of which the departure time is outside the simulation period and merge the tables. Each worker flow is counted as one vehicle trip.

4.2.4.1 Data

The universe of CTPP Table 3-001 is all workers: workers in households; workers in group quarters; workers in civilian industries; and workers in the Armed Forces. Three tables in Part 3 have as their universe workers residing in households (all industries are included). Although in general the distinction between workers in households and workers in group quarters is potentially significant for the purpose of creating a model's external commuting trip table, Table 3-001 was used for the NCT case study, and any issues with doing so are minimal.

In the NCT model, the worker flow data in Table 3-001 are used for different purposes. First, they are the foundation of the external commuting trip table. Second, worker flow data are used to differentiate the endogenous working households from the exogenous working

[2] Residual tract is the term used here to refer to the entities that were used in CTPP 2000 to serve as the work place of the workers assigned to residual workplace categories in the worker flow databases prepared for summary level 140, i.e., state-county-tract. In these databases, QPOWTRACT = 99999. The workers whose place of work could not be geocoded to a census tract were assigned a place of work in the appropriate county. See *Appendix N: Residual Workplace Categories in Part 2 of CTPP 2000* (http://download.ctpp.transportation.org/training/Appendix_N.pdf).

households (see the section below on exogenous and endogenous households). (A working household has at least one worker.)

Using Table 3-001 for both purposes potentially introduces some error: error would occur only if the geographical distribution of commuting trips made by workers in group quarters or Armed Forces workers—specifically the proportion of total commuting trips that are internal-external—differs from the geographical distribution of commuting trips made by civilian workers in households, and any error would be limited to the zone or zones with a substantial number of either workers in group quarters or Armed Forces workers. Therefore it is a possibility that, for those zones, use of Table 3-001 (all workers) causes the number of endogenous working households to be overstated or understated. In contrast, a benefit of using Table 3-001 for constructing the external commuting trip table is that the number of internal-external or external-internal commuting trips is accurately estimated because all such flows are counted.

Using CTPP 2000 data, we investigated the significance of workers in group quarters and workers in the Armed Forces and found that no issues arise from using Table 3-001. In the NCT core area, more than 97% of the workers who lived there resided in households, and more than 97% of the workers in all industries whose workplace was in the core area resided in households.

The number of Armed Forces workers who reside in the NCT core area is 59. Some or all are internal-external commuting workers, and it is appropriate to include those flows in the external commuting trip matrix. None (if any) of those workers' internal-internal commuting flows are generated by the NCT TRANUS model because it does not include the Armed Forces industry in the activities database.

The number of Armed Forces workers who work in the NCT core area is 62. Some, possibly all, are external-internal commuting workers, but it is not possible to determine how many because their place of residence cannot be determined from the CTPP data. No attempt is made to remove them from the external commuting trip matrix.

4.2.4.2 External-internal and internal-external commuting trips

For the NCT model, we investigated these buffers: 20 miles; 25 miles; 30 miles; 35 miles; 40 miles; 45 miles; 50 miles; and 80 miles. The 80-mile buffer includes census tracts in KY and SC, but those locales seem very unlikely to be the origins or destinations of commuting trips that are frequently made to or from the core study area. Therefore the appropriate buffer is less than 80 miles, and the relevant states for external commuting trips are NC, TN, VA, and WV.

The flows to or from the 45-mile buffer account for 87.5% of all external flows, and the flows to or from the 50-mile buffer, 89.0% of all external flows. We chose the 50-mile buffer.

The residual worker flows are a very large proportion of total worker flows. For example, for the NCT study area's 50-mile buffer, 4,040 of 9,720 internal-external worker flows end in a residual tract. The exact destinations of internal-external flows are unimportant. The destination tract does not need to be determined; the external zone that is the likely point of departure from the core study area suffices for the purpose of constructing the exogenous commuting trip table.

The destinations of the external-internal worker flows that end in a residual tract must be resolved with more precision because to be included in the model they must end in a census tract. Many flows end in a residual tract. For example, in one NC county that is in the core study area, 440 out of 590 flows end in a residual tract. If the residual-tract flows were a small proportion of total flows, it would be reasonable to allocate the former in proportion to the distribution of flows to the census tracts, but with so many residual-tract flows another allocation method must be used.

We allocated the residual-tract flows that end in the core study area using the results of the worker flow analysis conducted with data obtained from LEHD Origin-Destination Employment Statistics (LODES) Version 5 (which uses the Census 2000 geographies). The vintage of the data is 2002, the year closest to 2000. The analysis was conducted for the private primary jobs. We summarized the LODES flows in a set of five tables, one for each county in the NCT core study area. The rows in each table are origins, specifically external stations; thus the flows that originate in the tracts in the 50-mile buffer are aggregated by external zone. The columns in each table are the census tracts in one of the core study area counties. Each cell in a table is the ratio of 1) the worker flows that originate in a particular external zone and end in a particular census tract to 2) the total number of worker flows that originate in the 50-mile buffer and end in a county of interest. Those ratios are used to allocate each core county's residual-tract flows to the county's genuine tracts. For example, if 5% of the LODES worker flows that "originate" in external zone 101 end in census tract 37009970100, then 5% of the CTPP worker flows that both "originate" in the same external zone and end in the county's residual tract also end in census tract 37009970100. Thus, the spatial pattern of the worker flows reported by the LODES data is assumed to apply to the CTPP residual-tract flows.

The last analytical steps are to estimate the proportions of the home-to-work trips and work-to-home trips of which the departure time is in the simulation period. The details are discussed below in the section pertaining to departure times.

4.3 Employment, Households, and Residential Floor Space

4.3.1 Overview

The scenario assessment models portray the study areas' employment, population, and consumption of space—in TRANUS jargon, the area's "activities." Consumption of space is the distinctive sine qua non of land-use models. Only by including floor space and/or land are models endowed with the ability to predict in a convincing way the land-use pattern that may emerge after a major change in the transportation infrastructure or a major policy initiative to achieve a new development vision.

