Linking Land Use, Transportation and Travel Behavior in Ohio

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16. Abstract

This study developed a Regional Land Use Allocation Decision Analysis Tool, which enables decision makers to quantify the impacts of population and employment distribution in terms of the resulting VMT (Vehicle Miles Traveled). The study addresses the need for improving our understanding of the links between land use and transportation and provides ODOT a user-friendly modeling tool to develop forecasts based on different land use, transportation, and policy scenarios. The Regional Land Use Allocation Decision Analysis Tool developed through this study has two main components: a Land Allocation Component and a Transportation Component. This tool forecasts the impacts of future land-use policies in Ohio, based on alternative assumptions of highway and mass transit corridor development, zoning and environmental constraints, regional growth or decline projections, and changes in travel associated with auto trip generation rates and trip distances.

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1. INTRODUCTION

Links between travel demand, transportation system characteristics, urban form and distribution of population and employment have been the focus of several studies in the literature (Badoe and Miller, 2000; Boarnet and Crane, 2001; Boarnet and Sarmiento, 1998; Cervero et al., 2006; Cervero and Kockelman, 1997; Clifton et al., 2012; Ewing and Cervero, 2001; Ewing and Cervero, 2010; Ewing et al., 2011; Frank and Pivo, 1994). These have been viewed as the sources of several challenges related to energy consumption, global warming, environmental quality, and economic viability. Increasing mobility, primarily in terms of vehicle miles traveled (VMT), has been one key contributor to these challenges, particularly in terms of traffic congestion, greenhouse gas (GHG) emissions, air pollution and fuel consumption (Badoe and Miller, 2000; Ewing et al., 2011; Stead, 1999). Deterioration of central urban areas and traditional downtowns along with urban sprawl, and the increased use of motorized modes - particularly private vehicles- have changed people's lifestyles.

Facing major challenges related to energy consumption, global warming, environmental quality, and economic viability, metropolitan regions around the world are examining the consequences of alternative growth patterns on resource consumption. As we plan for new land use policies and investments in the transportation system over the next decade, we will face a new set of challenges tied to the changing demographic and economic conditions in Ohio, in addition to the rising costs of energy and related policies aimed at reducing the carbon footprint of our economy. The first step in understanding the possible implications of these changes is a deeper understanding of the current relationships between *land use* and *travel behavior*, and how these might be impacted by *future land use*, *transportation* and *energy policies*.

Household travel accounts for more than 80 percent of miles traveled on our nation's roadways and three-quarters of the CO_2 emissions from on-road mobile sources (Federal Highway Administration, 2009). The carbon footprint of daily travel for an individual household is based on the types of vehicles that household owns, the fuel efficiency, and the number of miles traveled. Although there are many technological innovations with the potential to reduce transportation emissions from passenger vehicles, several researchers agree that the technological innovations alone will not be enough to reach targeted reductions in emissions, as the projected increase in vehicle miles traveled will outpace the advances in fuel economy and lower carbon fuels (Ewing et al., 2008; Rajan, 2006; Schipper, 2010).

Land use and transportation policies will play a major role in reducing the GHG emissions and shaping the travel patterns in the future. Therefore, there is need to improve our understanding of the links between the land use, transportation policies and individual/household travel behavior to develop sound policies and investment decisions to combat the negative consequences of travel. The tools provided as a result of this research enables the decision makers to make informed decisions regarding the future land use policies, and transportation investments.

2. OBJECTIVES & PROJECT SCOPE

This study creates a *Regional Land Use Allocation Decision Analysis Tool*, which will enable decision makers to quantify the impacts of population and employment distribution and the resulting Vehicle Miles Traveled (VMT). Within this consideration, this study addresses the need for improving our understanding of the links between land use and transportation, and provides ODOT a user-friendly modeling tool to develop forecasts of future auto trip ends, trip distances and VMT based on different land use, transportation and policy scenarios.

Applying an understanding of travel patterns to planning efforts by ODOT and its metropolitan planning organization (MPO) partners will involve the transformation of a regional model that allocates future population and employment to appropriate sites for statewide use. One step in this direction was made by *Mid-Ohio Regional Planning Commission (MORPC)* in a *Regional Growth Model* developed by Smart Mobility Incorporated. The model, originally in a spreadsheet, used data on current land use, environmental and other constraints to allocate population and employment associated with expected future land uses in the central Ohio region based on a grid of 40 acre cells and on a measure of development likelihood. The model was translated for use in the CUBE software which greatly improves its performance but still had to be updated to connect the resulting output to forecasts of impacts on transportation demand, and other impacts that could be impacted by policy and market changes over time.

The Regional Land Use Allocation Decision Analysis Tool developed through this study has two main components: Land Allocation Component and Transportation Component. This tool forecasts the impacts of future land-use policies in Ohio, based on alternative assumptions of highway and mass transit corridor development, zoning and environmental constraints, and changes in travel associated with auto trip generation rates and distances.

The model uses information concerning infrastructure availability (transportation facility accessibility, sewer, water services), future land-use characteristics where available, and environmental constraints to allocate regional and county forecasts of population and employment to 40 acre cells in each metropolitan region of Ohio. The outputs of the land-allocation model inform the subsequent transportation models in terms of population and employment distribution to forecast auto trips and trip distances for each future scenario. These forecasting models estimate the number of auto trips and the associated distances as a function of household characteristics, population and employment distribution aggregated at the Traffic Analysis Zone (TAZ) level.

3. TRANSPORTATION COMPONENT

The transportation component of this study has two main models both estimated at the TAZ level: (i) auto trip rate model and (ii) auto trip distance model. The outputs of the land allocation model together with available data from Census, ODOT and transit agencies inform the transportation component. Figure 1 below demonstrates how the transportation component for the model works. In this section of the report, the data used for developing these models, estimation procedures and model results are presented. Appendix D includes the datasets used for model estimations accompanied by variable descriptions.

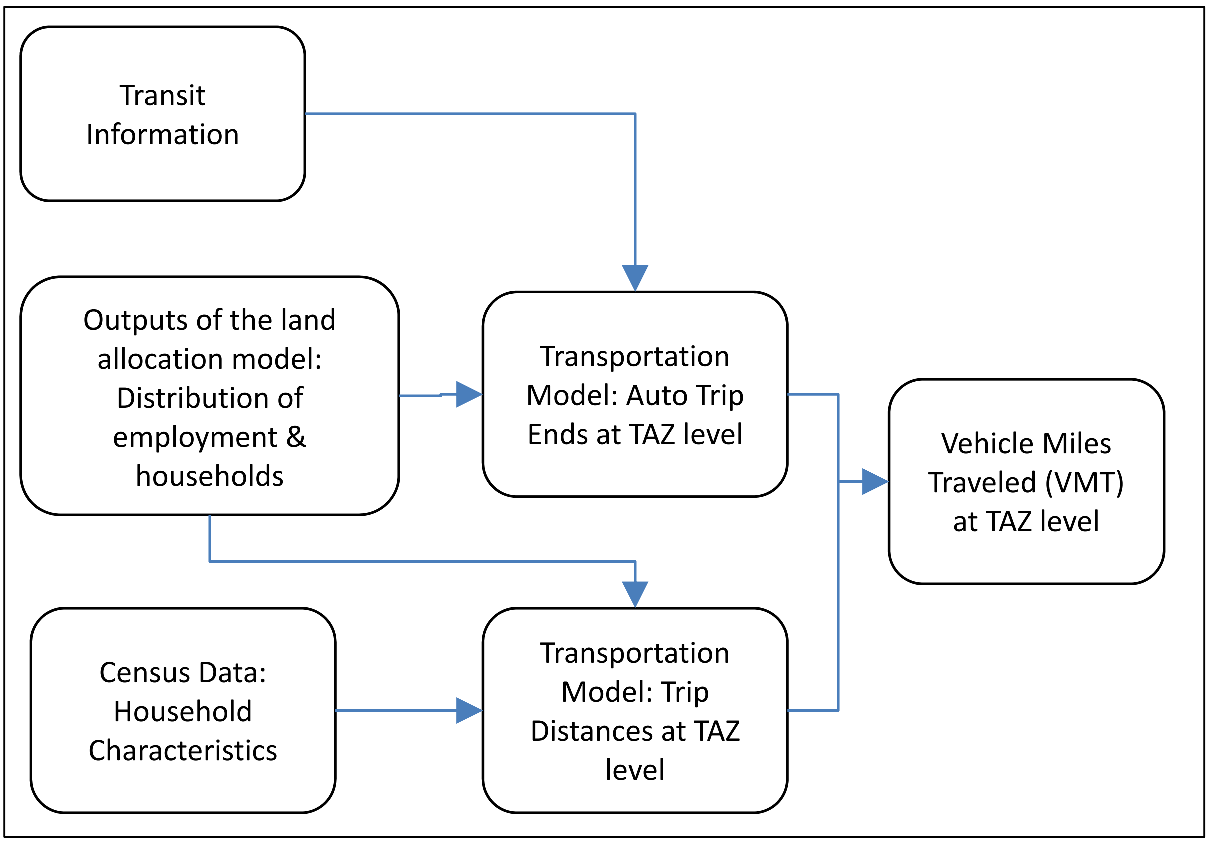


Figure 1: Transportation Component

3.1 Data

Datasets from different sources were assembled for this part of the project. The following household travel surveys were used for calculating trip distances across the state.

- 2001-2003 Ohio Statewide Household Travel Survey
  - Locations include Toledo, Lima, Dayton, Springfield, Akron, Canton, Mansfield, Steubenville, Youngstown and rural
- 1996 Cincinnati Household Travel Survey
- 1994 Cleveland Household Travel Survey
- 1999 Mid-Ohio Household Travel Survey

The household travel surveys listed above included information on the location of each household's residence as well as the origins and destinations of each trip (geo-coded), which enabled the researchers to calculate network travel distances, travel times, and several land use characteristics, except for the Cleveland area. The Cleveland Household Travel Survey did not include the geo-codes (or addresses) of the trip origins and destinations.

In addition to the household travel surveys, several land use and transportation system related variables are calculated based on the data acquired from the Central Ohio Transit Authority (COTA), Mid-Ohio Regional Planning Commission (MORPC), Ohio Department of Transportation (ODOT), and 2000 Census.

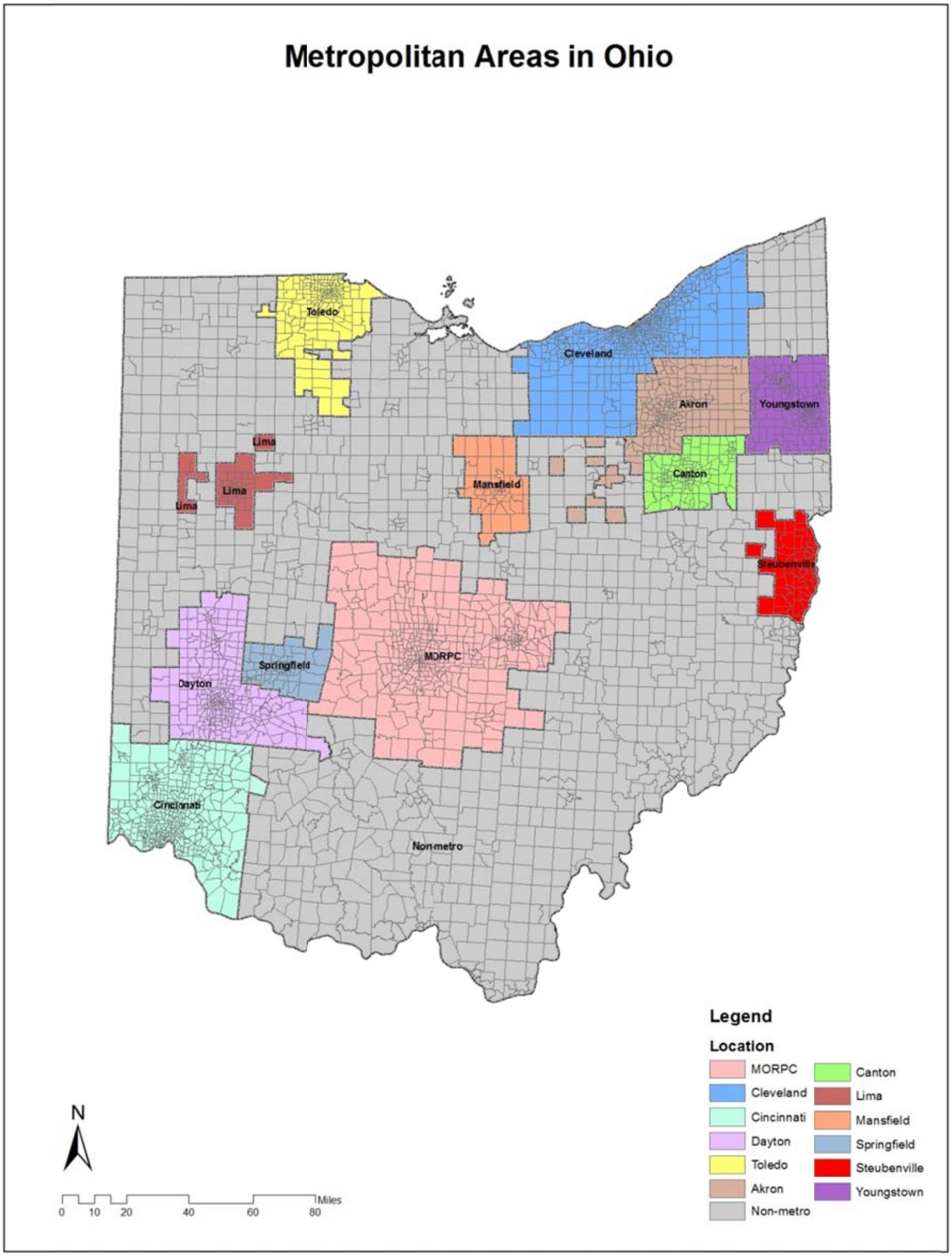
The first decision was to determine what spatial unit to use for model estimation and analysis. Census tracts were determined to be the best practical proxy for neighborhoods due to the wealth of data available for that geography, although there is an extensive literature about neighborhood definition in geography and other fields (Claudia et al., 2001; Dietz, 2002; Guo and Bhat, 2007). In this study, the unit of analysis was chosen as the TAZ level. Most of the TAZs are smaller in size than census tracts, which allowed for capturing more detailed variations in land-use and built environment characteristics. The following table, Table 1, presents the distribution of Ohio's TAZs from the Ohio Statewide Travel Demand Model. Map 1 illustrates the locations of these TAZs.

Table 1: Distribution of TAZs

	N	Percent
Akron	215	5.87
Canton	133	3.63
Cincinnati	432	11.8
Cleveland	460	12.57
Dayton	296	8.09
Lima	50	1.37
Mid-Ohio	412	11.26
Mansfield	63	1.72
Non-metro	1,127	30.79
Springfield	66	1.8
Steubenville	66	1.8
Toledo	175	4.78
Youngstown	165	4.51
Total	3,660	100

3.2 Descriptive Statistics

Data on number of jobs, households and population at each TAZ were readily available through ODOT for the year 2000. Table 2 presents the average number of jobs, households and population at the TAZ level across the state based on these data. Table 3 presents the corresponding densities.



Map 1: Distribution of TAZs across Ohio

Table 2: Total Employment, Population and Households at the TAZ level (2000)

	Employment		Population		Households		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	1,926	2,544	3,398	2,198	1,333	883	215
Canton	1,686	1,965	2,887	2,176	1,132	888	133
Cincinnati	2,310	3,234	3,515	2,457	1,373	973	432
Cleveland	2,958	3,859	4,699	3,207	1,865	1,297	460
Dayton	1,756	2,568	2,766	2,432	1,107	1,004	296
Lima	1,356	1,447	1,997	1,425	754	563	50
Mid-Ohio	2,712	4,281	3,872	4,182	1,530	1,735	412
Mansfield	1,202	1,518	2,122	1,582	815	690	63
Non-metro	1,252	2,025	2,369	2,123	901	845	1,127
Springfield	1,126	1,280	2,273	1,825	890	736	66
Steubenville	584	1,102	1,215	1,148	499	499	66
Toledo	2,040	2,474	3,183	2,291	1,268	951	175
Youngstown	1,506	1,831	2,749	2,311	1,099	965	165
Total	1,887	2,908	3,102	2,762	1,215	1,124	3,660

Table 3: Densities (*) of households, employment and population across TAZs (2000)

	Employment density		Population density		Household density		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	1,239	3,566	1,766	2,104	720	865	215
Canton	1,137	2,065	1,434	1,753	571	705	133
Cincinnati	3,668	19,901	2,357	2,444	989	1,121	432
Cleveland	3,747	19,215	3,447	3,579	1,400	1,493	460
Dayton	1,483	4,596	1,635	2,054	674	851	296
Lima	1,218	2,783	1,202	1,696	476	662	50
Mid-Ohio	2,443	15,575	1,469	2,145	601	890	412
Mansfield	986	2,344	1,151	1,827	427	686	63
Non-metro	195	580	283	653	113	266	1,127
Springfield	966	2,274	1,191	1,668	467	657	66
Steubenville	454	1,443	554	1,154	235	499	66
Toledo	1,728	5,334	2,118	2,301	856	924	175
Youngstown	1,104	2,807	1,328	1,448	532	580	165
Total	1,665	11,260	1,481	2,291	604	959	3,660

* Per square mile

For household characteristics, the available data were available through Census and at the census tract level. Therefore values at the TAZ level are calculated based on the values at the tract level. First, using ArcGIS, both census tract and TAZ shape-files of the State of Ohio are converted into raster files. In order to get a better estimate of the population at the TAZ level, all the tracts are divided into 500 foot square cells which are assigned the value for that tract. This was done so that we could more accurately represent the population as we overlayed the TAZ boundaries. The boundary of the TAZ is then overlaid and the mean values of the cells that fall within the TAZ boundary are calculated to estimate the value for the TAZ. The following table, Table 4, presents the data on vehicle ownership, household size and median household income at the TAZ level.

Table 4: TAZ Characteristics (Household Size, Median Household Income and Vehicles per Household Driver)

	Household Size		Median Household Income		Vehicles per Household Driver		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	2.54	0.25	47,170.2	15,885.5	1.88	0.34	215
Canton	2.54	0.18	40,753.1	9,809.1	1.90	0.27	133
Cincinnati	2.51	0.36	48,869.7	18,313.8	1.77	0.46	432
Cleveland	2.45	0.44	46,799.1	22,086.5	1.64	0.50	460
Dayton	2.50	0.26	44,567.5	14,385.4	1.85	0.39	296
Lima	2.55	0.19	39,833.0	11,629.9	1.89	0.36	50
Mid-Ohio	2.56	0.30	49,005.6	15,630.8	1.93	0.38	412
Mansfield	2.53	0.23	40,314.4	9,943.5	1.89	0.33	63
Non-metro	2.63	0.19	38,582.6	7,119.6	2.02	0.21	1,127
Springfield	2.53	0.16	45,669.3	10,713.4	1.93	0.33	66
Steubenville	2.44	0.15	32,588.9	5,828.9	1.86	0.28	66
Toledo	2.53	0.26	44,023.8	14,646.1	1.76	0.37	175
Youngstown	2.47	0.27	37,449.1	12,227.1	1.76	0.40	165
Total	2.54	0.29	43,345.8	14,923.5	1.87	0.38	3,660

The land allocation model allocates employment in 4 categories: retail, industry, office and other. The data acquired from ODOT had 16 subgroups, and these subgroups are reorganized into four categories to match the land allocation model's outputs. Subgroups of these employment categories are summarized in Table 5. The following tables, Table 6 and Table 7 report the distribution of employment in these 4 categories across the state at the TAZ level.