4.3.2 Employment

4.3.2.1 Industry sectors included in the scenario assessment models

The scenario assessment models have three types or sectors of civilian employment. They are aggregations of industries defined by two-digit NAICS codes and equivalently defined by the industry labels found in CTPP 2000.

1. Agriculture, Forestry, Fishing and Hunting, and Mining (AFFHM) sector: NAICS codes 11 and 21.
2. Commercial sector.
    a. NAICS codes 44-45, 51, 52-53, 54, 55, 56, 61, 62, 71, 72, 81, and 92.
    b. Retail trade; information; finance, insurance, and real estate and rental and leasing (FIRE); professional, scientific, management, administrative, and waste management services;, health, and social services; arts, entertainment, recreation, accommodation, and food services; other services (except public administration); and public administration.
3. Other Industries sector.
    a. NAICS codes 22, 23, 31-33, 42, and 48-49.
    b. Construction; manufacturing; wholesale trade; transportation and warehousing and utilities.

4.3.2.2 Employment data

The source of the employment data is CTPP 2000 Table 2-004, and the unit of measurement is persons at place of work (and who were at work). Workers are classified according to the industry that provides the worker's only job or primary job, which is the one at which he or she worked the most hours in the week preceding completion of the census long form.

The table's universe is all workers. It comprises workers residing in households and workers residing in group quarters.

Workers in households in contrast to workers in group quarters

Table 2-004 is the only at-workplace table in CTPP 2000 that tabulates workers by industry. The distinction between workers in households and workers in group quarters is significant because the scenario-assessment models represent not a study-area's entire population but only the population in households. The dynamic relationship between employment and population that is fundamental to the scenario assessment models predicates growth in the number of households on growth in employment. Consequently, the most appropriate representation of employment is workers in households and excludes workers in group quarters, but CTPP 2000 data do not include a tabulation of the former by industry.

Use of Table 2-004 leads to an overestimate of the number of workers in households by workplace, but the inaccuracy is negligible for the NCT study area. A comparison of the grand total number of all workers in all industries (Table 2-004) to the grand total number of workers in all industries in households (Table 2-031) in the five core counties shows that more than 97% of the workers at work in the area resided in households.

Workers whose workplace is a residual tract

For some counties in the three study areas, Table 2-004 includes workers assigned to residual tracts, and the number of such workers can be large relative to a county's total employment. Residual-tract workers must be allocated to census tracts. A previous section describes the process used in the North Carolina – Tennessee study. For the Ohio and Washington State studies, a simpler approach could be implemented: assume that the spatial pattern of the workers assigned to the genuine tracts also applies to the residual-tract workers. Thus, for each county of interest and each TRANUS industry sector, the residual-tract workers were allocated to the genuine tracts in proportion to a genuine tract's share of the total county employment that had been assigned to the genuine tracts.

4.3.2.3 Additional significant classifications of workers

Workers must be further classified to allow the models to simulate their correct roles in the dynamic relationship between employment growth and household growth. The models distinguish between resident and nonresident workers, and the models further classify the resident workers as exogenous or endogenous. All of the resident workers in the AFFHM sector and Other Industries sector are exogenous. Some but not all of the resident workers in the Commercial sector are exogenous.

Employee's residence—in the core study area or in the buffer?

An intrinsic feature of the TRANUS modeling platform is the ability to explicitly describe local labor markets: industries' demand for employees and households' supply of employees. When constructing the activities database, a decision must be made about how to represent the

geography of the labor markets, especially labor supply, and proper specification requires differential treatment of the workers who live and work in the core study area and those workers whose workplace is inside the core study area but whose residence is outside the core study area and in the buffer that contains the origins of the external-internal commuting trips. The latter workers are referred to as nonresident workers.

The location of a worker's residence determines whether the worker is included in the activities database and how a model simulates his or her home-based work trips. The nonresident workers are excluded from the activities database because including them would imply that they live in the core study area. Nonetheless, their home-based work trips should be included in a model, to avoid understating traffic volumes on the core study area's network. Those trips are included in a trip table that is provided as an exogenous input to the travel demand model.

Exogenous resident workers in contrast to endogenous resident workers

In TRANUS-based models, the classification of workers—only the resident workers—as exogenous or endogenous has implications for a model's structure and function. We first explain the distinction from the perspective of an industry sector of which all employees are exogenous. Then we consider an industry sector of which some employees are exogenous and some are endogenous. Both types of industry sector are included in our models.

An entirely exogenous industry or industry sector is characterized by demand that is external to the study area or it is characterized by fixed establishment locations. The AFFHM and Other Industries sectors are entirely exogenous. The constituent industries may be regarded as basic or primary industries—a classification commonly used in regional science to connote the predominance of exports of locally-produced goods and services. Also the scenarios do not anticipate a significant rearrangement of the locations of agriculture, natural resource extraction, or heavy industry. The locations of the industries' establishments may be regarded as completely fixed during the scenarios planning horizons, and that characteristic is represented in TRANUS models by designating all employees as exogenous.

An entirely endogenous industry or industry sector has the opposite characteristics. Its goods and services are predominantly demanded by the other industries or households in the core study area. The scenarios involve changes that create incentives for rearrangement of the existing establishment's locations (existing at the time of the base scenario), and their new locations cannot be meaningfully specified in advance. Another dynamic consideration is apposite: when an industry or industry sector has endogenous employees, and a scenario anticipates employment growth, a model predicts the locations of the new establishments—bringing to bear a model's locational choice algorithms, thus freeing the analyst from the

impossible task of manually predicting the locations of the new establishments and the number of new workers employed in each zone and industry sector.

The Commercial sector is unique because it has both exogenous employees and endogenous employees. Its existing establishments have some propensity to relocate in response to a major change in the locations of households. The scenarios of interest have population growth and consequently have induced growth of Commercial establishments, and the presence of endogenous Commercial employees triggers application of the algorithms that place the new establishments.

The Commercial sector's exogenous employees live and work in the core study area and produce commodities that are exported from the area. The sector's endogenous employees also live and work in the study area, but their production is consumed locally by the core study area's households. The households' demands for Commercial goods and services are inferred from the national 2002 Consumer Expenditure Survey (see the section below on commercial goods and services demand coefficients). Those demands are assumed for strategic reasons to be entirely satisfied by local production. The rationale for the assumption stems from modeling considerations: the assumption maximizes the number of Commercial employees who are subject to relocation and may be attracted to the new and relocating households, thus increasing the potential of the growth scenarios to reduce the growth in VMT by locating Commercial establishments closer to households.

4.3.3 Households

4.3.3.1 Households classified by family structure

The scenario assessment models represent the population living in households. The households are classified into six types or sectors based on age of householder, presence of children, and marital status (see Figure 17).

1. Single-person households in which the householder is aged 15-64 years, inclusive.
2. Married couples with children.
3. Married couples without children.
4. Other families with children.
5. 65-years and older households.
6. All others.

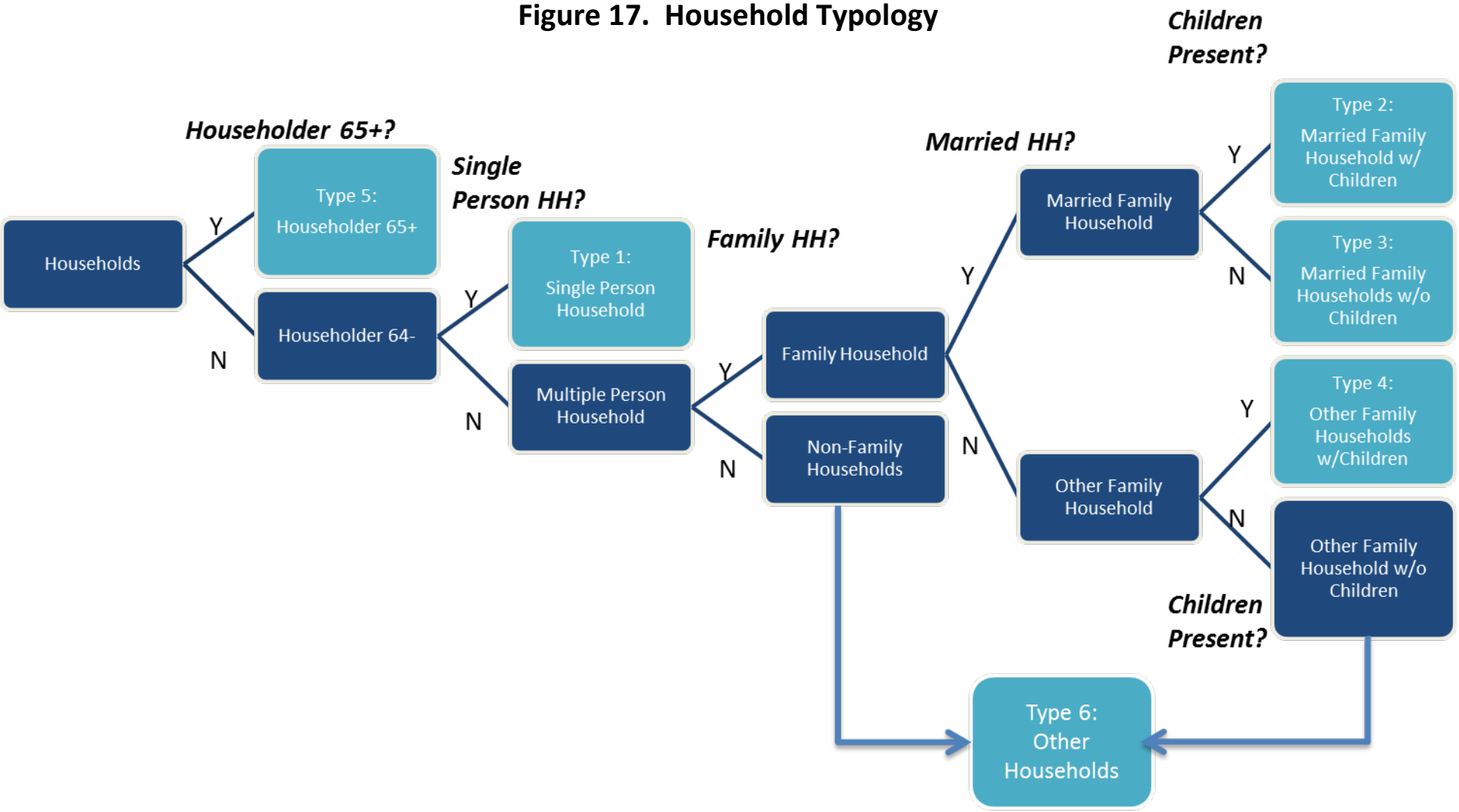
The household typology specifically identifies the households with older members, the type 5 households. Because of the potential for relatively high incidence of mobility-impaired members, those households are receiving special attention in discussions of future rural transportation needs.

The typology is robust. It was applied to the housing survey and household travel surveys that are used to build the scenario assessment models.

4.3.3.2 Household data

The 2000 Census of Population and Housing is the source of the data on households. The specific source is Summary File 1 (100 % data), Table P20: Households by Age of Householder by Household Type (Including Living Alone) by Presence of Own Children.

Figure 17. Household Typology



4.3.3.3 Exogenous and endogenous households

Households may be exogenous because their members are unemployed or employed in the Armed Forces, or do not participate in the labor market at all. The other reason for classification as exogenous is that a household's members commute to a workplace outside the core study area but in the buffer.

2000 PUMS (person level) data were used to estimate household-level unemployment/not-in-labor-force rates, by household type. For the NCT study area, North Carolina PUMA 00500 was used. It includes three counties that are in the core study area (Ashe, Watauga, and Avery), and two counties (Mitchell and Yancey) that are not in the core study area. The PUMA is the one microdata area that best matches the core study area.