Table 5: Employment categories

Industry Code (ODOT)	Industry	Land Allocation Model
1	Agriculture, Forestry & Fisheries	Other
2	Primary Metal Products	Industry
3	Light Industry	Industry
4	Heavy Industry	Industry
5	Transportation Equipment	Other
6	Wholesale	Industry
7	Retail	Retail
8	Hotel and Accommodations	Retail
9	Construction	Other
10	Health Care	Office
11	Transportation Handling	Other
12	Utilities Service	Other
13	Other Services	Retail
14	Grade-school Education	Office
15	Post- Secondary Education	Office
16	Government and Other	Office

Table 6: Number of Jobs in Retail, Industry, Office and Other Categories at TAZ level

	Retail Jobs		Industry Jobs		
	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	442	605	456	954	215
Canton	388	659	418	869	133
Cincinnati	492	778	457	1,129	432
Cleveland	603	887	642	1,172	460
Dayton	387	603	332	722	296
Lima	298	606	190	328	50
Mid-Ohio	583	960	441	1,017	412
Mansfield	292	457	265	516	63
Non-metro	275	496	282	635	1,127
Springfield	275	390	156	262	66
Steubenville	135	287	130	448	66
Toledo	498	761	310	545	175
Youngstown	395	695	244	380	165
Total	414	703	378	857	3,660

	Office Jobs		Other Jobs		
	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	295	1,004	676	1,145	215
Canton	254	616	483	684	133
Cincinnati	344	1,212	997	2,132	432
Cleveland	509	1,493	1,191	2,425	460
Dayton	343	1,410	642	1,338	296
Lima	260	676	526	653	50
Mid-Ohio	483	2,127	1,201	2,340	412
Mansfield	204	550	374	484	63
Non-metro	172	462	324	660	1,127
Springfield	174	391	389	792	66
Steubenville	113	328	179	342	66
Toledo	334	983	831	1,379	175
Youngstown	258	661	510	937	165
Total	306	1,165	698	1,593	3,660

Table 7: Retail, industry, office and other employment densities at the TAZ level

	Retail density		Industry density		
	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	271	619	233	617	215
Canton	215	469	303	845	133
Cincinnati	505	1,873	541	2,451	432
Cleveland	638	4,680	552	1,411	460
Dayton	271	735	292	876	296
Lima	198	338	123	214	50
Mid-Ohio	420	2,591	214	617	412
Mansfield	182	380	195	487	63
Non-metro	46	137	39	125	1,127
Springfield	191	358	111	259	66
Steubenville	94	266	125	675	66
Toledo	336	650	251	918	175
Youngstown	224	520	161	332	165
Total	284	2,019	246	1,100	3,660

	Office density		Other density		
	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	304	1,570	461	1,666	215
Canton	245	922	322	634	133
Cincinnati	978	7,921	2,119	15,527	432
Cleveland	740	3,714	1,813	11,113	460
Dayton	338	1,893	597	2,414	296
Lima	371	1,299	492	1,269	50
Mid-Ohio	943	9,638	1,223	8,568	412
Mansfield	236	930	374	1,011	63
Non-metro	36	153	51	185	1,127
Springfield	162	574	428	1,604	66
Steubenville	100	319	129	408	66
Toledo	437	2,509	771	3,153	175
Youngstown	283	1,395	369	1,236	165
Total	427	4,538	795	7,348	3,660

To account for transit availability in auto trip end models, we calculated the number of transit stops in each TAZ. We contacted the regional transit agencies and were able to acquire the GIS layers for transit stops from the agencies serving the 6 metropolitan regions listed in Table 8.

Table 8, presents the average number of transit stops at the TAZ level. The number of transit stops includes both bus and rail stops. Only Cleveland area has rail transit stops.

Table 8: Number of Transit Stops at the TAZ level

	Mean	Std. Dev.	N
Akron	11.67	16.32	215
Cincinnati	11.37	18.11	432
Cleveland	19.19	21.34	460
Dayton	11.32	15.91	296
Mid-Ohio	9.79	18.58	412
Toledo	12.37	16.05	175

In order to use in our analysis, we acquired the outputs (trip ends at the TAZ level) of the Ohio Statewide Model through MORPC. The model was run using 2000 data. The Ohio Statewide Model (OSM) is an integrated economic, land use, and travel demand forecasting model. This model was developed by the ODOT Modeling & Forecasting Section to serve as an important tool for large multi-region corridor studies, system-wide congestion analysis, and traffic forecasting in the rural areas of the state not covered by urban MPO models. The tool developed in this study differs from OSM with its simple and flexible interface as well as its stand-alone land use allocation model.

The OSM is made up of multiple components covering residents, visitors, and freight travels. Among them, a Personal Travel (PT) model forecasts the person movements arising from the population within the model area engaging in spatially-separated activities, based on the concept of tours. A tour is defined as a sequence of activities that begins and ends at the same location: home (home-based tours) or work (work-based tours). In the PT model, personal travel is classified into short distance travel (SDT) and long distance travel (LDT). SDT includes all work tours, regardless of tour length, and all non-work tours to destinations within 50 miles of the home location. The following table, Table 9, reports the trip ends at the TAZ level.

Table 9: Number of Auto Trips Ends in Persons and Vehicles

	Auto trip ends (autos)		Auto trip ends (persons)		
	Mean	Std. Dev.	Mean	Std. Dev.	N
Akron	16,261	11,706	21,466	15,262	215
Canton	14,339	13,417	18,946	17,597	133
Cincinnati	16,894	12,998	22,439	17,070	432
Cleveland	23,485	17,140	30,929	22,426	460
Dayton	14,154	13,336	18,569	17,356	296
Lima	10,888	10,236	14,358	13,442	50
Mid-Ohio	19,745	22,903	25,892	29,879	412
Mansfield	10,521	10,184	13,869	13,398	63
Non-metro	11,403	15,157	15,109	19,772	1,127
Springfield	10,555	9,194	14,023	12,142	66
Steubenville	5,708	7,225	7,636	9,685	66
Toledo	17,514	15,134	23,026	19,669	175
Youngstown	14,762	14,534	19,460	19,049	165
Total	15,427	16,123	20,358	21,062	3,660

*Source: Ohio Statewide Model (Model runs completed by MORPC)

Trip distances for all trip purposes are calculated using the Household Travel Surveys. First, network travel distances are calculated based on the geo-coded trip origins and destinations for all trips. Then, the mean values of these distances are calculated at the TAZ level, using the survey weights attached to households. The calculations are based only on the auto trips as the aim of this research is developing a tool to forecasts the resulting auto VMT under different scenarios. As shown in Table 10, the average trip distance at the state level is 7.8 miles. The longest average trip distance was observed at nonmetropolitan TAZs.

Table 10: Average Trip Distance at TAZ level (miles)

	Mean	Std. Dev.	N
Akron	7.45	3.69	210
Canton	6.65	2.83	131
Cincinnati	7.30	3.33	426
Cleveland	7.19	3.58	429
Dayton	7.54	4.82	285
Lima	6.95	2.44	47
Mid-Ohio	8.38	5.44	359
Mansfield	7.40	5.53	63
Non-metro	9.23	5.82	897
Springfield	6.91	2.35	64
Steubenville	8.05	3.83	60
Toledo	6.36	3.32	172
Youngstown	6.21	2.74	164
Total	7.83	4.65	3,307

3.3 Auto Trip Ends Model

The model introduced here aims to answer the question 'how many auto-trips will be generated' given a distribution of households, employment and availability of transit across the state, and is inspired by a recent study by Wu et al. (2012). For the auto-trip ends regression model, the vehicle trip ends are regressed with number of households and number of jobs in 4 employment categories. These employment categories (retail, industry, office and other) are based on the categories used by the land-allocation model. Subgroups of these employment categories are summarized in Table 5. Two separate models were estimated; one for urban TAZs, and one for nonmetropolitan TAZs.

Daily vehicle trip ends at the TAZ level are based on the Ohio Statewide Model results: vehicle trip ends at the TAZ level for year 2000. Year 2000 values were used as the corresponding population and employment values at the TAZ level were available for this year.

Ordinary least squares estimation was used to analyze the links between number of households, number of jobs and transit availability on auto trip rates. The functional form for the regression model and the variables of interest are described below and in Table 11.

$$
\begin{aligned}
Y = \quad & \beta_1 * (\text{number of households}) + \\
& \beta_2 * (\text{number of retail jobs}) + \\
& \beta_3 * (\text{number of office jobs}) + \\
& \beta_4 * (\text{number of industry jobs}) + \\
& \beta_5 * (\text{number of other jobs}) + \\
& \beta_6 * (\text{number of retail jobs x transit availability}) + \\
& \beta_7 * (\text{number of retail jobs x transit availability}) + \\
& \beta_8 * (\text{number of retail jobs x transit availability})
\end{aligned}
$$

The dependent variable *Y* represents the trip ends at the TAZ level. The intercept of the regression is forced to zero, as TAZs with no employment and households should not generate any vehicle trips for the model purposes.

To account for transit availability and how it affects the number of auto trips, interaction terms were introduced. The number of jobs in retail, office and other categories were multiplied by the transit availability binary variable, which takes a value of 1 if there is a transit stop within the TAZ or if there is a transit stop within 0.5 mile radius of the TAZ centroid, and 0 (zero) otherwise. The interaction effects of transit availability and jobs in the industry category as well as households did not result in statistically significant estimates; therefore they were dropped from the model variables.

Table 11: Variable definitions for Auto Trip Rates at the TAZ level

Variable name	Explanation	Source
Households	Num. of households at TAZ	Output of the land allocation model
Retail	Num. of retail jobs at TAZ	Output of the land allocation model
Industry	Num. of industry jobs at TAZ	Output of the land allocation model
Office	Num. of office jobs at TAZ	Output of the land allocation model
Other	Num. of other jobs at TAZ	Output of the land allocation model
Retail jobs X transit	Interaction variable	These interaction variables are calculated based on the outputs of the land allocation model and transit availability
Office jobs X transit	Interaction variable	
Other jobs X transit	Interaction variable	

The model coefficients are estimated separately for urban TAZs and nonmetropolitan TAZs. As there are no transit stops in nonmetropolitan areas, the model corresponding to these TAZs does not include the transit interaction variables. The interaction variables for TAZs in metropolitan areas without transit simply take on the value of 0 (zero). The descriptive statistics for the estimation samples and the model results for urban and rural/nonmetropolitan areas are reported in Tables 12, 13 and 14, respectively.

Table 12: Descriptive Statistics of the Estimation Sample - Auto Trip Rate Models

Metropolitan TAZs		
	Mean	Std. Dev.
Number of households	1,356.590	1,203.72
Number of retail jobs	476.511	771.04
Number of industry jobs	421.332	936.78
Number of office jobs	366.765	1,364.47
Number of other jobs	867.394	1,842.94
Transit availability (binary variable)	0.389	0.48
Sample size	2,533	
Nonmetropolitan TAZs		
	Mean	Std. Dev.
Number of households	899.821	842.80
Number of retail jobs	273.701	494.17
Number of industry jobs	281.480	633.97
Number of office jobs	170.942	460.28
Number of other jobs	322.339	657.17
Sample size	1,127	

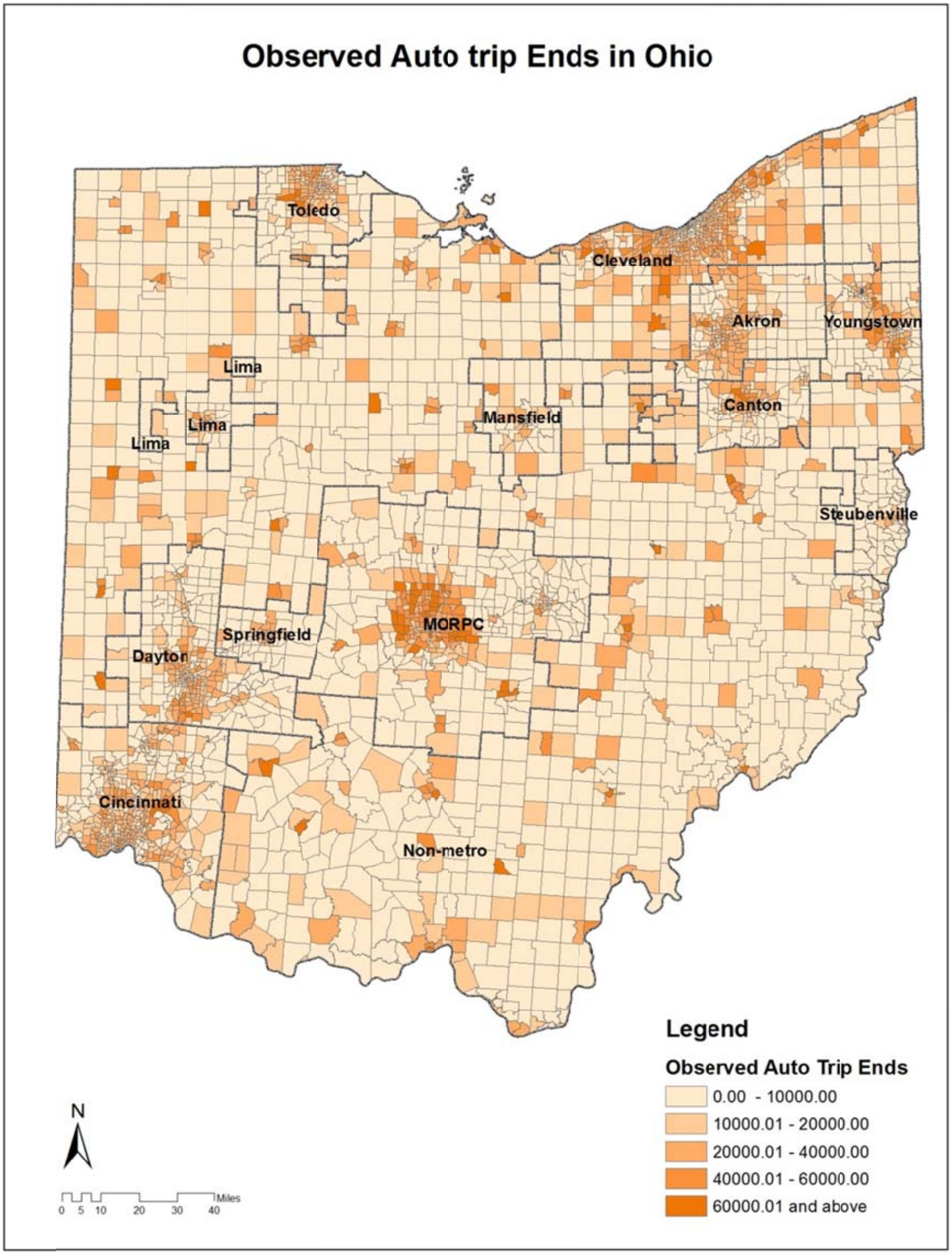
Table 13: Trip Rate Model: Metropolitan Areas

Dependent variable= Number of auto trip ends		
	Coefficient	t stat.
Households	8.552816	149.57
Retail employment	9.597324	43.99
Industry employment	1.770398	19.75
Office employment	1.606300	7.39
Other employment	1.258461	7.44
Retail X transit availability	-2.175085	-8.69
Office X transit availability	-0.465794	-2.05
Other X transit availability	-0.483172	-2.74
Number of observations		2533
R^2		0.9718
Adjusted R^2		0.9717

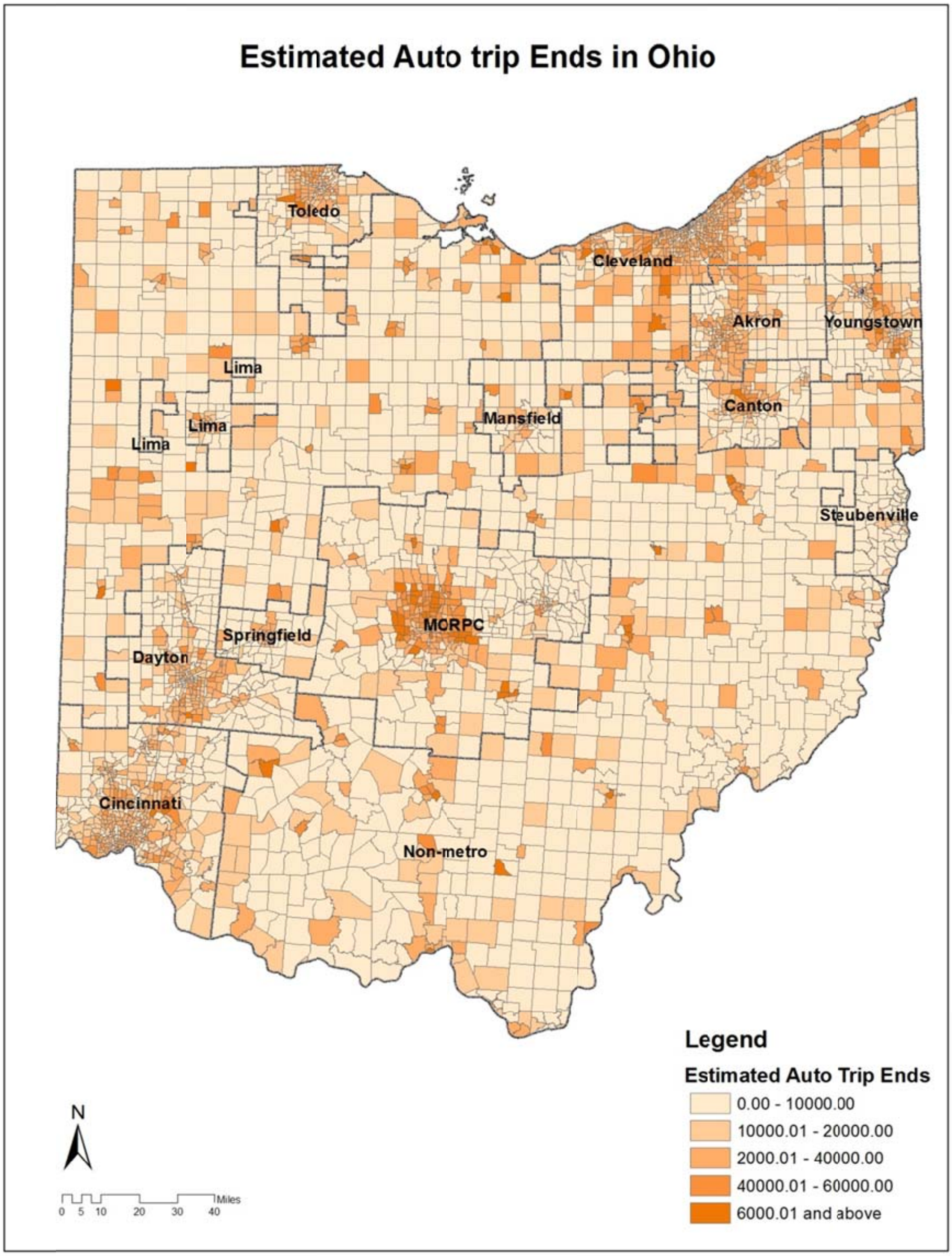
Table 14: Trip Rate Model: Non-metropolitan Areas

Dependent variable= Number of auto trip ends		
	Coefficient	t stat.
Households	7.743520	75.5
Retail employment	10.98464	47.48
Industry employment	2.264124	17.59
Office employment	3.810378	18.34
Other employment	2.318551	14.36
Number of observations		1,127
R^2		0.9851
Adjusted R^2		0.9850

The following two maps (Map 2 and Map 3) illustrate the observed (outputs of the OSM model) and estimated auto trip ends across the region.