CTPP 2000 Table 3-001 was used to classify the working households, by zone. In the NCT model, the internal zones are census tracts. Each tract's ratio of internal-external worker flows to total worker flows determines the proportion of working households that are exogenous.

4.3.4 Residential floor space

The most elaborate land-use models include floor space or building type and land for both residences and business establishments. The research team looked for but was unable to find local data such as tax-assessor parcel data that are adequate for estimating the consumption of either floor space or land in the study areas. Parcel data in a digital format typically were available for a minority of counties, and none of the parcel data that were available applied to the year 2000 or a nearby year. The research team turned to the 2001 American Housing Survey (AHS) public-use microdata (housing unit) to estimate floor space consumption and housing cost for all case study areas.

4.3.4.1 Residential floor space types

The scenario assessment models represent the consumption of space for residential purposes in terms of floor space (sq. ft.) by building type, of which there are three.

1. Single-unit building (one-family house), detached from or attached to any other building.
2. Building with two or more apartments.
3. Manufactured (mobile) home.

In the activities database, the mobile home sector is something of a catchall sector. It effectively includes housing units that differ from the sector's typical unit, which is a mobile home. The units that actually are boats, recreational vehicles, etc. are counted as mobile homes.

4.4.4.2 Estimating consumption of residential floor space

The entire AHS dataset was filtered to create two subsets containing only the records for the housing units in small communities and rural areas. Those records were identified in a process that relied on the AHS "metro3" variable and the boundaries of the small-community/rural-area Commuting Zones. The variable metro3 identifies a housing unit's geographical context with a five-part typology that includes three place types that are relevant: "inside MSA, but not in central city – rural" (metro3 = 3); "outside MSA, urban" (metro3 = 4); and "outside MSA, rural" (metro3 = 5). (The MSA boundaries that are relevant to the 2000 AHS are those which were current as of the 1980 decennial census.) The MSA boundaries were overlaid on the Commuting Zones. The housing units that are "inside MSA, but not in central city – rural" are not relevant to the type 1 or type 2 Commuting Zones (the least densely populated), but those housing units are relevant to the type 3 Commuting Zones (the most densely populated). All of the housing units for which the geographical context is either "outside MSA, urban" or "outside MSA, rural" are relevant to all Commuting Zones. Therefore two subsets of the AHS data were created: one for the types 1 and 2 Commuting Zones (metro3 = 4 or 5) and another for the type 3 Commuting Zones (metro3 = 3, 4, or 5).

We estimated consumption of floor space by census tract/block group and by type of housing unit in the base year (2000) by piecing together data from the 2001 AHS and from the 2000 decennial census, and conducting Monte Carlo simulations. The estimates could not be made directly because no national database reports consumption of floor space by building type and by block group. The 2000 decennial census reports the number of occupied housing units by building type and by block group/tract but not floor space. The AHS microdata report floor space in occupied housing units by building type and by housing unit but not by block group/tract. From the AHS microdata, the research team generated cumulative frequency distributions of floor space consumption by housing unit and by building type; from the census, we tabulated the number of occupied housing units by building type in each study-area block group/tract. Then we randomly drew a value of floor space consumption for each occupied housing unit, thus "estimating" actual consumption for every occupied housing unit in every block group/tract in the three case study areas.

4.4 Transportation Infrastructure Database: Roadway Network and Public Transit

A model's transportation infrastructure database describes the supply of transportation services that are provided by the roadway network and any public transit. Depending on the small community or rural area, public transit may be available for trips made within the boundaries of one or more towns, or for trips, typically commuting trips, that connect a bedroom community with an urban employment center.

Any and all freeways, ramps, highways, and park-and-ride lots are present in the models' networks. Collector streets and local roads are included as needed to achieve plausible traffic volumes and average travel speeds. Every zone (census tract or census block group) has one or more centroid connectors. Traffic volumes and average travel speeds on the roads attached to the centroid connectors were examined after the first trial run of the traffic assignment phase. Centroid connectors were added or moved as needed to avoid artificially high levels of traffic congestion on the roads to which the connectors were initially attached.

A road's (link's) attributes are length, vehicular capacity (equivalent vehicles), directionality (1-way or 2-way), and link type. Link type is equivalent to functional classification and sets the volume-delay function, maximum speed by "operator" such as privately owned vehicle, and distance-related variable cost ($/mile) that applies to all links that have been assigned to the link type. Centroid connectors have infinite capacity and the minimum length allowed by the modeling platform (0.01 mile).

Public transit, typically fixed-route service provided by buses, is available in all three case studies. Chillicothe (OH) has fixed-route-with-deviation service, which is modeled as fixed-route service. All transit stops in a study-area's core counties are represented.

4.5 External Commuting Trips

Every case study model contains a fixed origin-destination table of the external-internal and internal-external commuting trips. The former are made by the workers who reside outside the core study area (the internal zones) but in a specified buffer and work in the core study area. The latter trips are made by the workers who reside in the core study area and work outside but in the specified buffer. The trip table has trips in both the home-to-work and work-to-home directions. Only the trips of which the departure time is in the 16-hour simulation period are included. A previous section provides a detailed summary of the methodology used to create the trip table used in the North Carolina – Tennessee model. The trip table used in a case study's base-scenario model is used without modification in every growth scenario.

4.6 Land Use Parameters

The parameters that are referred to as "land use" parameters include coefficients for the demands for labor, commercial goods and services, and residential floor space. Other land use parameters represent the process that establishes the probabilities that a commodity that is demanded in a zone is obtained from the zone itself or some other zone.

4.6.1 Labor demand coefficients

In all case studies, business establishments' and governments' demands for labor are expressed with a single parameter, "Minimum Demand," meaning that demand is perfectly inelastic. Even though those demands are certainly elastic (especially in the economic long run), practical

considerations such as data availability justify use of perfectly inelastic demand. Further, it is safe to assume that the development scenarios of interest would not change the technologies used in the production of goods and services, providing another rationale for perfectly inelastic demand.

4.6.1.1 Initial values

For the Ohio case study, the research team used the rural subsample of the 2001-2003 Ohio Statewide Household Travel Survey to estimate each employment sector's labor demand coefficients (one for each household sector). The surveyed households were classified according to the typology described above. The households with at least one civilian employee—"employed" households—were identified. Each employee's industry affiliation (or primary affiliation) was recoded to match the scenario assessment model's employment sectors. For each combination of employment sector and household type, households per worker were calculated, thus yielding the initial labor demand coefficients.

After developing the Ohio model, another approach was used to estimate the initial values of the labor demand coefficients for the other models. This alternative approach is computationally simpler than the approach used for the Ohio model but not fundamentally different. It exploits procedures and an Excel workbook developed to facilitate construction of land use forecasting models built with the TELUM modeling platform.

TELUM "converts" employees to households using the following formula.[3]

$$HH_j = \sum_i \left[EMP_i \times \left(\frac{RNCR}{RJPE}\right) \times \left(\frac{1.0}{1.0 - UNEMP_i}\right) \times CNV_{ij} \times \left(\frac{1.0}{EMPHH_j}\right) \right]$$

HH_j ≡ number of households in household sector j.

EMP_i ≡ number of employees in industry sector i.

RNCR ≡ regional net commuting rate.

RJPE ≡ regional ratio of jobs per employee.

$UNEMP_i$ ≡ unemployment rate for industry sector i.

CNV_{ij} ≡ scaled proportion of employees in industry sector i who belong to household sector j. Scaling means that the unscaled proportion ($CNVU_{ij}$) calculated in the last iteration (minor cycle 2) of TELUM's iterative proportional fitting process is multiplied by the

[3] *Users Manual: TELUM (Transportation Economic and Land Use Model): Version 5.0*, p. 4.17 (http://www.telus-national.org/products/TELUMUserManual.pdf).

Rescaling Factor RF. RF ≡ grand total of Calculated Number of Employees by Income Category ÷ grand total of Adjusted Emp (Industry Target). (Income Category is equivalent to household category.) $CNV_{ij} = CNVU_{ij} * RF$.

$EMPHH_j$ ≡ ratio of employees per household for household sector j.

The formula may be rewritten as the sum across industry sectors of the number of sector-j households with at least one employee or "potential" employee in industry sector i, HH_j^i. A potential employee is an unemployed worker who is still in the labor force and hence may return to work. If an industry's unemployment rate is zero, then the formula yields the number of employed sector j households with at least one employee in industry sector i.

$$HH_j = \sum_i HH_j^i$$

$$HH_j^i = EMP_i \times \left(\frac{RNCR}{RJPE}\right) \times \left(\frac{1.0}{1.0 - UNEMP_i}\right) \times CNV_{ij} \times \left(\frac{1.0}{EMPHH_j}\right) \quad \Rightarrow$$

$$\frac{HH_j^i}{EMP_i} = \left(\frac{RNCR}{RJPE}\right) \times \left(\frac{1.0}{1.0 - UNEMP_i}\right) \times CNV_{ij} \times \left(\frac{1.0}{EMPHH_j}\right)$$

In the context of the TRANUS-based models, HH_j^i is the number of endogenous households in household sector j providing labor to employment sector i, and $\frac{HH_j^i}{EMP_i}$ is the initial labor demand coefficient for employment sector i and household sector j—provided that $UNEMP_i$ has been set to zero and the regional net commuting rate (RNCR) has been set to one. Those settings are necessary to ensure that the formula yields only the endogenous households (as that term is used in the context of the TRANUS-based scenario assessment models).

We used the 2000 PUMS (public use microdata sample) to obtain the data on labor force participation that are needed to calculate the TELUM-based labor demand coefficients. None of the 2000 Public Use Microdata Areas (PUMAs), the geographic areas corresponding to PUMS files, coincide with the NC-TN or WA study areas. For each area, the PUMA having the most similar geographical extent was chosen.

4.6.1.2 Calibrated values

The initial values of the labor demand coefficients did not ensure that, for an entire study area, demand equals supply. That was to be expected, if for no other reason than that the geographical extent of a study area does not match the geographical extent of the data used to estimate the labor demand coefficients. Excel's solver function was used to adjust the labor demand coefficients until labor supply equals labor demand for each employment sector. The

adjusted (calibrated) values were provided to the scenario assessment models' land use parameter database.

4.6.2 Commercial goods and services demand coefficients

The scenario assessment models explicitly represent households' demands for commercial goods and services produced by the business establishments and other organizations in the commercial employment sector. In view of the purpose of the scenarios, household demand is assumed to be perfectly inelastic.

4.6.2.1 Initial values

The 2002 Consumer Expenditure Survey; Quarterly Census of Employment and Wages; and the U.S. Bureau of Economic Analysis Benchmark Input-Output Data, 2002 Standard Use Table were used to estimate each household sector's demand coefficient for the commercial commodities. The unit of measurement is employee-equivalents per household. Because the parameters were estimated using national data, all case studies use the same values.

4.6.2.2 Calibrated values

Unlike the labor demand coefficients, the commercial commodity demand coefficients are not calibrated, i.e., adjusted after completion of the process of estimating their initial values. Some but not all of the households' consumption is satisfied by the commercial establishments in a study area. Conversely, some but not all of the establishments' production is consumed locally. The data that are in the public domain on household consumption patterns do not allow estimation of the imports and exports of the commercial goods and services. Nonetheless, a choice must be made about the proportion of household demand that is supplied locally, and the assumption was made that all demand is supplied locally.

The value of the "local demand proportion"—even if it were less than one—has significant implications for construction of the activities database. To be internally consistent, the total number of Sector 2 Commercial employees who are determined to be endogenous must exactly equal the number of employees implied jointly by the number of households, commercial demand coefficients, and the local demand proportion. An algorithm was developed to differentiate endogenous from exogenous employees.