Map 2: Observed Auto Trip Ends



Map 3: Estimated Auto Trip Ends

3.4 Trip Distance Model

Ordinary least squares estimation in log-linear form was used to analyze the effects of household characteristics, employment and population distribution on the resulting trip distances at the TAZ level. The functional form for the regression model used in this study and the variables of interest are described below and in Table 15.

$$
\begin{aligned}
Ln(Y) = \quad & \alpha + \\
& \beta_1 * (\text{household size}) + \\
& \beta_2 * (\text{household income in \$, divided by 10,000}) + \\
& \beta_3 * (\text{vehicles per household driver}) + \\
& \beta_4 * (\text{density of retail jobs}) + \\
& \beta_5 * (\text{density of industry/office/other jobs}) + \\
& \beta_6 * (\text{density of households}) + \\
& \beta_7 * (\text{JOB-HH index within 20 minutes}) + \\
& \beta_8 * (\text{Akron}) + \\
& \beta_9 * (\text{Canton}) + \\
& \beta_{10} * (\text{Dayton}) + \\
& \beta_{11} * (\text{Lima}) + \\
& \beta_{12} * (\text{Mansfield}) + \\
& \beta_{13} * (\text{Springfield}) + \\
& \beta_{14} * (\text{Steubenville}) + \\
& \beta_{15} * (\text{Toledo}) + \\
& \beta_{16} * (\text{Youngstown}) + \\
& \beta_{17} * (\text{Non-metro})
\end{aligned}
$$

The dependent variable *ln (Y)* represents the natural log of the mean trip distance (in miles) at the TAZ level and α is a constant. The variables related to household characteristics (household size, income and vehicles per household driver) are all calculated based on 2000 Census data and converted to TAZ level as discussed in Section 3.2 Descriptive Statistics.

Table 15: Variable Definitions, Trip Distance Model

Variable	Description	Source
Household size	Average household size at TAZ level	Census
Household income ($10k)	Median household income at TAZ level (in $, divided by 10,000)	Census
Vehicles per hh driver	Vehicle per household driver at TAZ level	Census
Retail density	Number of retail jobs divided by the TAZ area (square miles)	Output of the land allocation model/ divided by area
Industry, office and other employment density	Sum of all employment categorized under industry, office and other categories divided by the TAZ area	Output of the land allocation model/ divided by area
Household density	Number of households divided by the TAZ area	Output of the land allocation model/ divided by area
JOB_HH	Index. Calculation equation is explained below.	Output of the land allocation model/ needs to be calculated
Location variables(*)	All are binary variables. (1= if true, 0 otherwise) (Akron, Canton, Dayton, Lima, Mansfield, Springfield, Steubenville, Toledo, Youngstown, Non-metro)	

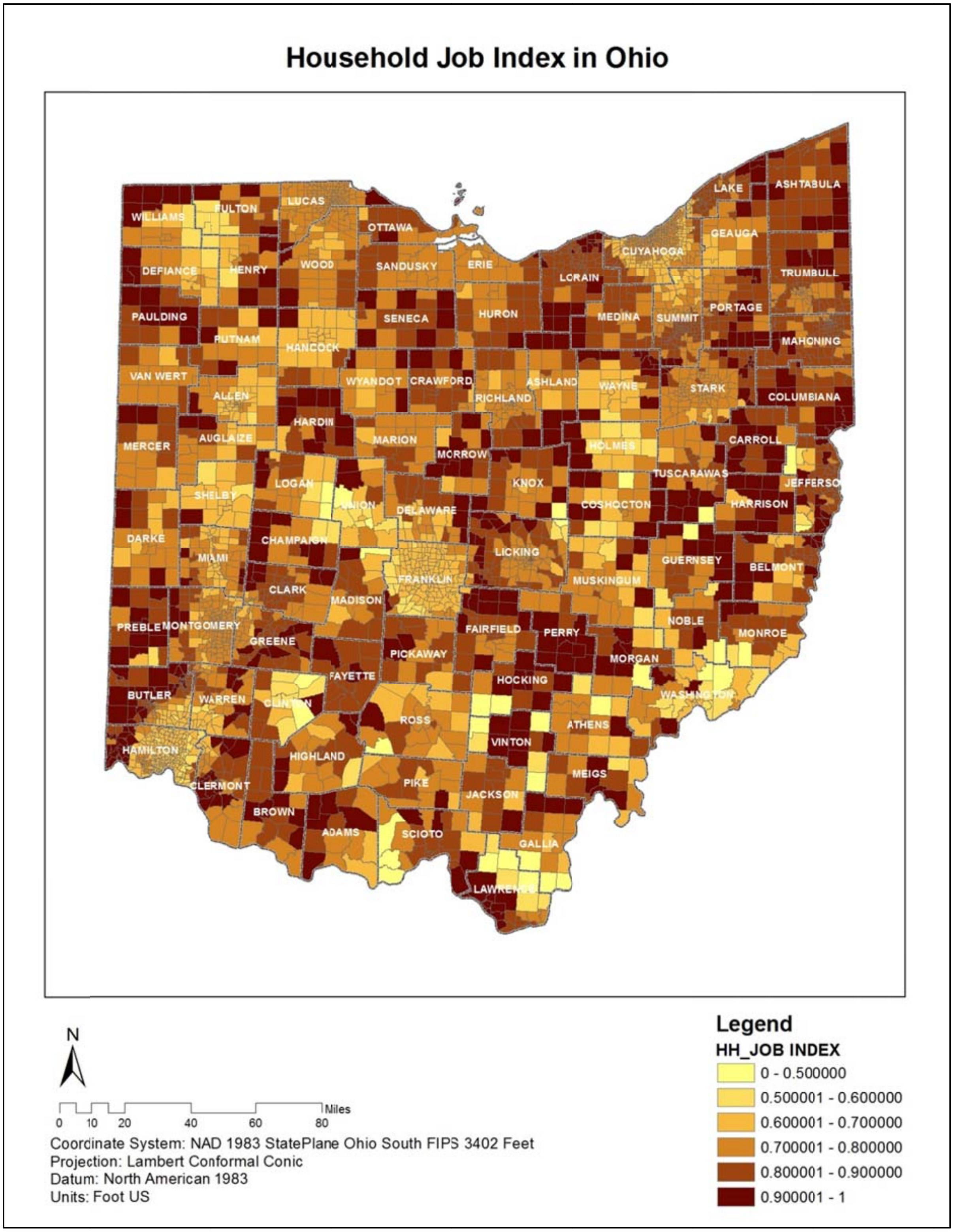
*Binary variables for all locations are initially added to the model and the ones which turned out to be statistically not significant were dropped from the model

The employment and household densities are calculated based on the outputs of the land allocation model. In addition, an index which measures the job-population balance for each TAZ based on a 20 minute driving time from the TAZ centroid is also calculated based on the land allocation model outputs and included in this model. The total number of jobs and households are calculated for each TAZ, and all the neighboring TAZs within a 20 minute driving distance. The calculation of this index refers to the equation in Ewing et al.'s paper (Ewing et al., 2011). Based on the empirical facts in the study area, the value 0.2 (which was used by Ewing et al.

(2011) for the population number), representing a balance of employment and population, was adjusted to 1 to represent a balance between jobs and number of households in this study. The number of households is used instead of the population, as the land allocation model gives the number of households as the output.

$$JOB\_HH\,index = 1 - \frac{|\,number of\;\; jobs - number of\;households|}{(number of\;\; jobs + number of\;households)}$$

The index varies between 0 (zero) and 1. An index value of 1 indicates that there will be one job for each household within a 20 minute driving. An index value of 0 (zero) indicates that there are only households or jobs present in a given 20 minute driving distance. As the index value approaches 1, the index represents a more balanced area in terms of households and jobs. Map 4 illustrates the distribution of this index across Ohio.



Map 4: Household- Job Index

Table 16 presents the descriptive statistics of the trip distance model estimation sample. Based on the estimation sample, the average trip length is 7.9 miles, average household size is 2.5 persons, median income is $43,190 and vehicles per household driver is 1.88. The mean value of Job-Household Index calculated based on the year 2000 employment and household numbers is 0.77.

Table 16 Descriptive Statistics of the Estimation Sample

	Mean	Std. Dev.	Variable type
Average distance	7.928	4.781	Continuous
Household size	2.545	0.265	Continuous
Income in $10,000	4.319	1.387	Continuous
Vehicles per household driver	1.884	0.356	Continuous
Retail density	258.854	1,289.046	Continuous
Industry/office/other density	1,370.305	11,681.9	Continuous
Household density	541.928	818.988	Continuous
Job-Household index	0.773	0.103	Continuous
Akron	0.073	0.26	Dummy
Canton	0.045	0.208	Dummy
Dayton	0.099	0.299	Dummy
Lima	0.016	0.127	Dummy
Mansfield	0.021	0.144	Dummy
Non-metro	0.308	0.462	Dummy
Springfield	0.022	0.147	Dummy
Steubenville	0.021	0.143	Dummy
Toledo	0.059	0.236	Dummy
Youngstown	0.056	0.229	Dummy

The trip distance model estimates for the region are presented in Table 17. This table also reports the elasticities associated with these variables. For continuous variables (such as household income, employment and household densities) the elasticity effect is calculated at the sample means and indicates the percent change in the dependent variable with respect to a 1% change in the independent variable. For dummy variables, we report the percent change in the dependent variable due to a discrete change (from zero to one) in the dummy variable.

Table 17 Trip Distance Model

Dependent variable: *ln* (trip distance in miles)			
	Coef.	t	Elasticities
Household size	0.0815765	1.87	0.208
Income in $10,000	-0.0590675	-6.22	-0.255
Vehicles per household driver	0.3815368	8.04	0.721
Retail density	0.0000350	-2.83	0.009
Industry/office/other density	6.86E-06	5.06	0.009
Household density	-0.0001720	-12.06	-0.093
Job-Household index	-0.2427046	-2.39	-0.187
Akron	-0.0545613	-1.61	-5.310
Canton	-0.2312551	-5.20	-20.646
Dayton	-0.0953771	-2.97	-9.097
Lima	-0.1916624	-2.74	-17.441
Mansfield	-0.2148394	-3.52	-19.333
Non-metro	-0.1292200	-4.69	-12.122
Springfield	-0.1591444	-2.64	-14.713
Steubenville	-0.1218713	-1.90	-11.474
Toledo	-0.1879413	-4.84	-17.134
Youngstown	-0.2725348	-6.62	-23.855
Constant	1.6488620	13.33	
Number of observations	2878		
R^2	0.1959		
Adjusted R^2	0.1911		

The findings reveal that trip distances are longer for TAZs with lower household and retail employment densities as well as lower Job-Household indexes. All else being equal a 1% increase in vehicles per household driver will lead to a 0.7% increase in trip distances. Although at a first glance, the elasticities for household and employment densities seem low, they are generally consistent with the literature. A 1% increase in Job-Household index (towards a more balanced job-household distribution) will reduce the trip distances by 0.19%.

3.5 Summary of Findings

This chapter presented the data used for the auto trip ends and trip distance models, model estimation processes and the estimation results. The outputs of the land allocation model (distribution of jobs and households) inform these two transportation models. The estimated models are then used to project the number of auto trip ends and trip distances under different household and employment distribution scenarios in order to project the VMT associated with each TAZ. For each TAZ, the number of auto trips ends is multiplied by the average trip distance at the TAZ level to calculate the estimated VMT associated with each TAZ.

The model results are generally consistent with the existing literature. The explanatory power of the auto trip end models are quite high, both with R^2 values above 0.95. There are auto trips associated with each employment and household, and the availability of transit reduces the number of auto trips associated with certain types of employment. The effect of transit varies across different job categories. The effect is highest on the retail employment related trips.

The distance model provides estimates of average trip distances at the TAZ level, as a function of household characteristics, distribution of households and employment. Although the R^2 value for this model is relatively low as compared to the trip ends model, this level of fit is not dissimilar from comparable models reported in the literature. Several recent studies aiming at explaining trip distances through regression analysis report R^2 values ranging from 0.10 to 0.20 (Axisa et al., 2012; Heres-Del-Valle and Niemeier, 2011; Morency et al., 2011).

The next section of the report presents the land allocation component, followed by descriptions of land allocation scenarios and the results of the scenario runs.

4. THE LAND ALLOCATION MODEL

4.1 Original Model

The project began with the original land allocation developed for MORPC. That model had been translated to run in CUBE. The model divided the region into 40 acres cells with data tabulated on the current number of jobs and households in each cell. Additional data gathered on the potential for development of the cell based on a set of criteria for both employment and households are then used to create a score representing the probability of development. Tables 18 and 19 show these categories and scores for each of these cell characteristics. Complete data were available from Mid-Ohio Regional Planning Commission for all of the variables for central Ohio. However, data were not available at the same level of detail for the other metropolitan areas of Ohio, requiring some changes in the weighting scheme. These differences are discussed in the data section of this report.

Next, each cell is assigned a future land use based on current local land use plans. Each of those land uses is constrained in terms of the density of jobs or households that can be assigned to the cell, providing an upper limit on the total growth of the cell. Those constraints are shown in Table 20. Here again, data at the same level of detail were not available statewide, necessitating a reduction in the number of categories applied in other regions.

Given a forecast of future jobs and households at both the regional and county level, the model then allocates households and employment to the cells in the order from highest to lowest scores, filling each of the target cells to a "predetermined" percentage of capacity and continuing until the target forecast growth total at the county or regional scale is reached. In this way, a future land use pattern emerges based on the availability of excess capacity in the cell and the assumed future land use, in the order relating to the ranking scores of the development potentials.

4.2 Introducing Random Processes

At the outset, it was determined that several steps should be made to improve the model. In each original form, the model was entirely deterministic – assigning growth to target cells in the order of their weighting up to the full capacity modified by a damping factor for the cell. In order to reflect the more realistic view of land use change as a somewhat random process, a Monte Carlo version of the model was created.

In addition, two versions of the model were developed for growth and decline scenarios. The Land Use Growth model is applied to the Central Ohio region where growth is consistently forecast over the next 35 years (from 2000 – 2035). The Land Use Growth Decline model is a version applied to the other metropolitan areas in Ohio where there is significant decline of households and jobs in significant parts of the region. Figure 2 shows the overall workflow that applies to both versions. The detailed model operations for households and jobs are shown as Figures 3 to 5 for the Land Use Growth Decline model. The Growth model functions in almost the same way without having to make a decision as to whether decline will occur in a cell.

The total growth forecast for households and jobs over the 35 year forecast period is divided evenly into annual growth totals. Those totals become the forecast control total for each year of the simulation. Development weightings for the cells are normalized based on the minimum and maximum score and assigned a value between zero and one. Then, a pseudo random number is generated and used to pick a target cell. A second random number is selected and compared to the normalized development score for that cell. If the score is greater than or equal to the random number, one increment of household or job development is assigned to that cell if additional households or jobs are available in that cell. An increment is 1/35 or about 3% of the total possible growth capacity of the cell. (The number of households or jobs in a cell is constrained by its future land use.)

Another random cell is then chosen and allocated a growth increment based on the same criteria. This is repeated until the annual growth total for the county and region are met. The model then moves to the next year and repeats the process across the 35 year development period yielding the future development pattern that is used in the transportation forecasts. Since random development of cells is allowed using the Monte Carlo algorithm spreading the development across the region, the damping factor in the original model was not used.

The forecasts of households and jobs in the four major categories are then summed into Traffic Analysis Zones (TAZ) for the region. Those totals are then used to generate the independent variables in the transportation models and provide a forecast of trips, trip distances, and vehicle miles travelled.

The model requires a significant amount of data for each cell in the target region. As part of our research effort, we have created the basic cell structure for all of the areas in the state where the model was applied. Outside of the Mid-Ohio region where complete cell-based data were available, publically available data were used to fill as many of the characteristics of the cells as possible for the values of factors shown in Table 18 and Table 19. Some of these were either available but at a lesser level of detail or were not available at all for the other regions of the state. The model will still function with fewer factors but will obviously not take those factors into account when allocating future land use changes. As additional data become available or can be gathered by the other regional planning agencies, the model inputs could be refined.

Appendix A details the sources of the statewide data and the changes in some of the levels of detail that were available for use in this research effort. Appendix B provides instructions for using GIS software to estimate cell values based on digital map data at different scales. The data used in the current study were delivered on DVD to the Ohio Department of Transportation as part of our final report materials.