The assumption that all demand is satisfied by local production leads to overestimation of the study area households' internal trips and underestimation of their external trips. Judging by the results of the traffic assignment process in the case study models, the assumed local demand proportion passes this reasonableness test: overestimation of the internal trips does not create artificially high levels of traffic congestion.

4.6.3 Residential floor space demand coefficients and substitution parameters

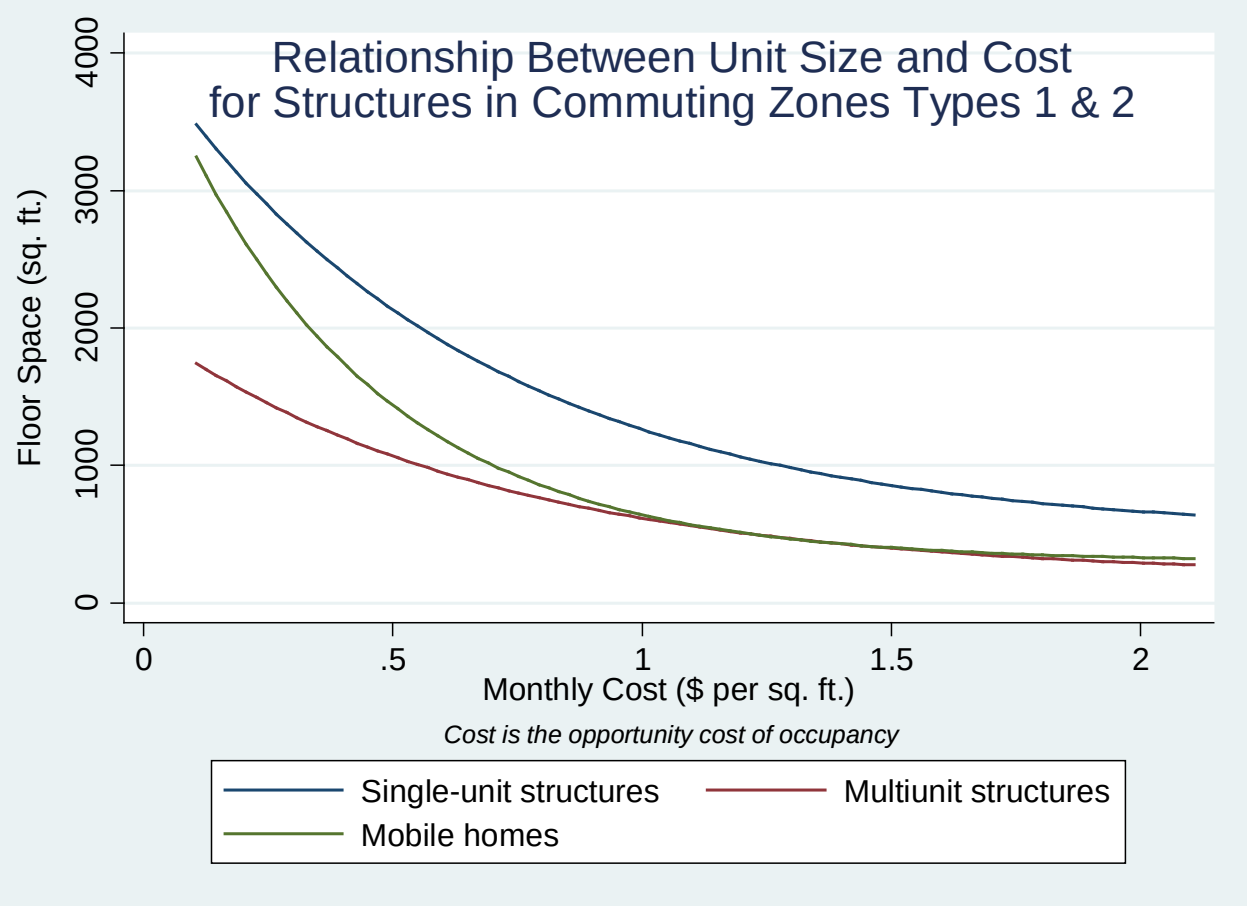
The demands for floor space in single-unit buildings, multiunit buildings, and manufactured (mobile) homes are specified with elastic demand functions, and substitution of one building type for another is possible. The primary reason is that such demand models enable the land use model to represent one of the fundamental attributes of land use dynamics: household growth is accommodated in part via greater intensity in the use of already-developed areas, which would be achieved by households (typically the new ones) choosing to live in housing units that are smaller than average and/or choosing to live in multiunit buildings instead of single-unit buildings or mobile homes.

4.6.3.1 Initial values

The initial values of the parameters that are used in TRANUS-based models to specify elastic demand functions were estimated using the 2001 American Housing Survey (see above). Two basic variables are essential for estimating demand functions: quantity and price (more precisely, opportunity cost of acquisition and possession). The survey data contain size of housing unit and many attributes that represent housing cost. To uniformly estimate housing cost across tenure status, type of housing unit, and geographical context, we constructed a single variable representing the monthly opportunity cost of occupancy.

Using the monthly opportunity cost of occupancy as the independent variable, we estimated floor-space demand models for occupied housing units in single-unit structures, housing units in multiunit structures, and mobile homes. The evidence (small p-values) is very strong that each estimated coefficient for the cost variable has the correct (negative) sign and is less than zero. Figure 18 illustrates the quantity-cost relationship for the housing units in the low population density and medium population density Commuting Zones (types 1 and 2, respectively).

Figure 18. Inverse Demand Curves for Residential Housing in the Low- to Medium-Density Commuting Zones



4.6.3.2 Calibrated values

For the residential floor space sectors, the calibration process focused exclusively on the substitution parameters, which could not be directly estimated using the housing survey data. Calibration entailed a trial-and-error process that begins with an assumption of the parameters' initial values and proceeds through multiple iterations of: execute the land use module; examine the floor space sectors' "shadow prices;" input new substitution parameters; and re-run the land use module. Shadow prices are model generated measures of the goodness of fit. The calibration process was ended when the shadow prices indicated an acceptable goodness of fit.