Table 18: Criteria and Weights for Employment Growth Scores

Category	Feature		Long description	Jobs
Econ Dev	TIF	TIF	Majority of grid in Tax Increment Financing (TIF) district	8
Econ Dev	CRA	CRA	Majority of grid in Community Reinvestment Area (CRA)	5
Econ Dev	Innovation Hubs	INNOHUB	Majority of grid in ODOD Innovation Hub zone	5
Econ Dev	CEDA	CEDA	Majority of grid in Cooperative Economic Development Agreement (CEDA) area	2
Econ Dev	JEDZ	JEDZ	Majority of grid in Joint Economic Development District/Zone (JEDD/JEDZ)	2
Econ Dev	EZ	EZ	Majority of grid in Enterprise Zone (EZ)	2
Environ	Forests	FOREST	More than 25% of grid with land cover of forest	-4
Environ	Streams (1/4 mile)	STREAM	Majority of grid within 1/4 mile of rivers and streams	-4
Environ	Wellhead Zone 5-year	WELL5	Majority of grid in Ohio EPA modeled 5-Year Wellhead Zone related to ground water wells	-4
Environ	High Slope (>24 %)	SLOPE	Majority of grid has slope greater than 24% in soil survey data	-4
Environ	Upstream from water in-take	CMZ	Majority of grid in Ohio EPA defined Corridor Management Zone (CMZ) related to surface water intakes	-6
Environ	Upground Reservoirs	UPRES	Majority of grid within 1/4 mile of upground reservoirs	-2
Environ	Wellhead Zone 1-year	WELL1	Majority of grid in Ohio EPA modeled 1-Year Wellhead Zone related to ground water wells	-6
Environ	Agricultural Easements	EASEMENT	More than 25% of grid in agricultural easement	-9
Infra	Adjacent to Developed	DEVELOPEDI	Considered together neighboring grids are at least 40% developed	9
Infra	Currently Served by Sanitary Sewer	SEWER	Majority of grid within a sanitary sewer service area	9

Infra	Major Intersections (1/2 mi)	INTSEC_H	Majority of grid within 1/2 mile of major intersections and interchanges	8
Infra	High Frequency of Transit Service	TRAN_H	Majority of grid within 1/4 mile of bus stop that has 336 buses/7-day week (avg. 2/hr.)	7
Infra	Major Intersection (1 mi)	INTSEC_1	Majority of grid within 1 mile of major intersections and interchanges	6
Infra	1/2 mi. of Currently Served by Sanitary Sewer	SEWER_H	Majority of grid within 1/2 mile of a sanitary sewer service area	6
Infra	Mixed Land Use Grid Types	MIXEDUSE	Future land use of grid has mixed use classification	6
Infra	Intermodal Yards (1/2 mi)	YARD_H	Majority of grid within 1/2 mile of intermodal yard	5
Infra	Medium Frequency of Transit Service	TRAN_M	Majority of grid within 1/4 mile of bus stop that has 168-335 buses/7-day week (avg. 1-2/hr.)	4
Infra	Airport (within 1 mile)	AIRPORT1M	Majority of grid within 1 mile of airport terminal	4
Infra	Future Sanitary Service Area	SEWER_F	Majority of grid within future sanitary service area according to 208 plans and local facility plans	3
Infra	Bike Facilities (Existing)	EX_BIKE	Majority of grid within 1/2 mile of bike lanes and paths	1
Infra	Small Average Census Block Size (density)	PED	Majority of grid has small average census block size (# of blocks per block group/block group area)	2
Infra	Intermodal Yards (1 mi)	YARD_1	Majority of grid within 1 mile of intermodal yard	2
Infra	Low Frequency of Transit Service	TRAN_L	Majority of grid within 1/4 mile of bus stop that has 1-167 buses/7-day week (avg. less than 1/hr.)	2
Infra	Bike Facilities (Future)	PR_BIKE	Majority of grid within 1/2 mile of future bike lanes and paths in Regional Bikeway Plan	1
Infra	Parks	PARKS	Majority of grid within 1/2 mile of parks	1
Infra	Congestion	CONGST	Majority of grid within 1/4 mile of roadway where volume exceeds	-1

			capacity all four modeled time periods of a day	
Nuisance	Airport Noise (65 db)	AIRPORT	Majority of grid within modeled noise ring around runways where airport noise > 65 db	0
Nuisance	Airport Noise (60 db or parcel boundary)	AIRPORT_O	Majority of grid within modeled noise ring around runways where airport noise > 60 db -OR- majority of grid within parcel boundaries of airport	0
Nuisance	Quarries	QUARRY	Majority of grid within 1/4 mile of quarry	-1
Nuisance	Substations & High Tension Lines	ELECTR	Majority of grid within 1/4 mile of substations & high tension power lines	-3
Nuisance	Landfills	LANDFILL	Majority of grid within 1/2 mile of landfills	-9
Nuisance	Wastewater Treatment Plant	WWTP	Majority of grid within 1/2 mile of wastewater treatment plant	-4

Table 19: Criteria and Weights for Household Growth Scores

Category	Feature		Long description	People
Econ Dev	TIF	TIF	Majority of grid in Tax Increment Financing (TIF) district	3
Econ Dev	CRA	CRA	Majority of grid in Community Reinvestment Area (CRA)	2
Econ Dev	Innovation Hubs	INNOHUB	Majority of grid in ODOD Innovation Hub zone	2
Econ Dev	CEDA	CEDA	Majority of grid in Cooperative Economic Development Agreement (CEDA) area	1
Econ Dev	JEDZ	JEDZ	Majority of grid in Joint Economic Development District/Zone (JEDD/JEDZ)	1
Econ Dev	EZ	EZ	Majority of grid in Enterprise Zone (EZ)	1
Environ	Forests	FOREST	More than 25% of grid with land cover of forest	-2
Environ	Wellhead Zone 5-year	STREAM	Majority of grid in Ohio EPA modeled 5-Year Wellhead Zone related to ground water wells	-2
Environ	High Slope (>24 %)	WELL5	Majority of grid has slope greater than 24% in soil survey data	-2
Environ	Streams (1/4 mi)	SLOPE	Majority of grid within 1/4 mile of rivers and streams	-4
Environ	Upstream from water in-take	CMZ	Majority of grid in Ohio EPA defined Corridor Management Zone (CMZ) related to surface water intakes	-6
Environ	Upground Reservoirs	UPRES	Majority of grid within 1/4 mile of upground reservoirs	-2
Environ	Wellhead Zone 1-year	WELL1	Majority of grid in Ohio EPA modeled 1-Year Wellhead Zone related to ground water wells	-6
Environ	Conservation and Ag Easements	EASEMENT	More than 25% of grid in conservation or agricultural easement	-9
Infra	Adjacent to Developed	DEVELOPEDI	Considered together neighboring grids are at least 40% developed	9
Infra	Currently Served by Sanitary Sewer	SEWER	Majority of grid within a sanitary sewer service area	8

Infra	Mixed Land Use Grid Types	MIXEDUSE	Future land use of grid has mixed use classification	7
Infra	Small Average Census Block Size (density)	PED	Majority of grid has small average census block size (# of blocks per block group/block group area)	7
Infra	High Frequency Transit Service	TRAN_H	Majority of grid within 1/4 mile of bus stop that has 336 buses/7-day week (avg. 2/hr.)	6
Infra	1/2 mi. of Currently Served by Sanitary Sewer	SEWER_H	Majority of grid within 1/2 mile of a sanitary sewer service area	5
Infra	Parks	PARKS	Majority of grid within 1/2 mile of parks	5
Infra	Major Intersection (1 mi)	INTSEC_1	Majority of grid within 1 mile of major intersections and interchanges	4
Infra	Medium Frequency Transit Service	TRAN_M	Majority of grid within 1/4 mile of bus stop that has 168-335 buses/7-day week (avg. 1-2/hr.)	4
Infra	Major Intersection (1/2 mi)	INTSEC_H	Majority of grid within 1/2 mile of major intersections and interchanges	4
Infra	Future Sanitary Service Area	SEWER_F	Majority of grid within future sanitary service area according to 208 plans and local facility plans	3
Infra	Bike Facilities (Existing)	EX_BIKE	Majority of grid within 1/2 mile of bike lanes and paths	1
Infra	Low Frequency Transit Service	TRAN_L	Majority of grid within 1/4 mile of bus stop that has 1-167 buses/7-day week (avg. less than 1/hr.)	2
Infra	Bike Facilities (Future)	PR_BIKE	Majority of grid within 1/2 mile of future bike lanes and paths in Regional Bikeway Plan	1
Infra	Airport	AIRPORT1M	Majority of grid within 1 mile of airport terminal	0
Infra	Intermodal Yards (1 mi)	YARD_1	Majority of grid within 1 mile of intermodal yard	-2
Infra	Congestion	CONGST	Majority of grid within 1/4 mile of roadway where volume exceeds capacity all four modeled time periods of a day	-2
Infra	Intermodal Yards (1/2 mi)	YARD_H	Majority of grid within 1/2 mile of intermodal yard	-3

Nuisance	Quarries	QUARRY	Majority of grid within 1/4 mile of quarry	-3
Nuisance	Airport Noise (60 db or parcel boundary)	AIRPORT	Majority of grid within modeled noise ring around runways where airport noise > 60 db -OR- majority of grid within parcel boundaries of airport	-6
Nuisance	Substations & High Tension Lines	ELECTR	Majority of grid within 1/4 mile of substations & high tension power lines	-9
Nuisance	Landfills	LANDFILL	Majority of grid within 1/2 mile of landfills	-9
Nuisance	Wastewater Treatment Plant	WWTP	Majority of grid within 1/2 mile of wastewater treatment plant	-9
Nuisance	Airport Noise (65 db)	AIRPORT_O	Majority of grid within modeled noise ring around runways where airport noise > 65 db	-9

Table 20: Density Constraints by Land Use Type

gridtype	Land Use Name	HH per acre	Jobs per acre	HH per 40 acre grid	Job per 40 acre grid	Notes
Ag	Agriculture	0.01	0.02	0.40	0.60	99.9 % agricultural
Off	Office	0.80	0.00	32.00		10% residential, 90% office. 20% of land taken out for roads and streets. Residential assumed at 10 units per acre. Office assumed at 10000 square feet per acre with 350 square feet per employee
OffU	Office (URBAN)	1.20	77.71	48.00	3108.57	15% residential, 85% office. 20% of land taken out for roads and streets. Residential assumed at 10 units per acre. Office assumed at 40000 square feet per acre with 350 square feet per employee
Rcomm	Regional Commercial	0.00	34.00	0.00	1360.00	100% commercial. 15% of land taken out for roads and streets. Commercial assumed at 10000 square feet per acre with 250 square feet per employee
Ccom	Community Commercial	0.80	20.57	32.00	822.86	10% residential, 90% commercial. 20% of land taken out for roads and streets. Residential assumed at 10 units per acre. Commercial assumed at 10000 square feet per

						acre with 350 square feet per employee
Ncom	Neighborhood Commercial	0.64	28.80	25.60	1152.00	10% residential, 90% commercial. 20% of land taken out for roads and streets. Residential assumed at 8 units per acre. Commercial assumed at 10000 square feet per acre with 250 square feet per employee
NmixU	Neighborhood Mix (Urban-as in county seats, towns and villages)	2.24	14.40	89.60	576.00	40% residential, 60% commercial. 20% of land taken out for roads and streets. Residential assumed at 7 units per acre. Commercial assumed at 10000 square feet per acre with 250 square feet per employee
Nmix	Neighborhood Mix (as in suburban areas)	2.40	12.00	96.00	480.00	60% residential, 40% commercial. 20% of land taken out for roads and streets. Residential assumed at 5 units per acre. Commercial assumed at 10000 square feet per acre with 250 square feet per employee
Ind	Industry	0.12	10.39	4.80	415.63	5% residential, 95% industry. 20% of land taken out for roads and streets. Residential assumed at 3 units per acre. industry

						assumed at 12500 square feet per acre with 800 square feet per employee, and an additional 10% land reduction
Lind	Light Industry	0.40	7.62	16.00	304.69	25% residential, 75% industry. 20% of land taken out for roads and streets. Residential assumed at 2 units per acre. industry assumed at 12500 square feet per acre with 800 square feet per employee, and an additional 10% land reduction
Ware	Warehouse/Distribution	0.00	5.83	0.00	233.33	0% residential, 100% industry. 20% of land taken out for roads and streets. Residential assumed at 8 units per acre. industry assumed at 12500 square feet per acre with1500 square feet per employee, and an additional 10% land reduction
Quar	Quarry	0.00	4.50	0.00	180.00	100% quarry. 10% of land taken out for roads and streets. 12500 square feet per acre, 2500 square feet per employee.
Os	Open Space	0.00	0.00	0.00	0.00	no residential, no employment
pro	Protected	0.00	0.00	0.00	0.00	no residential, no

						employment
Park	Park	0.00	0.03	0.00	1.00	no residential, no employment, .03 employees per acre
Hurb	Residential High Urban	6.40	45.71	256.00	1828.57	50% residential, 50% commercial. 20% of land taken out for roads and streets. Residential at 16 units per acre. Commercial at 40000 square feet per acre, and 350 square feet per employee
Lurb	Residential Low Urban	5.40	12.00	216.00	480.00	60% residential, 40% commercial. 10% of land taken out for roads and streets. Residential at 10 units per acre. Commercial at 10000 square feet per acre, and 300 square feet per employee
Hsub	Residential High Suburban	6.75	7.50	270.00	300.00	75% residential, 25% commercial. 10% of land taken out for roads and streets. Residential at 10 units per acre. Commercial at 10000 square feet per acre, and 300 square feet per employee
Msub	Residential Mod Suburban	3.04	1.33	121.60	53.33	95% residential, 5% commercial. 20% of land taken out for roads and streets. Residential at 4 units per acre. Commercial

						at 10000 square feet per acre, and 300 square feet per employee
Sub	Residential Suburban	1.52	1.33	60.80	53.33	95% residential, 5% commercial. 20% of land taken out for roads and streets. Residential at 2 units per acre. Commercial at 10000 square feet per acre, and 300 square feet per employee
Lsub	Residential Low	1.14	1.13	45.60	45.33	95% residential, 5% commercial. 20% of land taken out for roads and streets. Residential at 1.5 units per acre. Commercial at 8500 square feet per acre, and 300 square feet per employee
Rrur	Residential Rural	0.40	0.00	16.00	0.00	100% residential, 0% commercial. 20% of land taken out for roads and streets. Residential at 0.5 units per acre.
Rest	Residential Rural Estate	0.16	0.00	6.40	0.00	100% residential, 0% commercial. 20% of land taken out for roads and streets. Residential at 0.2 units per acre.
Wat	Water	0.00		0.00	0.00	no residential or commercial
Row	Right of Way	0.00	0.00	0.00	0.00	no residential or

						commercial
Hed	Higher Education	0.38	71.72	15.00	2868.75	10% residential, 90% university. 25% of land taken out for roads and streets. Residential at 5 units per acre. University at 8500 square feet per acre, and 80 square feet per employee
Ed	Education	0.50	9.84	20.00	393.75	20% residential, 80% school. 20% of land taken out for roads and streets. Residential at 2.5 units per acre. School at 8500 square feet per acre, and 200 square feet per employee
Corf	Correctional Facility	0.00	32.40	0.00	1296.00	No residential, 100% correctional facility. 10% of land taken out for roads and streets. Correctional facility at 9000 square feet per acre, and 250 square feet per employee
Govt	Government	0.28	16.39	11.20	655.71	10% residential, 90% university. 20% of land taken out for roads and streets. Residential at 3.5 units per acre. Govt bldgs at 8500 square feet per acre, and 350 square feet per employee
Utl	Utility	0.00	0.80	0.00	32.00	No residential, 100% utility. 20% of land taken out for

							roads and streets. Utility at 5000 square feet per acre, and 10000 square feet per employee
REL	Religious Facility		0.28	1.75	11.20	69.94	10% residential, 90% religious. 20% of land taken out for roads and streets. Residential at 3.5 units per acre. Religious at 8500 square feet per acre, and 1000 square feet per employee
HOS	Hospital		0.28	61.20	11.20	2448.00	10% residential, 90% university. 20% of land taken out for roads and streets. Residential at 3.5 units per acre. University at 8500 square feet per acre, and 100 square feet per employee
AIR	Airport		0.00	1.08	0.00	43.20	No residential, 100% utility. 10% of land taken out for roads and streets. Utility at 3000 square feet per acre, and 2500 square feet per employee
RRYD	Rail Yard		0.00	1.50	0.00	60.00	No residential, 100% utility. 25% of land taken out for roads and streets. Utility at 5000 square feet per acre, and 2500 square feet per employee

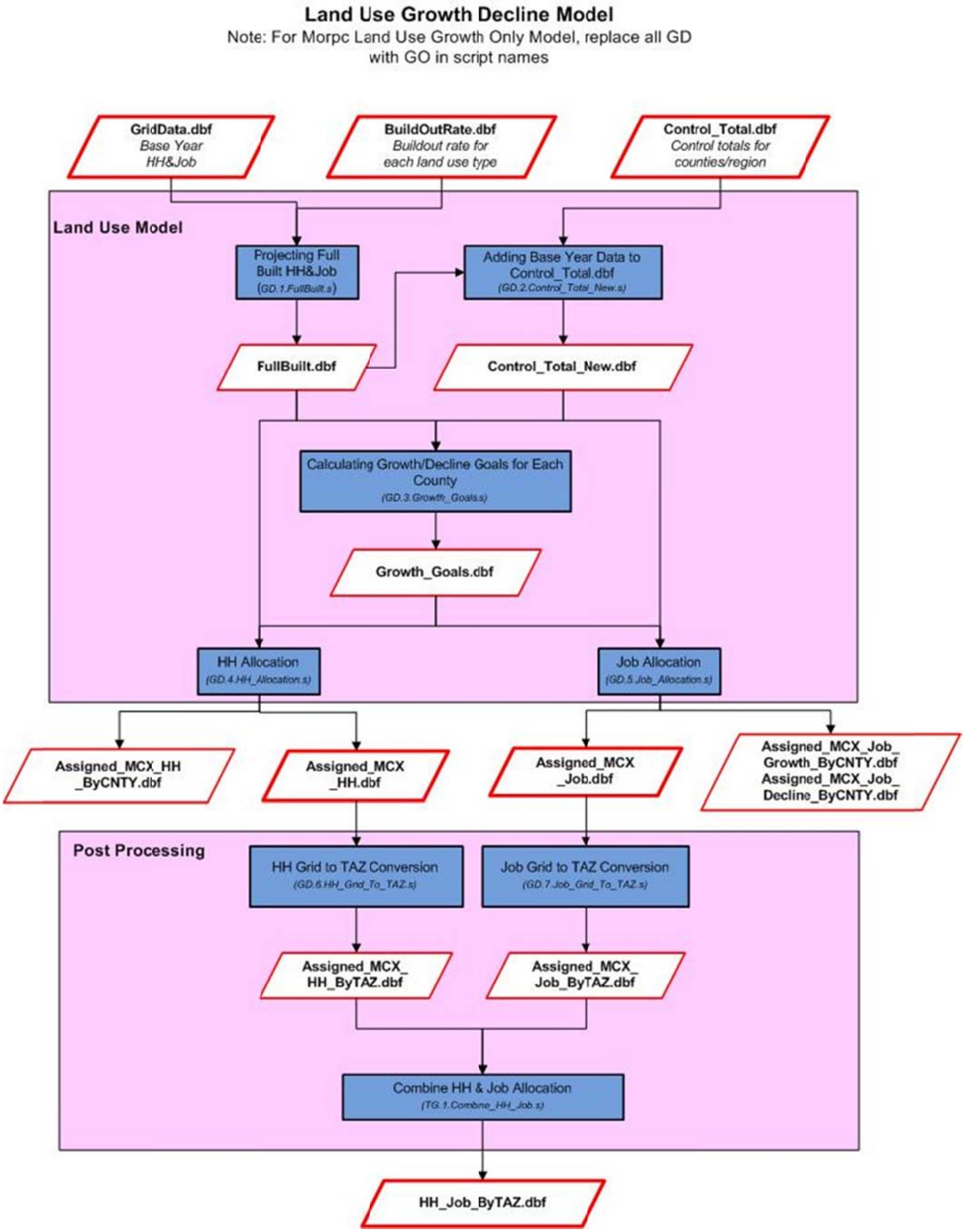


Figure 2: Overall Analysis Procedures in Land Allocation Models

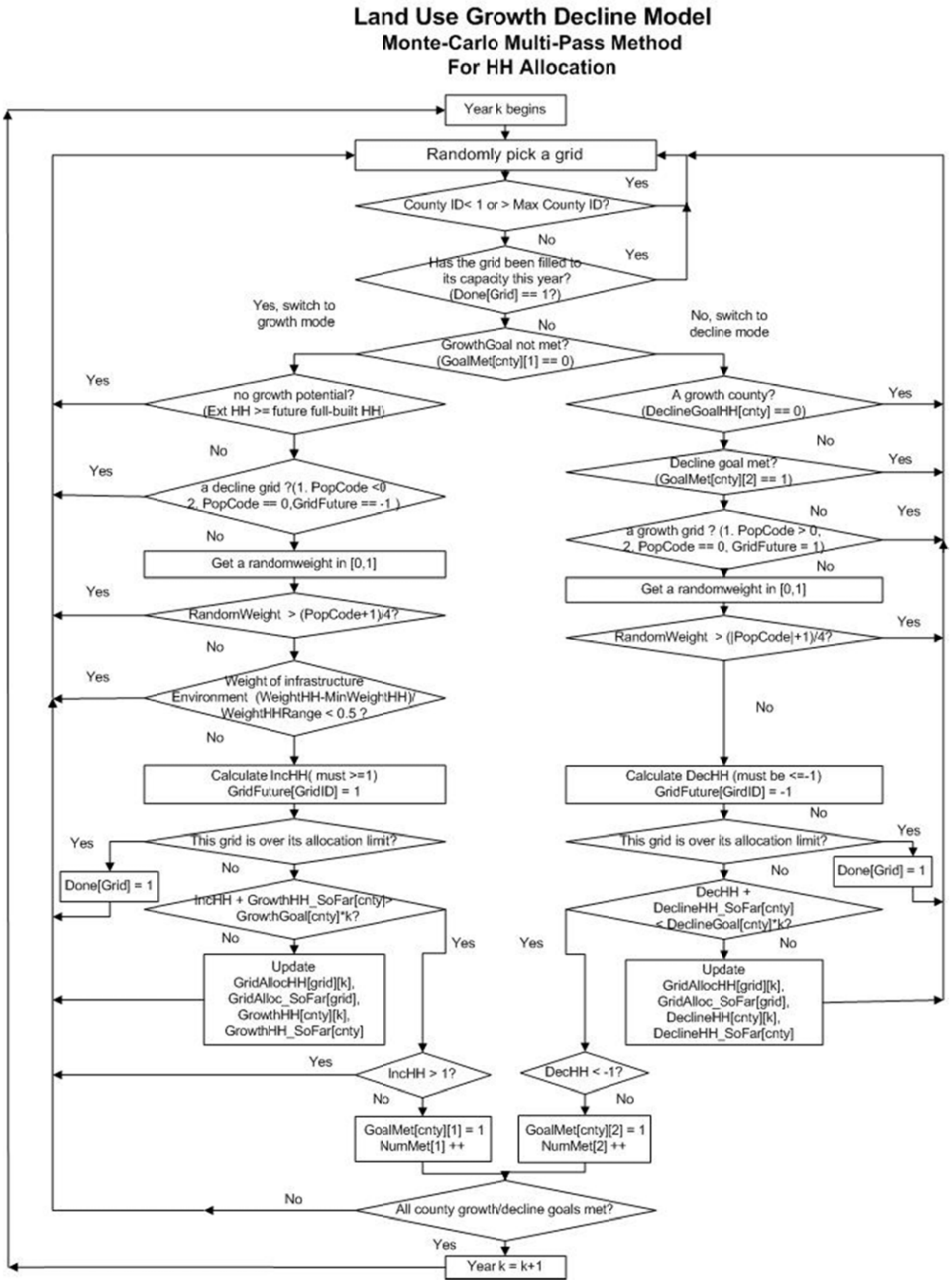


Figure 3: Procedure for Household Allocation

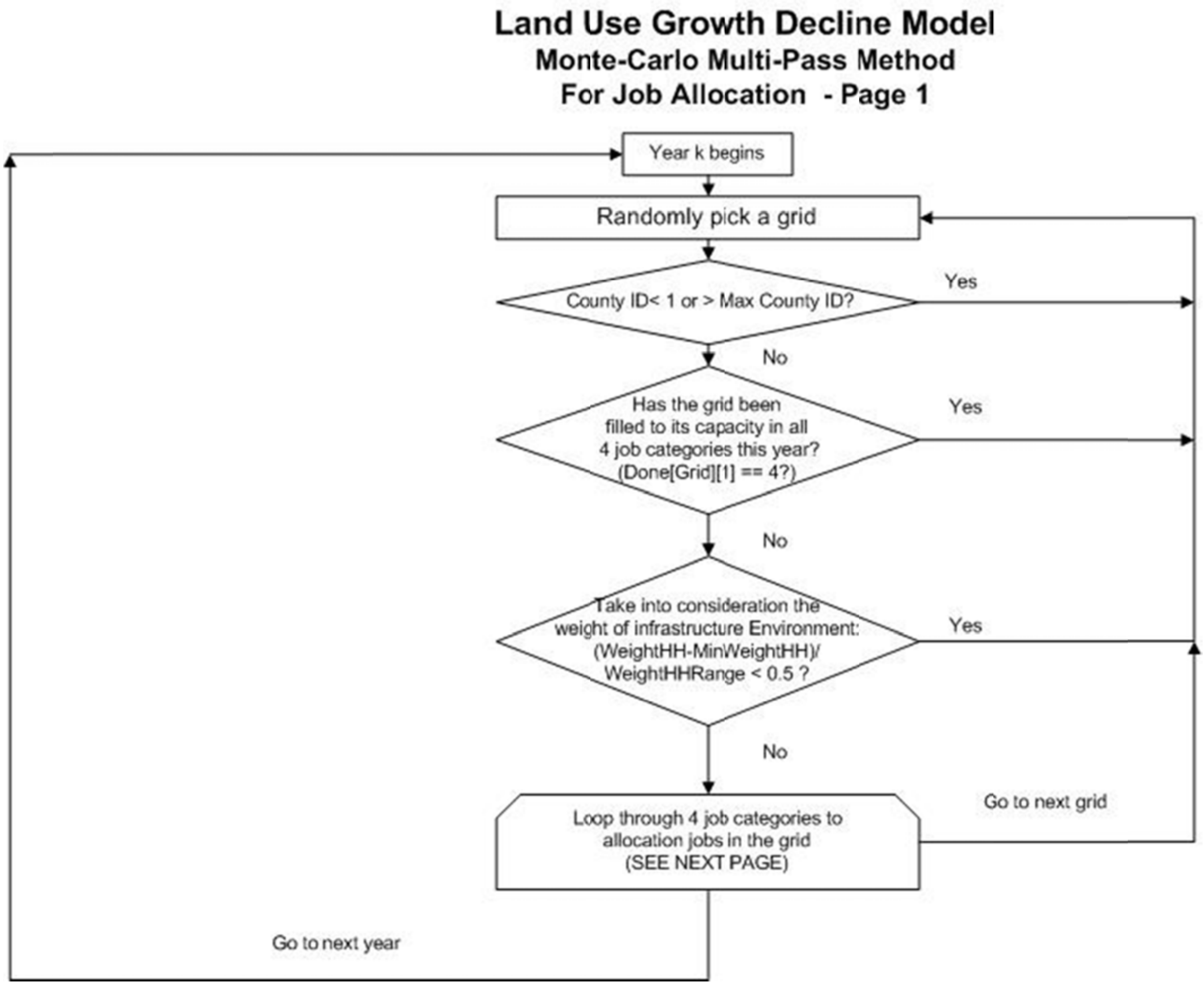


Figure 4: Procedure for Allocating Jobs - Part 1

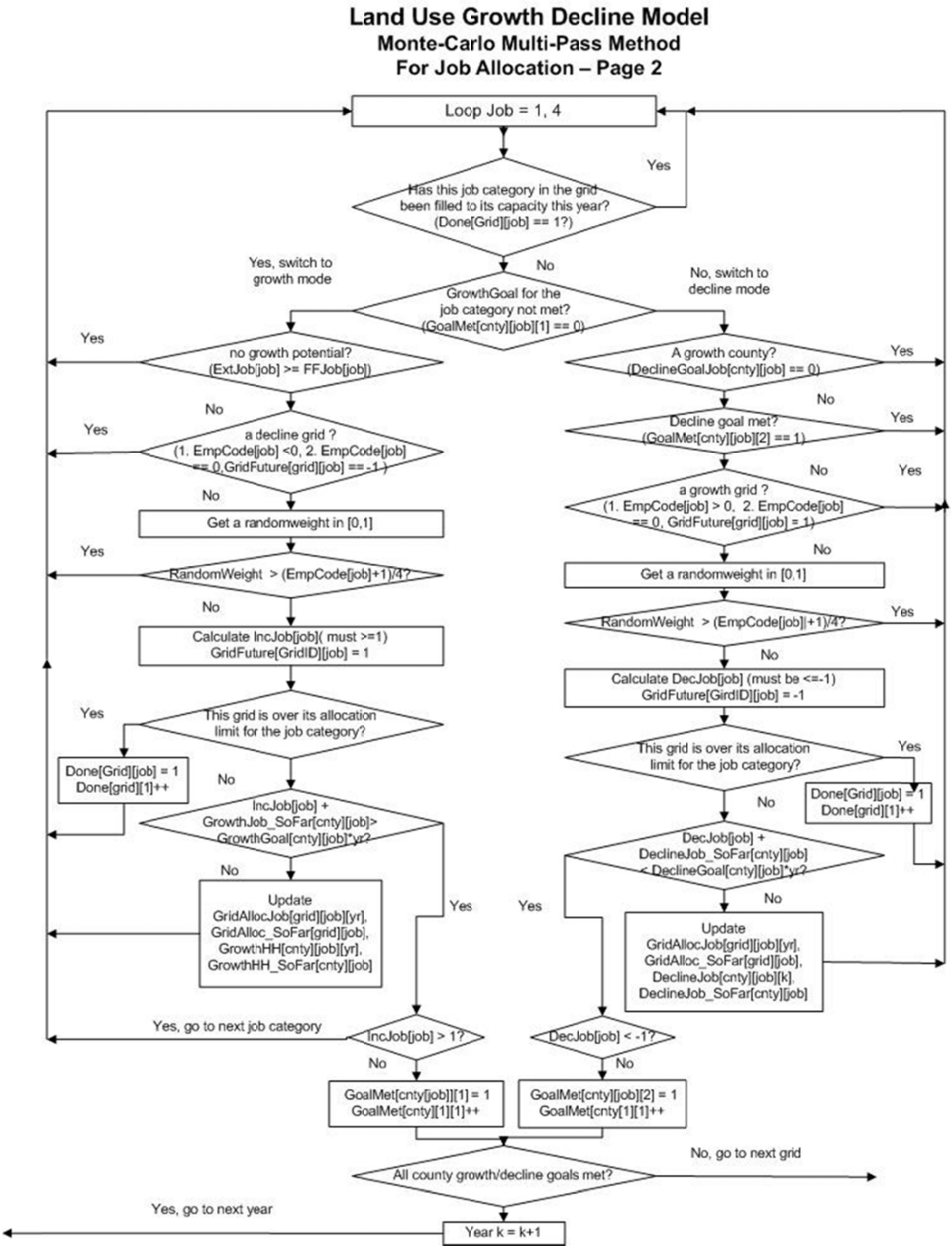


Figure 5: Allocation of Jobs - Part 2

Because of the random processes, multiple model runs with the same input data will yield slightly different results. The model was tested and the variation in the final transportation forecasts was found to differ by less than 2% in the final forecast after 35 years.

4.3 Addressing Declining Regions

With the exception of central Ohio, parts of Ohio's metropolitan regions have been declining in both population and jobs over the past several decades. This decline has been uneven both across counties in those regions as well as within counties. In some areas, there has been a decline in population and in total jobs but with some growth in certain job categories and declines in others. For example, in Cuyahoga County, there is a forecast decline of approximately 56,000 households and 123,000 jobs of which almost 92,000 are in industry jobs. Yet when one examines the historical trends within the county, there are certain subareas that have grown in retail and other service jobs at the same time the overall decline has occurred.

As a result, an alternative forecasting procedure is required for regions with forecasts in partial decline that better reflected these spatial differences in trends. In order to approximate the distribution of growth and decline, population and employment trends were analyzed across all of the remaining metropolitan regions in Ohio.

For population and household trends, 2000 and 2010 census block group data were used to establish the direction and degree of change for each block group. These differences were then classified into seven groups numbered from -3 to +3 where 0 represents areas with small positive and negative changes and the other groups the degree of positive or negative changes in households.

Employment by category is available only through selected County Business Patterns data compiled at the zip code level. A similar analysis of employment change was undertaken using the data from 2004 through 2010 to classify all zip codes into groupings also ranging from -3 to +3.

Data from these groupings were then used to designate the values for each of the cells based on the proportion of the cell associated with each of the larger geographic categories. The scores then assigned to the cells were used in a revised version of the model for declining regions. The structure of the model for those regions is shown in Figures 4 and 5.

In this version of the model, there is both decline and growth in the target counties in different categories of population and employment. Since there is a net decline overall, any growth in a subarea of the county must be offset by additional decline elsewhere in the county. A cell is selected at random and then compared to a random number based on the growth/decline score. If its score is positive, if might be allocated an increment of growth with a 25%, 50%, or 75% probability for scores of 1, 2, or 3 respectively. Growth cells are also checked against their development weight and only grow if the weight probability is 0.50 or greater, that is if the development attractiveness is sufficiently high. This avoids the potential problem of growing cells without the prerequisite infrastructure and locational advantages.

If the cell score is negative, it may be allocated decline with a 25%, 50%, or 75% probability for scores of -1, -2, or -3 respectively. Cells with scores of zero can be allocated either decline or growth with a corresponding probability. Once a cell has been picked to decline or grow, it stays in that same category for the remainder of the run.

For each year of the run, 1/35 of the growth or decline is allocated until the appropriate subtotals for growth and net decline are met. This cycle is repeated for each forecast year until the end date forecast is approximately reached. The pattern will reflect the historical growth and decline trends for the region forecast into the future unless changes are made to the various indicator scores.

5. SCENARIOS OF FUTURE DEVELOPMENT

In order to demonstrate the application of the land use allocation model and its linkages to the forecast of trips and trip length, four different scenarios of future employment and household changes were created. The changes that were used are relatively arbitrary in that there is nothing in the land use allocation model that actually predicts where land use change will occur.

For areas such as the mid-Ohio region that are growing, the allocation of future land use is based on the highest probability of development because those sites have the best location, access to infrastructure, and avoidance of environmental hazards or areas of environmental conservation. The intensity of those developments is based on the current zoning or other local knowledge of probable development patterns.

For the other major metropolitan areas in the state where the population and employment has been declining, the basis for change is related to the historical pattern of out-migration and job loss for subareas losing population and jobs and historical patterns of population gain and job gain for other subareas. The future land use intensity or loss of intensity is again related to what was found concerning current zoning. For those other areas, the available data were not as robust but are sufficient for the initial model development. Future use of the model should include efforts to update the local data with the direct involvement of the regional agencies.

The scenarios are constructed to illustrate how differences in assumptions about land use intensity, the location of future land use and job growth, and the interactions with transit availability could impact trip distribution. Each of the scenarios is described next along with a summary of the target areas that are impacted in each of the metropolitan areas of the state included in this modeling effort.

5.1 Scenario Descriptions

Scenario 1 – Continuation of Past Trends

The first scenario was used as the base case against which all other scenarios are compared. This scenario assumes that past trends will continue in the same pattern as in the past decade. The control totals for future jobs and households are based on forecasts which also make those assumptions. In the Mid-Ohio region this is a forecast of growth while in the other regions it is a forecast of a combination of growth and decline. The maps illustrating the growth and decline rates across the metropolitan areas are presented in Appendix C.

Scenario 2 – Development of Selected Industry Sites

Information on four potential development sites was received from ODOT's Office of Jobs and Commerce. However, only two of those sites were both in areas where the base data have been compiled and where sufficient information about their development was available. The second scenario focuses on the development of these two sites and the impacts that would have on trip production in the immediate region. No adjustments are made in the overall job or household forecasts. However, the probability of development of these sites is essentially made 100% and the number of jobs forecast is congruent with the estimates provided. These scenarios demonstrate the usefulness of the model to provide a quick estimate of the impacts of large scale site development on the local trip production.

Scenario 3 – Reversal of Negative Growth and Growth at Higher Intensity

The third scenario focuses on the possible impacts of a reversal of historic growth patterns and intensities on trip production. This entailed two kinds of changes in the land use allocation model. First, for the regions that have experienced major decline, it means a reversal of that decline with an adjustment to the regional forecasts for household and employment changes. For mid-Ohio, the same growth forecast is used. However, all areas are subject to another significant change – an increase in the intensity of development. Rather than the historical growth pattern of increasing suburban sprawl and decline in central city neighborhoods, the target areas for the growth forecasts are in those central city areas at higher densities. This scenario represents a possible trend toward central city redevelopment in response to increasing energy costs, costs of building materials, and possible future policies to reduce greenhouse gas emissions. This scenario is accomplished by increasing the probability of development in the target subareas as well as designating the target future land use at higher intensities, especially for housing. For example, areas are moved from single family detached housing to multi-family housing categories, increasing the future household totals from 55 households per cell to 150 households per cell. Job growth is also forecast to be concentrated closer to the urban core.

Scenario 4 – Combining Growth Reversal with Transit Availability

Our final scenario combines the land use allocation changes from Scenario 3 with a provision of additional transit availability in those areas that lacked such access in the past. This is accomplished by designating any TAZ that originally did not have transit available (based on being with one-half mile of a transit stop) and making transit available in that area. Those changes impact the trip production and are intended to reflect the potential for more viable public transit provision in higher density areas at a time when energy costs are rising.

5.2 Model Results

Each of the model runs provides information at several different scales. First, one can examine the pattern of development at the cell scale and compare the distribution of growth and decline between the base case and each of the scenarios or across all of the scenarios for both employment and households. Second, one can examine the impacts on travel patterns in and around the TAZs which were allocated the most significant growth and decline. This view is particularly suited to examine the impacts of scenario 3 where specific sites are developed at higher use intensities. Finally, one can compare the overall impacts of the scenarios on the trips, trip distances, and vehicle miles travelled in the region.

Here, we will concentrate on the latter two views of the results as a summary of our findings. A detailed view of the patterns of future development at the cell scale and other detailed findings can be found in Appendix D.