4.6.4 Location demand parameters

The location demand function is the heart of the land use module because the function calculates the probability that a good or service demanded in any particular zone is supplied by the producers in that zone or in another zone. The probabilities are calculated with a multinomial logit model (see below for the technical details). Those functions are relevant to

the commodities that are transportable: labor and commercial goods and services. In TRANUS-based models, the location demand function includes a component, called the "attractor function," that represents a zone's attractiveness to a particular employment sector or household sector. An employment or household sector is attracted by one or more other employment and household sectors.

The location demand parameters must be specified for the commercial employment sector and all household sectors, seven sectors total. In each model, the number of parameters is 7*(13 + number of internal zones). For example, the number of parameters in the Washington case study model is 1,554. Because it is impossible to derive an analytic solution that is equivalent to the algorithm that the TRANUS modeling platform uses to simulate locational choice, it is impossible to statistically estimate the parameters and hence a trial-and-error process must be used to calibrate them.

4.6.4.1 Initial values

All case studies used the same set of initial values. The sector- and zone-specific parameters (called "weights") were set to one, implying that the zones are equally attractive. The parameters that represent whether and to what degree one sector attracts another were set to one for the sector being attracted (a model necessity) and to zero for the other sectors. The dispersion parameter in the multinomial logit model; the parameter that reflects the relative importance of price versus transportation cost; and the other parameters ("scaling" parameters) were set to one.

4.6.4.2 Calibrated values

The calibration process followed the same outline as that used to calibrate the substitution parameters: assume initial values and repeatedly execute the land use module, examine the endogenous sectors' shadow prices, input new parameters, and re-run the land use module. Attention was focused on the parameters in the attractor function that convey the relative importance of each sector because they represent the clustering process that has been found in other studies of to be a fundamental characteristic of actual land use patterns.

For each model, the parameters of interest were systematically changed, and scores of calibration experiments were conducted. The calibration process was stopped, and the parameters' final values identified, when the goodness of fit indicators (shadow prices) reached acceptable levels.

4.7 Travel Demand Parameters

4.7.1 Private vehicle operating costs

A fixed value was used for the variable cost of operating a privately owned vehicle, $0.234 per mile. That value is the national average expenditure in the year 2001 on repairs, depreciation, fuel tax, and fuel. The source of the estimates is FHWA's *Our Nation's Highways: 2000*.[4]

4.7.2 Departure times

The simulation period begins at 6:00 AM and ends at 9:59 PM, which should be sufficient to capture almost all of the personal trips that are made with the greatest frequency. The specific start and end times were chosen when the research team developed the OH case study, and they correspond to the beginning and end of the weekday service provided by the study area's public transit operator.

The exogenous commuting trip table has the home-to-work trips and the work-to-home trips that are external-internal or internal-external and have a departure time in the simulation period. To estimate the desired number of home-to-work trips, the total number of such trips was multiplied by the proportion of workers who left home for work during the simulation period. To estimate the desired number of work-to-home trips, the total number of such trips was multiplied by the proportion of workers who left work during the simulation period.

CTPP 2000 Table 1-001 was used to estimate the proportion of workers who left home for work, and hence commuting trips, during the simulation period. Table 1-001 reports time leaving home to go to work, and the table's universe is all workers; comparable data for only the workers residing in households is not available from CTPP 2000.

To estimate the proportion of workers who left work to return home during the simulation period, a source other than CTPP 2000 must be used because it does not report the relevant departure times. The research team used the 2009 National Household Travel Survey because the data are appropriate and because of the sizeable rurally-oriented add-on sample that was included for North Carolina.

The home-to-work departure-time proportion was estimated in the following way.

1. Extract the trip records for the trips that were not made on a weekend and that were made by persons in households in the small communities or rural areas in NC or TN. The operational definition of a small community or rural area is an urbanized area with a population 50,000 – 199,999 or an area that is not urban.

[4] U.S., Federal Highway Administration, n.d., *Our Nation's Highways: 2000*, p. 13 (https://www.fhwa.dot.gov/ohim/onh00/onh2p1.htm).

2. Mark the trips with these origin-destination or trip purpose characteristics: work – home, go to work – home, or return to work – home.
3. Calculate the proportion of all such trips that have a departure time in the simulation period.

The estimated proportion is 0.94. That estimate may not be precisely correct because the criterion that selects trips on the basis of travel day excludes the trips made on Fridays after 5:59 PM. In addition, some irrelevant trips are included because the filter on trip purpose is too inclusive. Ideally, the departure time of the trips ending at work should be considered to eliminate from the analysis the trips of which the departure time for work is not in the simulation period. The result of the first limitation is that too few trips are included in the departure-time analysis, but the result of the second limitation is that too many trips are included. The net effect is undoubtedly of no practical significance.

4.7.3 Path search

The purpose of the path search algorithm is to construct the choice set containing the paths that the traffic assignment algorithm uses. Paths comprise operators and links. Path search constructs a single choice set for all of the travel demand categories that are included in a particular mode. The relevant parameters are the maximum number of paths; the mode-specific overlapping-control factor ("Oz Factor"); and the operator/link-type specific Overlap Factors (which override the Oz Factor).

For the mode that applies exclusively to the external commuting trips, the NCT model (and all other case-study models) includes a single operator, auto. That mode's maximum number of paths is one. The resulting choice sets have the least-costly path for the respective origin and destination. The implicit behavioral assumption is that the journey to work for the persons who may be expected to travel the greatest distances exhibits low spatial dispersion and tends toward the least-costly trip.

The other mode pertains to the internal-internal trips. The behavioral assumption that applies to those trips asserts that paths exhibit both greater spatial dispersion and greater variety of operators. The assumption may be justified in different ways. Home-based shopping trips, for example, are not always the shortest because consumers' preferences for retail goods may not be satisfied by the goods that are available at the stores nearest their homes. Obviously, walking and public transit are realistic options for the internal-internal trips. Compared to the external-trip mode, the internal-trip mode's path-choice parameters must be set to allow a greater variety of paths.