5.3 Scenario Results

Scenario 1

Scenario 1 investigated the impacts of continuing current trends on land use patterns and the related transportation impacts. The results are summarized in Tables 21 to 26. The tables show the numbers of households and jobs, by categories that are inputs to the model for the base year 2000. The same information is given for the forecast year 2035. Then, the table shows for both years the forecast in the number of trips, VMT, and trip distance and the differences between the starting and ending year.

The tables show the shifts in population and jobs for each of the regions and the corresponding impacts on number of trips and VMT. With the exception of the Columbus region, there is a forecast of decline in the number of trips. The decline in the corresponding VMT is offset to some degree by the forecast of additional trip distances as the historical trends toward sprawl are continued. In declining regions, there is a net decline in VMT. For the Columbus region the historic growth and sprawl patterns are continued with substantial increases in the number of trips and VMT along with the increases in trip distances.

Table 21: Scenario 1 Base Case Forecast Akron Region

	2000	2035	Change	% change
Num of hh	463,004.35	487,463.35	24,459.00	5.28
Num of jobs	649,711.53	653,618.53	3,907.00	0.60
Office jobs	102,800.70	214,255.70	111,455.00	108.42
Retail jobs	157,701.02	82,558.02	-75,143.00	-47.65
Industry jobs	164,837.05	243,041.05	78,204.00	47.44
Other jobs	224,373.61	113,764.61	-110,609.00	-49.30
Number of trips	3,000,389.03	2,883,725.12	-116,663.91	-3.89
VMT	18,420,891.78	17,954,809.34	-466,082.45	-2.53
Trip distance	6.14	6.23	0.09	1.41

Table 22: Scenario 1 Base Case Forecast Cincinnati Region

	2000	2035	Change	% change
Num of hh	591,854.66	541,314.66	-50,540.00	-8.54
Num of jobs	988,594.86	886,201.86	-102,393.00	-10.36
Office jobs	148,363.70	296,721.70	148,358.00	100.00
Retail jobs	212,367.12	108,093.12	-104,274.00	-49.10
Industry jobs	197,206.40	276,654.40	79,448.00	40.29
Other jobs	430,657.64	204,732.64	-225,925.00	-52.46
Number of trips	3,854,772.09	3,312,377.52	-542,394.56	-14.07
VMT	24,759,410.77	22,040,854.91	-2,718,555.85	-10.98
Trip distance	6.42	6.65	0.23	3.60

Table 23: Scenario 1 Base Case Forecast Cleveland Region

	2000	2035	Change	% change
Num of hh	853,161.63	827,979.60	-25,182.00	-2.95
Num of jobs	1,351,628.81	984,949.80	-366,679.00	-27.13
Office jobs	233,800.35	277,480.40	43,680.00	18.68
Retail jobs	276,235.33	131,997.30	-144,238.00	-52.22
Industry jobs	294,663.57	300,452.60	5,789.00	1.97
Other jobs	546,929.56	275,019.60	-271,910.00	-49.72
Number of trips	5,414,715.91	4,653,406.95	-761,308.96	-14.06
VMT	31,454,997.84	27,853,518.33	-3,601,479.51	-11.45
Trip distance	5.81	5.99	0.18	3.04

Table 24: Scenario 1 Base Case Forecast Dayton Region

	2000	2035	Change	% change
Num of hh	359,403.60	367,392.64	7,989.00	2.22
Num of jobs	536,813.20	389,506.24	-147,307.00	-27.44
Office jobs	106,071.10	125,242.05	19,171.00	18.07
Retail jobs	123,118.50	67,312.54	-55,806.00	-45.33
Industry jobs	105,262.10	127,772.14	22,510.00	21.39
Other jobs	202,361.50	69,179.51	-133,182.00	-65.81
Number of trips	2,295,603.97	2,081,707.48	-213,896.49	-9.32
VMT	14,226,244.93	12,767,841.60	-1,458,403.34	-10.25
Trip distance	6.20	6.13	-0.06	-1.03

Table 25: Scenario 1 Base Case Forecast Mid-Ohio Region

	2000	2035	Change	% change
Num of hh	707,979.00	901,808.00	193,829.000	27.38
Num of jobs	867,548.00	1,119,444.00	251,896.000	29.04
Office jobs	365,221.00	451,054.00	85,833.000	23.50
Retail jobs	197,758.00	257,390.00	59,632.000	30.15
Industry jobs	158,904.00	206,063.00	47,159.000	29.68
Other jobs	145,665.00	184,480.00	38,815.000	26.65
Number of trips	4,249,042.23	5,450,601.02	1,201,558.79	28.28
VMT	26,846,612.64	37,636,168.92	10,789,556.28	40.19
Trip distance	6.32	6.90	0.58	9.26

Table 26: Scenario 1 Base Case Forecast Toledo Region

	2000	2035	Change	% change
Num of hh	283,686.68	277,108.68	-6,578.00	-2.32
Num of jobs	404,479.69	300,988.69	-103,491.00	-25.59
Office jobs	72,224.82	94,185.82	21,961.00	30.41
Retail jobs	106,673.20	53,341.20	-53,332.00	-50.00
Industry jobs	80,028.01	100,203.01	20,175.00	25.21
Other jobs	169,179.02	76,884.02	-92,295.00	-54.56
Number of trips	1,871,290.78	1,616,191.36	-255,099.42	-13.63
VMT	-10,552,181.87	9,211,798.32	-1,340,383.55	-12.70
Trip distance	5.64	5.70	0.06	1.08

Scenario 2

Under Scenario 2, the impacts of two different development projects on the transportation impacts are simulated, especially in immediately surrounding areas. For each of the sites the cells that would be impacted were identified by the additional employment expected to occur at those sites. To make the forecast, the total employment for the site is divided by the number of cells to estimate the number of new jobs in each cell. The cells are then overlaid with the TAZ boundaries and the proportion of the site in each TAZ is used to allocate the new jobs to the TAZs.

The forecasts then used the year 2000 trip data and added the additional jobs to the relevant TAZs. The resulting forecast is compared to the same area forecasts without the additional jobs. It is also possible to run the full model with long-term allocations and to use those forecasts as the basis for comparison. However, the long term trends might then screen the impacts of the site development.

The first site considered is the possible full development of the Rickenbacker airport area near Lockborne. That area is forecast to add 17,871 jobs. Those jobs are concentrated in parts of 28 TAZs. The impacted area then includes an additional 39 TAZs that are adjacent to the directly impacted area. Map 5 shows the site and the impacted area. The impacts of the additional jobs are shown in Table 27. The change in jobs will create over 30,000 daily trips and 80,000 VMT each day. There is no difference in the number of trips adjacent to the site. However, the increase in the intensity of use and the change in balance between households and jobs will also cause a reduction in trip distances and a net reduction in VMT.

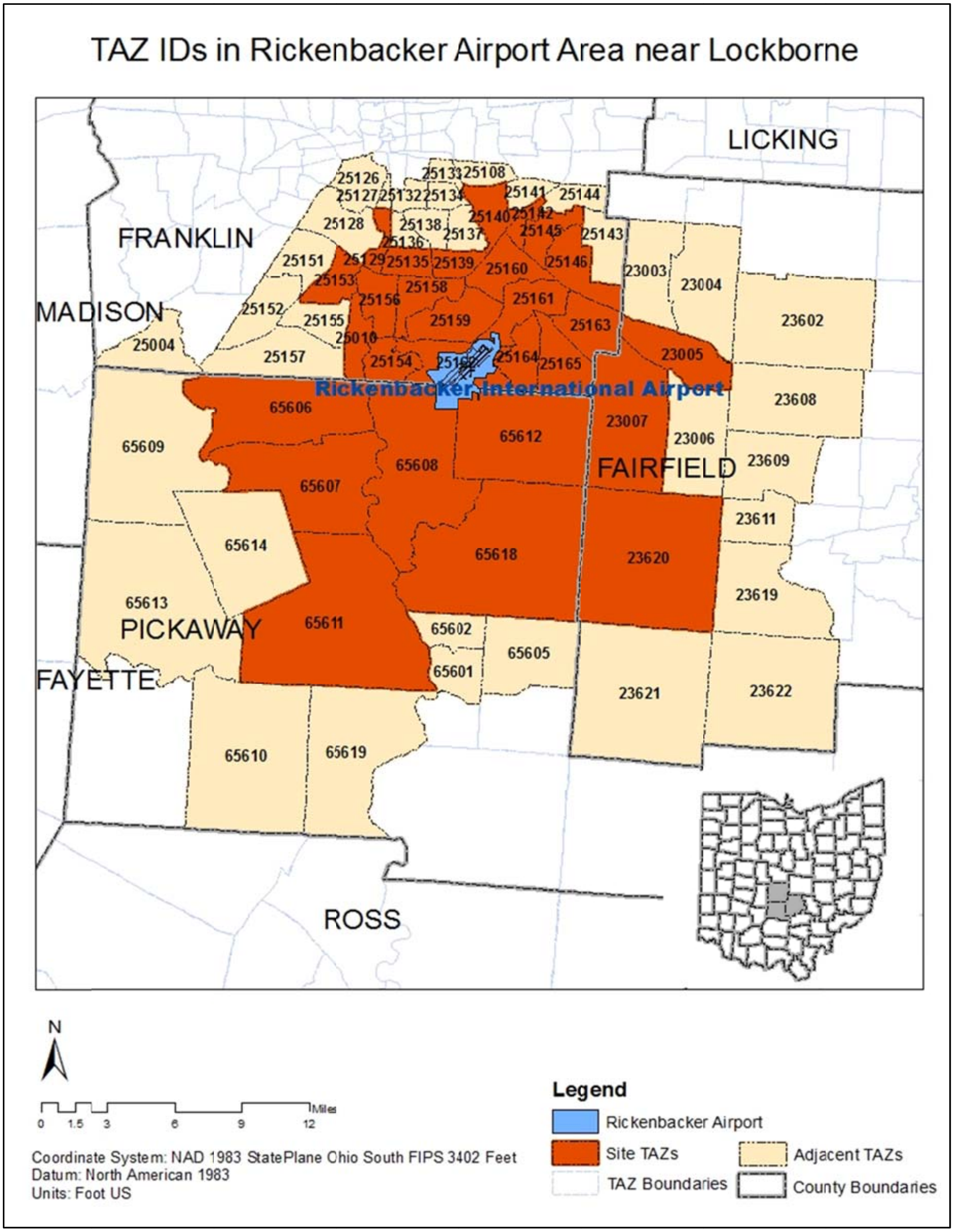
Table 27: Impact of Additional Jobs at Rickenbacker Site

Added Trips to Site	Added VMT from Site	Adjacent TAZ VMT	Change in Trip Distance
15,819.39	151,170.24	-1,769.99	-0.637%

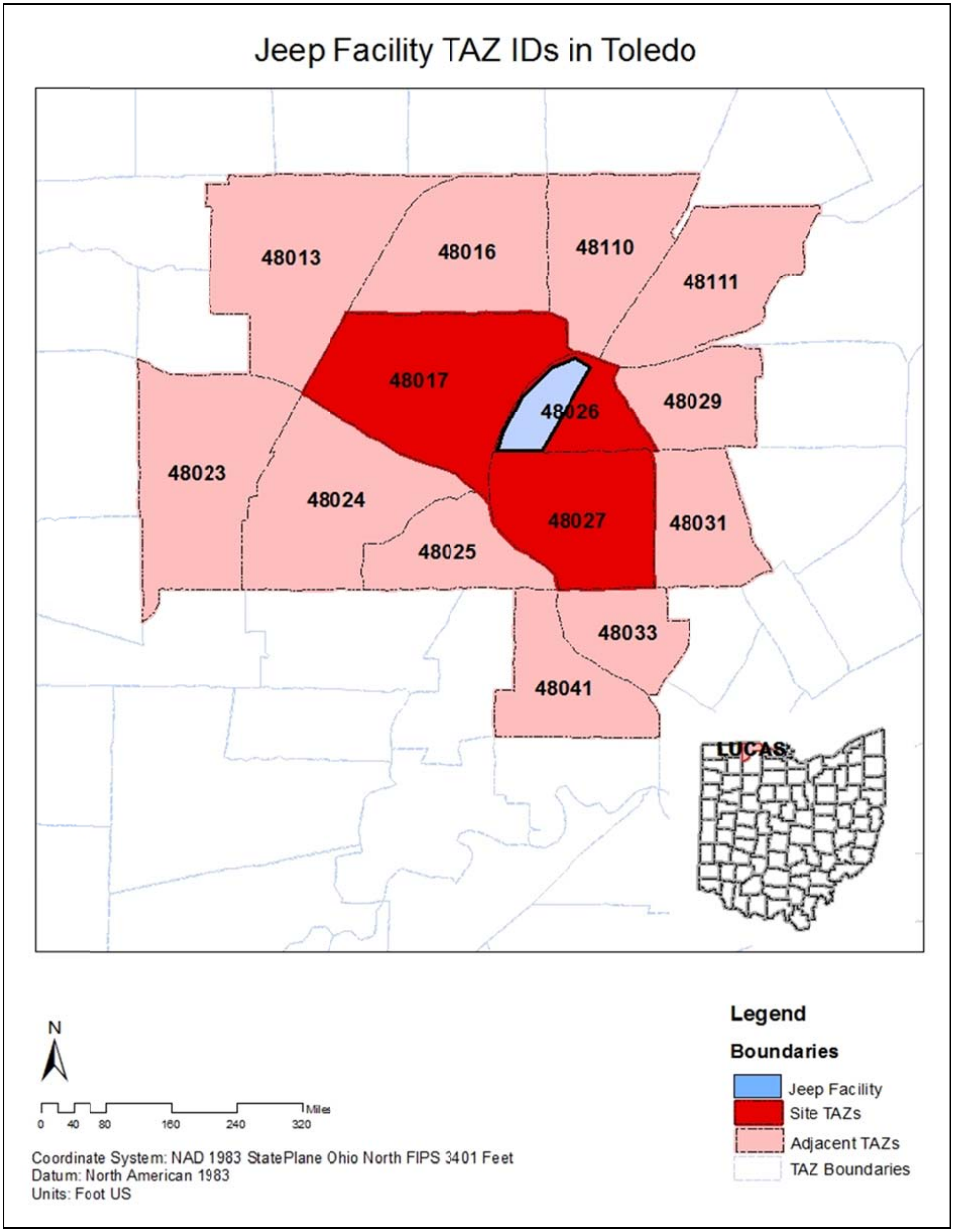
A similar impact occurs at the second site in Toledo – the redevelopment of a Jeep facility. Map 6 shows this site and the impacted area. That facility is expected to generate 1100 jobs across three TAZs. There are then eleven adjacent TAZs to the site. Table 28 shows the impacts on trips, VMT, and trip distance. Again there is no impact on number of trips in the adjacent areas.

Table 28: Impact of Additional Jobs at Toledo Site

Added Trips to Site	Added VMT from Site	Adjacent TAZ VMT	Change in Trip Distance
973.72	4,818.66	-2,368.43	-2.183%



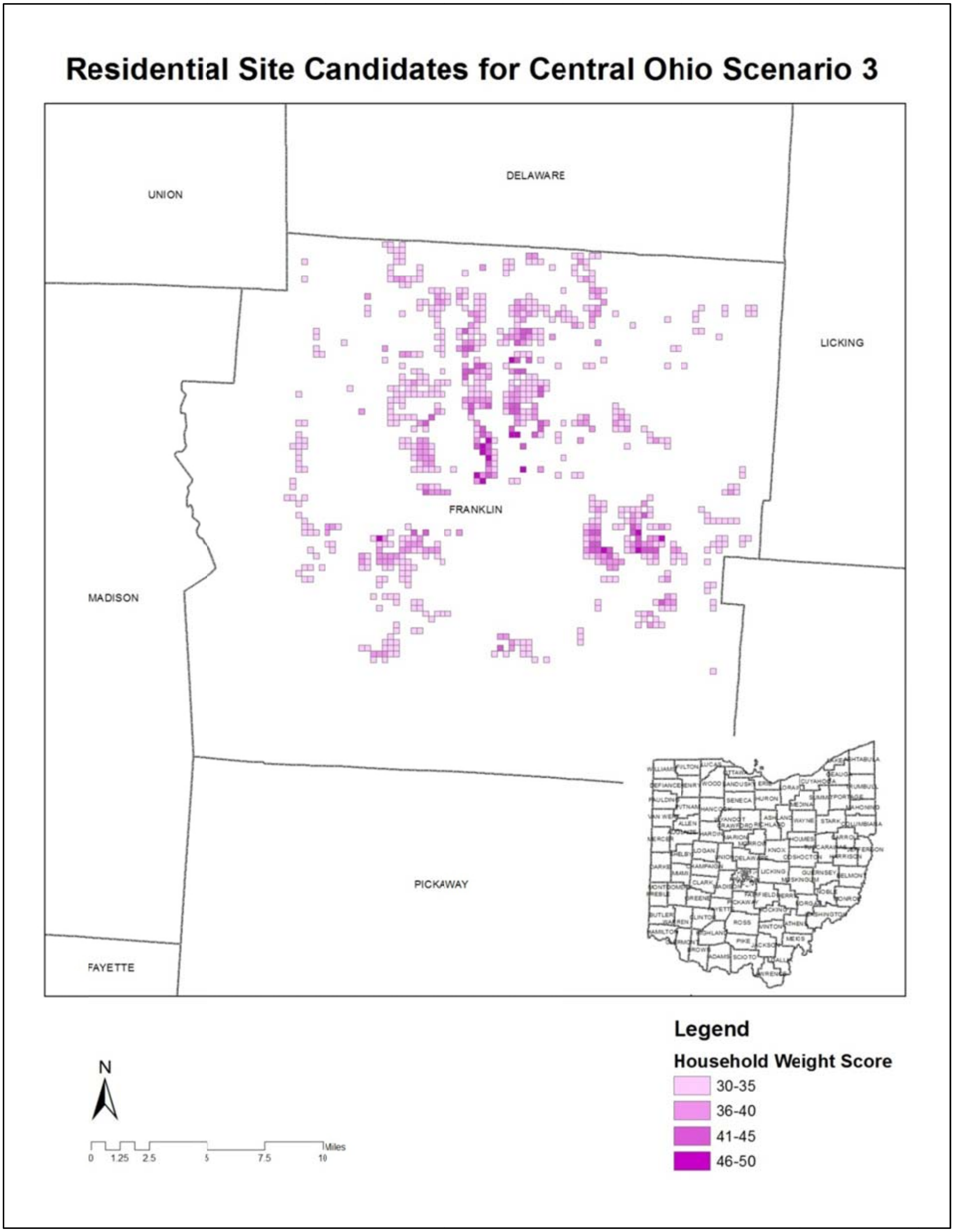
Map 5: Scenario 2- Development at Rickenbacker Airport Area



Map 6: Scenario 2- Development at Jeep Facility

Scenario 3

Scenario 3 represents a shift in development toward higher density to reflect the possible impacts of higher fuel costs and recent efforts to rebuilt walkable communities closer to the central city. For the Columbus area, this scenario is relatively straightforward since it represents just a reallocation of growth toward target areas that meet a particular criterion and then an adjustment of the weighting to be higher and change the future land use to a higher density category. Thus, for Columbus, cells in Franklin County with a future residential land use category that had a score of 30 or above were selected. This resulted in the selection of cells within Columbus and the closer suburbs within Franklin County, leaving out the less dense areas in surrounding counties. These cells were then modified by assigning them the maximum households score and changing the future land use to the next denser category from its current assignment. The result would push a significant amount of new residential development to those cells. Map 7 shows the residential site candidates for development in the Mid-Ohio region.



Map 7: Residential Site Candidates for Development in Mid-Ohio Region

For the other metropolitan areas, this forecast was more complex since a number of the counties are declining in population. In these cases, the candidate cells were chosen based on those areas that have experienced the highest level of decline in households and employment over the years 2000-2010. Those are cells that were given the -3 decline score based on historic data. Those cells were then assigned the maximum household or employment weight and were also assigned a future land use that was a higher density. In order to keep those developments from simply depopulating other parts of a declining region, the control totals for households and employment was increased by 15% to reflect the potential reversal of historic declining trends. The resulting scenario then describes a situation where the decline of the central cities reverses over the 35 year forecast period and areas which have been losing households and jobs are able to successfully redevelop.

Tables 29 to 34 show the resulting forecasts for these scenarios for each of the metropolitan regions. More detailed breakdowns of the results are shown in Appendix B. All of the areas reflect a general growth in trips and vehicle miles travelled as well as a decrease in trip distance associated with the higher density development. Model results can also be examined geographically both at the cell and the TAZ level to analyze the potential impacts on travel demand.

These scenarios illustrate how the model can be used to provide insights into the potential impacts of different future development patterns on travel trends within Ohio's metropolitan areas. The results can be linked to secondary impacts on congestion, fuel use, greenhouse gas production, air quality, and gasoline tax revenues to provide a rich framework for analysis of policy options and economic trends.

Table 29: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Akron

	2035 - Base	Scenario 3	Change	% change
Num of hh	487,463.35	507,121.35	19,658.00	4.03
Num of jobs	653,618.53	689,642.53	36,024.00	5.51
Office jobs	214,255.70	214,255.70	0.00	0.00
Retail jobs	82,558.02	82,519.02	-39.00	-0.05
Industry jobs	243,041.05	283,041.05	40,000.00	16.46
Other jobs	113,764.61	109,827.61	-3,937.00	-3.46
Number of trips	2,883,725.12	2,999,922.95	116,197.83	4.03
VMT	17,954,809.34	18,570,218.50	615,409.16	3.43
Trip distance	6.23	6.19	-0.04	-0.58

Table 30: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Cincinnati

	2035- Base	Scenario 3	Change	% change
Num of hh	541,314.66	590,847.66	49,533.00	9.15
Num of jobs	886,201.86	941,522.86	55,321.00	6.24
Office jobs	296,721.70	296,721.70	0.00	0.00
Retail jobs	108,093.12	106,587.12	-1,506.00	-1.39
Industry jobs	276,654.40	318,526.40	41,872.00	15.14
Other jobs	204,732.64	219,687.64	14,955.00	7.31
Number of trips	3,312,377.52	3,561,168.84	248,791.31	7.51
VMT	22,040,854.91	23,004,784.49	963,929.57	4.37
Trip distance	6.65	6.46	-0.19	-2.92

Table 31: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Cleveland

	2035-Base	Scenario 3	Change	% change
Num of hh	827,979.60	847,001.60	19,022.00	2.30
Num of jobs	984,949.80	1,039,610.80	54,661.00	5.55
Office jobs	277,480.40	277,487.40	7.00	0.00
Retail jobs	131,997.30	132,117.30	120.00	0.09
Industry jobs	300,452.60	334,375.60	33,923.00	11.29
Other jobs	275,019.60	295,630.60	20,611.00	7.50
Number of trips	4,653,406.95	4,773,291.07	119,884.12	2.58
VMT	27,853,518.33	28,357,016.78	503,498.45	1.81
Trip distance	5.99	5.94	-0.04	-0.75

Table 32: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Dayton

	2035 Base	Scenario 3	Change	% change
Num of hh	367,392.64	402,643.64	35,251.00	9.60
Num of jobs	389,506.24	415,286.24	25,780.00	6.62
Office jobs	125,242.05	127,112.05	1,870.00	1.49
Retail jobs	67,312.54	67,311.54	-1.00	0.00
Industry jobs	127,772.14	141,640.14	13,868.00	10.85
Other jobs	69,179.51	79,222.51	10,043.00	14.52
Number of trips	2,081,707.48	2,250,289.66	168,482.18	8.09
VMT	12,767,841.60	13,546,818.98	796,977.38	6.24
Trip distance	6.13	6.03	-0.10	-1.71

Table 33: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Mid-Ohio

	2035 Base	Scenario 3	Change	% change
Num of hh	901,808.00	937,099.00	35,291.00	3.91
Num of jobs	1,119,444.00	1,119,019.00	-425.00	-0.04
Office jobs	451,054.00	450,665.00	-389.00	-0.09
Retail jobs	257,390.00	257,182.00	-208.00	-0.08
Industry jobs	206,063.00	205,581.00	-482.00	-0.23
Other jobs	184,480.00	184,541.00	61.00	0.03
Number of trips	5,450,601.02	5,627,492.28	176,891.27	3.25
VMT	37,636,168.92	35,689,869.12	-1,946,299.80	-5.17
Trip distance	6.90	6.34	-0.56	-8.15

Table 34: Comparison of Base Case and Scenario 3 Forecasts for Year 2035 Toledo

	2035 base	Scenario 3	Change	% change
Num of hh	277,108.68	312,725.68	35,617.00	12.85
Num of jobs	300,988.69	357,943.69	56,955.00	18.92
Office jobs	94,185.82	94,325.82	140.00	0.15
Retail jobs	53,341.20	53,355.20	14.00	0.026
Industry jobs	100,203.01	151,167.01	50,964.00	50.86
Other jobs	76,884.02	82,721.02	5,837.00	7.59
Number of trips	1,616,191.36	1,816,358.87	200,167.51	12.39
VMT	9,211,798.32	10,140,915.58	929,117.26	10.09
Trip distance	5.70	5.58	-0.12	-2.05

Scenario 4

Scenario 4 uses the same land allocation forecasts as scenario 3 but adds an indicator to reflect the potential impacts of investments in transit. In particular, the TAZs that are designated for new, higher density growth are all also reassigned the transit availability dummy variable of 1 in the model. For those areas that were previously without transit (not within one-half mile of a transit stop) this represents a simplistic estimate of the impacts of transit investments in those areas on travel.

Table 35 summarizes the results of this scenario. Changing the transit availability dummy variable for the TAZs where higher density development was added has very minimal impacts on the VMT. The probable reason for this is the small coefficient assigned to this variable in the model. This projection should be used with some caution as recent ridership rates have increased but the datasets used in this study do not reflect those changes. Some thought should be given to updating this aspect of the model in the future as the relevant data become available.

Table 35: Scenario 4 Reductions in VMT from Adding Transit to TAZs

Region	Transit TAZ (had transit before the scenario application)	Transit Added	Scenario 3 VMT	Scenario 4 VMT	% Difference
Akron	54	20	18,570,218.50	18,474,029.05	-0.518
Cincinnati	87	51	23,004,784.49	22,785,366.37	-0.954
Dayton	71	24	13,564,818.98	13,505,679.60	-0.436
Mid-Ohio	90	7	35,689,869.12	35,635,272.38	-0.153
Toledo	88	49	10,140,915.58	10,053,737.93	-0.860

6. CONCLUSIONS

This study developed a *Regional Land Use Allocation Decision Analysis Tool*, which enables decision makers to quantify the impacts population and employment distribution in terms of the resulting VMT. This tool uses information concerning infrastructure availability (accessibility, sewer, water services), current land-use policies where available, and environmental constraints to allocate regional and county forecasts of population and employment to 40 acre cells in each metropolitan region of Ohio. The outputs of the land-allocation model inform the subsequent transportation models in terms of population and employment distribution to forecast auto trips and trip distances for each future scenario. These forecasting models estimate the number of auto trips and the associated distances as a function of household characteristics, population and employment distribution aggregated at the TAZ level.

As part of this study, four different land allocation scenarios and their impacts on the resulting VMT are analyzed using this tool. The scenarios are constructed with inputs from ODOT Technical Panel Members and aim to illustrate how differences in assumptions about land use intensity, the location of future land use and job growth, and the interactions with transit availability could impact auto trip rates, trip distances and VMT.

The first scenario assumes that past trends will continue in the same pattern as in the past decade. In the Mid-Ohio region this is a forecast of growth while in the other regions it is a forecast of continuing decline. The model results reveal that with the exception of the Columbus region, there is a forecast of decline in the number of trips. The decline in number of trips is offset to some degree by the forecast of additional trip distances as the historical trends toward sprawl are continued. In the Akron region this results in a slight increase in VMT while in the other declining regions, there is a net decline in VMT. For the Columbus region the historic growth and sprawl patterns are continued with substantial increases in the number of trips and VMT along with the increases in trip distances.

The second scenario is based on the development of selected industry sites.
Under Scenario 2, the impacts of two different development projects on the transportation impacts were simulated, especially in immediately surrounding areas. It was found that the increase in the intensity of use and the change in balance between households and jobs will cause a reduction in trip distances and a net reduction in VMT.

The third scenario assumes a reversal of historic growth patterns. For the regions that have experienced major decline, this means a reversal of this decline with an adjustment to the regional forecasts for household and employment changes. For mid-Ohio, the same growth forecast is used. In addition, rather than the historical growth pattern of increasing suburban sprawl and decline in central city neighborhoods, an increase in the intensity of development is assumed. The scenario results reflect a general growth in trips and vehicle miles travelled as well as a decrease in trip distances across all regions associated with the higher density development.

Scenario 4 uses the same land allocation forecasts as Scenario 3 but adds an indicator to reflect the potential impacts of investments in transit. In particular, the TAZs that are designated for new, higher density growth are all also reassigned the transit availability dummy variable of 1 in the model. The scenario runs revealed very minimal impacts on the VMT. The probable reason for this is the small coefficient assigned to this variable in our model. This projection should be used with some caution as recent ridership rates have increased but the datasets used in this study do not reflect those changes. Some thought should be given to updating this aspect of the model in the future as relevant and more recent data become available.

Although the project did not have the resources to assemble the datasets at the level of detail of the central Ohio region, the basic data and methodology are in place to provide the basis for future model improvements for the remainder of the state. As additional data become available and as we increase our understanding of the factors influencing land use change across Ohio, the data and model can easily be altered to reflect that new information. The scenarios presented in this report illustrate how the model can be used to provide insights into the potential impacts of different future development patterns on travel trends within Ohio's metropolitan areas. Future studies will focus on how these results can be linked to secondary impacts on congestion, fuel use, greenhouse gas production, air quality, and gasoline tax revenues to provide a rich framework for analysis of policy options and economic trends.

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APPENDIX A: CUBE Model Documentation

Introduction

The models described in the report were implemented in CUBE. This appendix describes the CUBE interface and the multiple scripts that need to be run for each of the scenarios presented. Data requirements and data structure related to those scripts are discussed at the end of this appendix.

There are three major sets of scripts and three data preparation scripts that can be run in CUBE. Table A-1 describes the purpose of each. The first part of a complete simulation is to run one of the two Land Use models. There are two versions – one is Land Use Growth Only model which is an altered version of the original MORPC model, it applies only to the Central Ohio region. The second is the Land Use Growth and Decline model which applies to each of the other metropolitan areas studied in this project. Figures A-1 and A-2 show the flow charts for the two models.

Table A- 1: CUBE Scripts for Land Allocation and Trip Models

Name	Purpose
Land Use Growth Only	Land allocation projection for Mid-Ohio Region using only growth factors
Land Use Growth and Decline	Land allocation projection for other regions using decline variables
Trip Generation	Prediction of trips, trip length, and VMT for any land allocation
Scenario 2 Preprocessing	Provides site selection and employment and housing projections for site specific projects
Scenario 3 Preprocessing	Creates changes in scores for selected cells and changes in control totals
Scenario 4 Preprocessing	Changes target TAZs transit availability flag

The outputs from the land use models create a summary of the cell-based changes in households and employment that are needed for input into the Trip Generation model. This model uses either the current or any future TAZ level summaries of households and employment along with the existing TAZ characteristics to forecast the trips, trip length, and VMT for each TAZ in the region. Figure A-3 shows the flow chart for Trip Generation model.

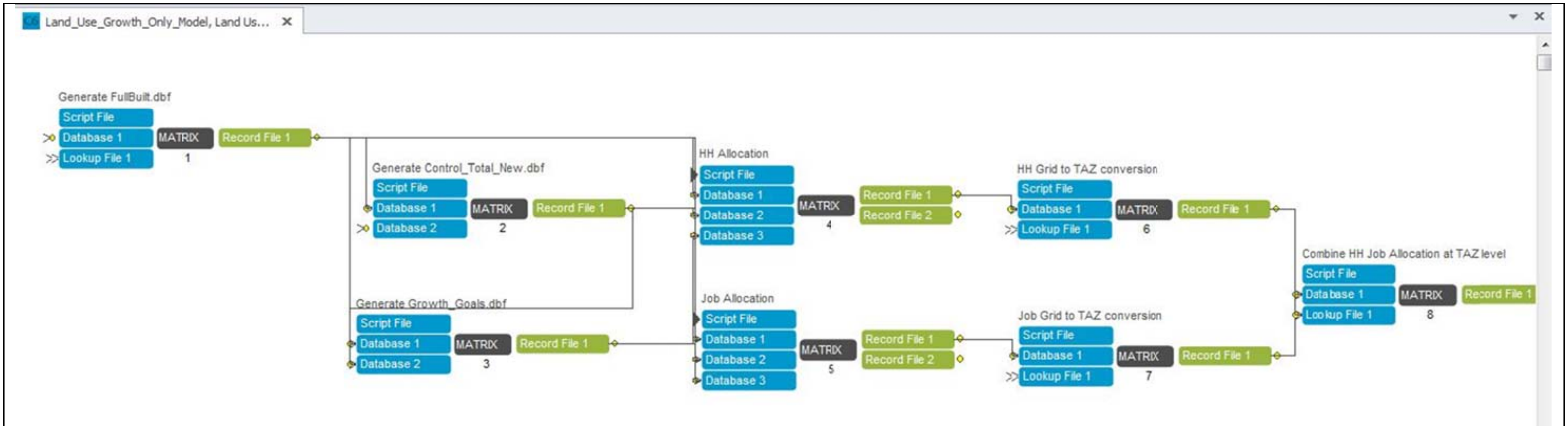


Figure A- 1: Flow Chart for Land Allocation Growth Model

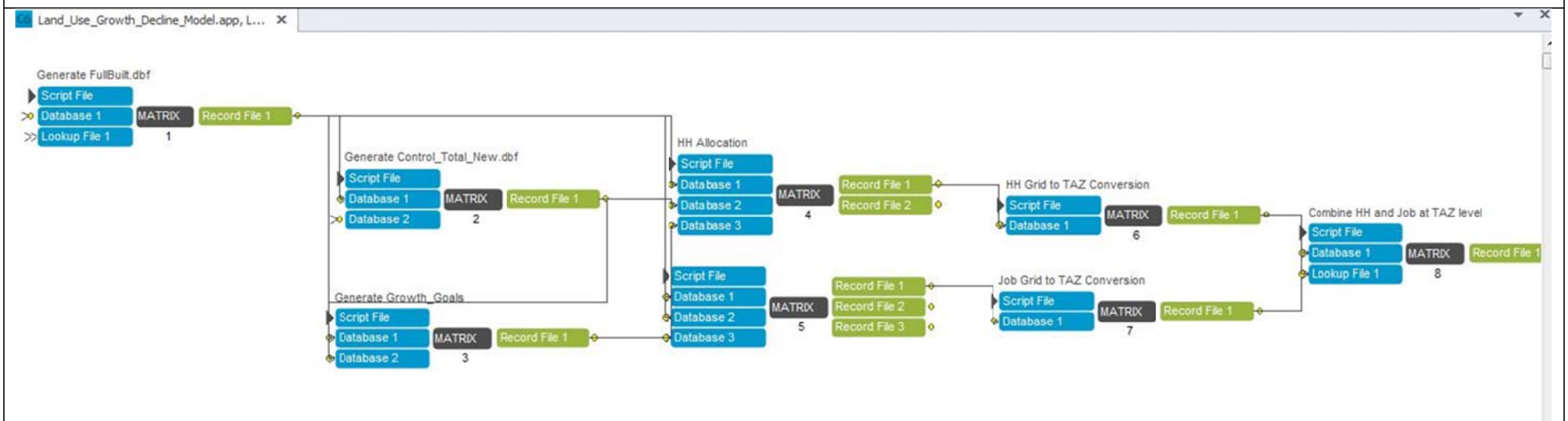


Figure A- 2: Flow Chart for Land Allocation Growth and Decline Model

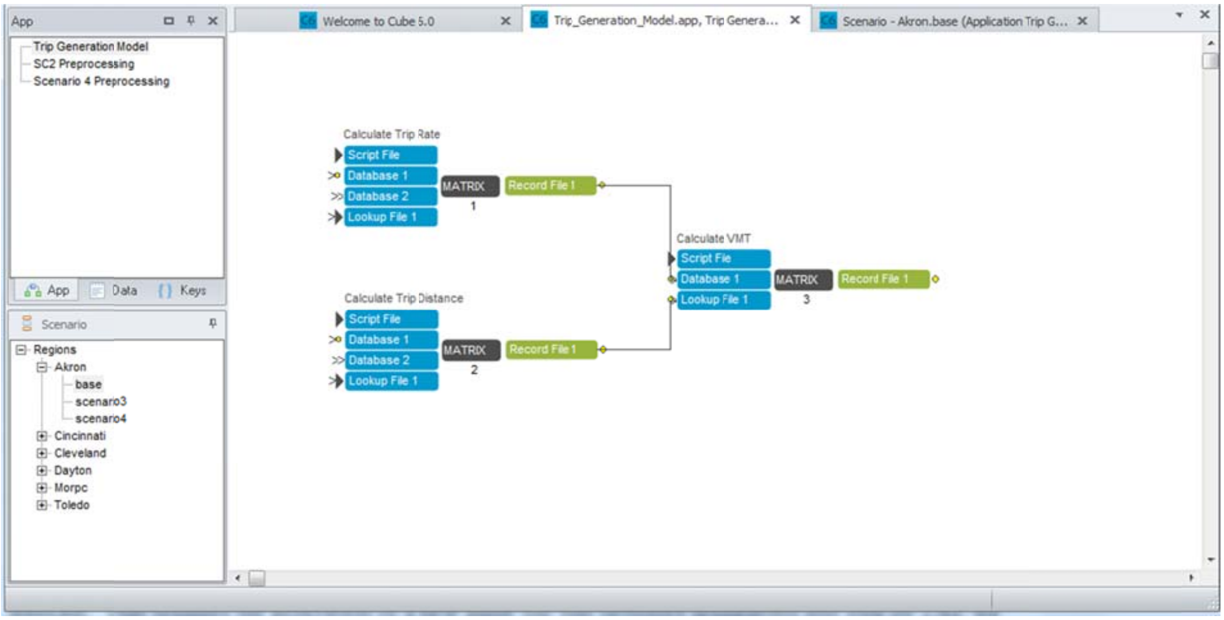


Figure A- 3: Flow Chart for Trip Generation and Distance Models

The other scripts were written as an aid to creating the input datasets for scenarios similar to those we reported on for this project. The Scenario 2 Preprocessing script reads a file which defines the TAZs where a specific development is located, the percentage of the area associated with the site, and the number of new jobs and/or households associated with the development. That information is used to change the TAZ job and household information to prepare for a comparison run of the trip generation model.