The latter's maximum number of paths is 12, and the other parameters were set at the conclusion of a series of experiments in which the Oz Factor and Overlap Factors were varied.

The results of interest were the number of paths that involve walk (by itself) and walk in conjunction with public transit for selected origin-destination pairs, i.e., several in Boone (NC) that are close together and/or that are served by public transit. The choice sets are constructed in the desired way when the mode's Oz Factor is set to two, and the Overlap Factor for auto is set to four, except for freeway links (for which the Oz Factor and the Overlap Factor are equal).

4.7.4 Values of travel time and of waiting time

Values of travel time and of waiting time were estimated for each trip purpose (travel demand category). The values were developed specifically for the Ohio case study (the first to be worked on), and they were also used in the other studies. The values are based on the person records in the rural component of the 2001-20003 Ohio Statewide Household Travel Survey and conventional rules of thumb.[5]

First, the average hourly wage of the householder in each household sector was calculated, as was the overall average. Then, for the home-based work trips, the value of travel time was set equal to one-half the average hourly wage, and the value of waiting time was set equal to the average hourly wage; those values are differentiated by household sector in parallel with the definitions of the six home-based work trip purposes. The other trip purposes—home-based commercial, home-based all other, and external commute—have travel demand parameters that are the same for all travelers, regardless of their household sector. For those trip purposes, the value of travel time was set equal to one-half of the overall hourly average wage, and the value of waiting time was set equal to the overall average hourly wage.

4.7.5 Trip generation

The basic logic of trip generation is this: an economic exchange between two zones (X_{ij}^{n}) is converted into a flow of persons or of goods and services between those zones (F_{ij}^{s}), and the flows are loaded as person trips and/or vehicle trips onto the transportation network (T_{ij}^{s}). In this notation, "n" represents a specific economic exchange such as purchase of the labor services provided by households; "i" and "j" represent internal zones; and "s" represents trip purpose or transport demand category. The trips that are loaded onto the network are the trips made during the 16-hour simulation period.

The transformation of flows equation converts economic exchanges into a flow of persons or of goods and services. When there is only one transport demand category (s) that an economic exchange (n) generates, and the exchange occurs daily, the transformation of flows equation is:

[5] NuStats (2004), *2001-2003 Ohio Statewide Household Travel Survey: Technical Memorandum*, Austin, TX. The survey data and documentation were downloaded from the University of Minnesota's Metropolitan Travel Survey Archive (http://www.surveyarchive.org/).

$F_{ij}^{s} = X_{ij}^{n}\, vol^{ns}\, pc^{ns} + X_{ji}^{n}\, vol^{ns}\, cp^{ns}.$

vol^{ns} is the "value-to-volume" factor that converts the units that are relevant to economic exchanges to the units that are relevant to trip generation. pc^{ns} is the factor (pure number) that represents the proportion of an economic exchange made in the production to consumption direction (e.g. home to work); cp^{ns} is the factor that represents the proportion of an economic exchange made in the consumption to production direction (e.g., work to home).

Trips are calculated by multiplying a flow times a trip rate, v^s: $T_{ij}^{s} = F_{ij}^{s}\, v^{s}$. Finally, when person trips must be expressed as vehicle trips, average auto occupancy is used for the trips made in a privately owned vehicle and average bus occupancy is used for the trips made via public transit.

In the scenario assessment models, the trip generation rates are completely inelastic, i.e., unresponsive to changes in the variable auto operating costs, value of travel time, value of waiting time, and bus fares. The assumption is convenient to make and, more substantively, the growth scenarios do not intend to change any of the household attributes that influence trip generation. In each case study, the trip generation rates are the same across all growth scenarios.

The trip generation parameters were estimated using the 2009 National Household Travel Survey.[6] That particular survey was used rather than multiple state-DOT funded surveys primarily due to considerations of efficiency: only one estimation methodology needed to be developed. The 2009 vintage was used because it had a large, rurally oriented add-on sample for North Carolina.

4.8 Accessibility Indices

Accessibility indices are central to the design of the growth scenarios and interpretation of the results of the scenario assessments. The indices are defined in operational terms as the denominator of the location demand function. The function is a multinomial logit model that estimates the probability that the producers in zone "j" supply the transportable goods and services of sector "n" demanded in zone "i"; the function is evaluated separately for each sector n:[7]

$$\Pr_{ij}^{n} = \frac{(A_j^n) \cdot \exp\left(-\beta^n \tilde{U}_{ij}^{n}\right)}{\sum_j (A_j^n) \cdot \exp\left(-\beta^n \tilde{U}_{ij}^{n}\right)}$$

[6] http://nhts.ornl.gov/download.shtml.

[7] Tomás de la Barra (2012), *Mathematical description of TRANUS*, p. 11.

http://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0cmFudXNtb2RlbHxneDo3YWQzYTk0OTkxN2RlN2Rj

X_{ij}^{n} quantity supplied by the sector *n* producers in zone *j* and demanded by the households, businesses, and government entities in zone *i*. This quantity is generated by a scenario assessment model's land use module.

A_{j}^{n} value of the attractor function (see above) when evaluated for sector *n* and zone *j*. Estimation of the function's parameters is discussed above.

$\widetilde{U}_{ij}^{n}$ cost, including production cost and generalized transport cost, of obtaining sector *n* commodities from the producers in zone *j* for consumption in zone *i*. This quantity is generated by a scenario assessment model's land use module.

β^{n} dispersion parameter. Estimation of this parameter is discussed above.

Thus, $\sum_{j}\left(A_{j}^{n}\right) exp\left(-\beta^{n}\widetilde{U}_{ij}^{n}\right)$ is an index of zone *i's* access to the households (by household sector) or employees (by employment sector) throughout a study area. The generalized transport costs that are used to calculate the accessibility indices reflect traffic congestion. An algorithm was implemented in Excel workbooks to calculate the accessibility indices.