The Scenario 3 Preprocessing script is used to change the cell characteristics for any subset of the cells in a region. The cell changes for each subset must be unique. It generally includes a change in households or jobs, a change in the development score for the cells, a change in the future land use, and a change in the growth/decline category for the cells. Given a set of input cells and the other criteria, the script alters the characteristics of that set of cells in preparation for a new land allocation forecast. The script also updates the control totals for growth based on input from the user. The script can be run multiple times to make changes to different subsets of cells.

Finally, the Scenario 4 Preprocessing script provides a list of TAZs where the variable for transit availability will be set to 1. The TAZ characteristics dataset is then altered and can be used to make a new trip forecast.

Land Use Allocation Models

To start the land allocation models, open CUBE and choose the appropriate land allocation model. The datasets for the Land Use Allocation Models are setup in a hierarchical format relating to the regions to which the models apply. This is illustrated by Figures A-4 and A-5. Under each region, there is a set of files relating to each scenario labeled by scenario name. With a particular scenario selected, there are input files created to run the model and model output files created following the run.

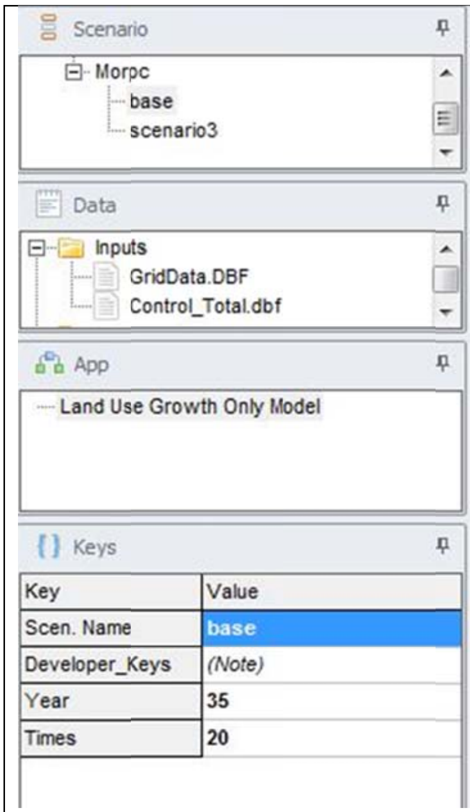


Figure A- 4: Data structure for growth model

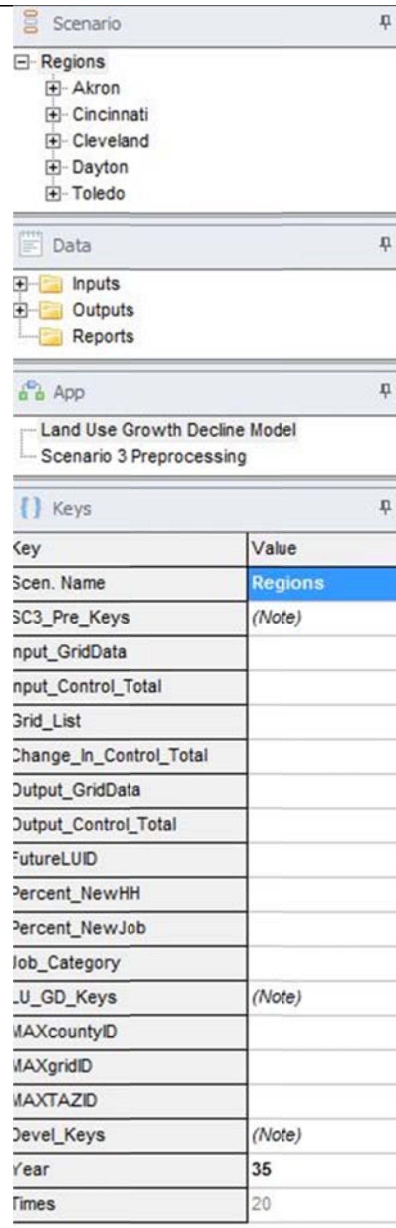


Figure A- 5: Data structure for growth/decline model

There are two input files required for each of the land allocation models. The Control_Total.dbf file has the control totals for household growth, employment by category, and total employment for each county in the region. Those are the target growth or decline totals for those subareas. The second file is the GridData.dbf file. This file has the cell data for the region, including a cell number, TAZ related information, and household and employment scores. The decline model also has the growth or decline indicators. The exact format and structure of each file is discussed in Appendix B along with data preparation instructions.

To start a new scenario, select Land Use Growth Only Model or Land Use Growth Decline Model in the **App** pane. Right click on a region in **Scenario** pane and choose **Add child (**Figure A- 6**)**. Name the resulting level with the scenario name. A window pops up for a description of the scenario (Figure A- 7). Doing this in Cube will create a new directory under that region in the file structure. You can then copy the relevant files to that directory from the operating system window. In the main window, you will be asked to give parameter values for the model (Figure A- 8).

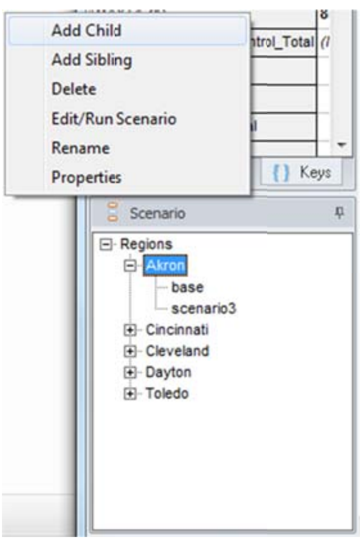


Figure A- 6: Creating a Child Folder

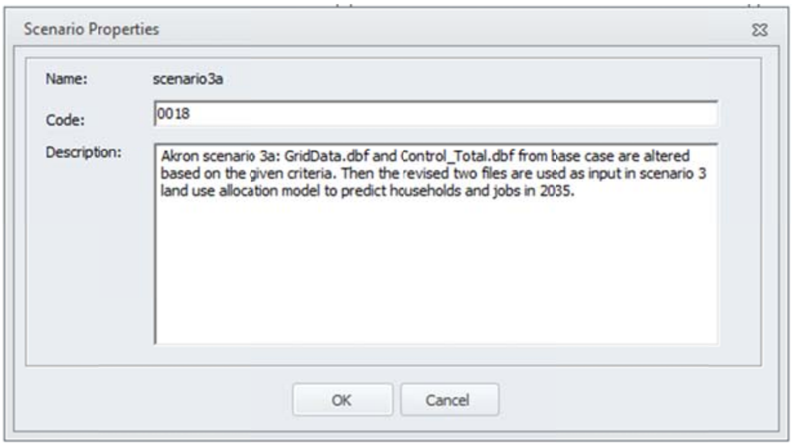


Figure A- 7: Scenario Popup Window

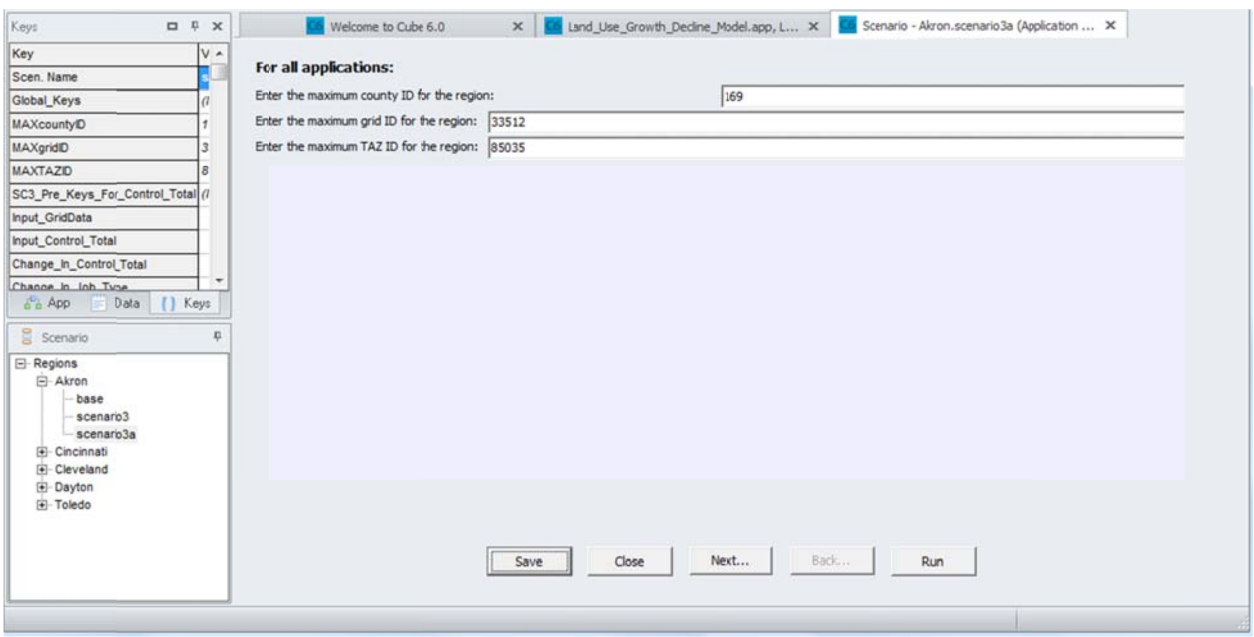


Figure A- 8: Prompt for Scenario Parameter Confirmation

With those files in place, click on**Run** and the model will run. This can take a significant amount of time for these large regions so go get a cup of coffee. When the model completes, there will be a set of output files for the run including the assigned households and jobs by cell by year, by TAZ, and by county. The TAZ based files then become the inputs for the Trip Model.

Any new scenario will require changes to the two input files. Several combinations of changes are possible:

- Change the future land use designations of a set of cells to represent a change in land use controls or other conditions that would impact that future land use or the intensity of use
- Change the household or jobs scores to reflect changes in the expected infrastructure (water and sewer lines, accessibility), development policy (targeted tax rebate areas or subsidized development), or to address "what if" questions
- Change the growth or decline indicators for regions with decline corresponding with either of the above changes
- Change the growth control totals for the counties in the region to reflect either upward or downward trends in growth or decline.

The important part of creating any scenario is to clearly define the target circumstances and how it is represented by the changes in the input data.

Changes could be made using a variety of software. The input tables can be opened in Excel or by other database or statistical programs and built-in functions can be used to filter and change values. The cells can also be selected in a GIS program. Its selection and data change options can be used to create new values for the cells. The resulting table needs to match the format of the sample tables with the same field labels and must be in dbf format. Some software will export in this format. Newer versions of Excel will not do this but there are several converters that can change data from Excel to dbf format identified in Appendix C.

The Scenario 3 script provides a simplified way to create a set of changes in the input data. Prior to running this script, one needs to define two new tables: a table with the list of the cells that are to be changed by the script and several additional parameters about the nature of the changes. The final results are new versions of the two input files that can be used to run a new scenario. Instruction on running scenario 3 preprocessing is given in next section.

Trip Models

Start the trip model by opening the CUBE file **Trip_Generation_Model.cat** in the project directory. On the left side panel, double click on Trip Generation Model in **App** pane, choose the appropriate region in **Scenario** pane and click to see the list of scenarios. In cases where you have run the Land Allocation model, double click on the scenario you want to run trip model. A window pops up asking for input about "MAX TAZ ID" and "TAZ_characteristics" file (Figure A- 9). These should be filled in with the correct values. For the base file run, the file name will be TAZ_chasracteristics.dbf. If you are running Scenario 4 after using that preprocessing application, the revised file name will be TAZ_characteristics_Sc4.dbf.

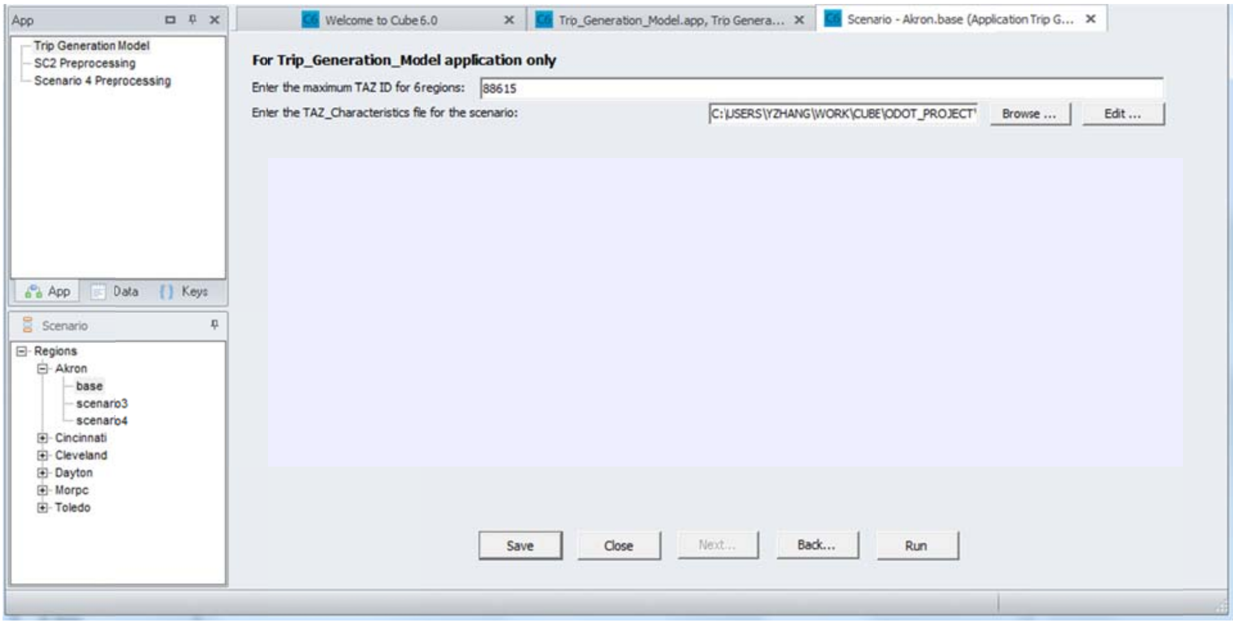


Figure A- 9: Confirmation of TAZ Values for Trip Generation Model

Click **Save** and then **Run** and the model will run and complete within a few minutes. The outputs will consist of these files:

TripDistance_ByTAZ.DBF – the predicted trip distances for each TAZ in the region

TripRate_ByTAZ.DBF – the predicted trip rates for each TAZ in the region

TripGeneration_ByTAZ.DBF – VMT, trip distance, and trip rate for each TAZ in the region.

The files can be read into any database, spreadsheet, or GIS program for further analysis, comparison with other runs, or mapping to see the resulting patterns.

Scenario 2 Preprocessing

In our Scenario 2 runs, we compared the impacts of the site specific changes to the base year (year 2000) households and jobs distributions by TAZ so that the impacts were not mixed with the results of the 2035 forecast. That requires the generation of a new input file that tabulates households and jobs by TAZ for that year. A second file is required that lists the TAZs where the site specific development will occur along with the distribution of the households and/or jobs predicted for that site development.

We used the pivot table feature in Microsoft Excel to create the first file. Open the file GridData.dbf from the base run folder for the target region in Excel. Select **Pivot Table** from the **Insert** menu on the ribbon. Select **TAZ** as the row labels and check HH, JOB, OFFICE, RETAIL, INDUSTRY, and OTHER to get those to sum at the TAZ level. Copy the resulting spreadsheet to a new workbook excluding the blank lines at the top and the grand totals at the bottom. Change the column labels to be:

TAZ_ID, HH, Job, JobOff, JobRet, JobInd, JobOth

Save the file with the name HH_Job_2000_ByTAZ.dbf (this name is mandatory in the current script). That file then needs to be converted to a dbf format to be read into CUBE. For those conversions, we used SPSS statistical package which can read in Excel files and export DBF4 format. Other packages can do the same thing and there are several inexpensive shareware programs that can be used instead.[1] Be sure all of the variables are saved as type numeric. Copy the dbf file into the Scenario 2 folder.

The second file needs to specify the new jobs and/or households by TAZ to be used in the new forecast. In order to derive these numbers, we identified the approximate project boundaries in GIS and overlaid those with the cell boundaries for the target region. The selected cells were saved as a separate file. Then, that file was joined spatially with the TAZ boundaries to discover which TAZs the site cells fell into. We then summarized that file by creating a count of the number of site cells within each TAZ. The count is then used as a proxy for the percentage of the households and jobs to allocate to the TAZ under scenario 2 based on the apportioning the totals for the development. If more detailed information is available for the site, a more refined allocation to the TAZs could be made. The resulting file was then saved in dbf format as that second target file for the Scenario 2 preprocessing. A sample file showing the needed variable labels is shown as Table A-2. The required fields are TAZ_ID, JOB, and HH.

Table A- 2: Example File for Target Development TAZ for Scenario 2

OBJECTID	TAZ_ID	FREQUENCY	PERCENTAGE	JOB	HH
1	48017	2	20.00	220	0.00
2	48026	6	60.00	660	0.00
3	48027	2	20.00	220	0.00

[1] See for example http://en.kioskea.net/download/download-13304-xls-to-dbf-converter; http://www.coolutils.com/XLS-to-DBF-In-Batch; http://xls-to-dbf-converter.softpedia.com/; http://xlsconverter.net/

Once the files are prepared and in the Scenario 2 directory, in CUBE double-click on SC2 Preprocessing in **App** pane and click on scenario2 for a region in **Scenario** pane (Figure A- 10). You need to give the program the name of the file represented in Table A-2. A window will pop up where you can enter the file name in the window. There are 3 pages in the window but for this application, you only need the page for "Scenario 2 preprocessing. Alternatively, you can specify the file name in the Keys panel on the left. You can then save the changes and run the preprocessor (Figure A- 11).

Once the preprocessing step has been run, run the Trip Model using the data in the scenario2 directory. That will provide the trip data by TAZ that can be compared to the base case statistics provided in this report and its related data files.

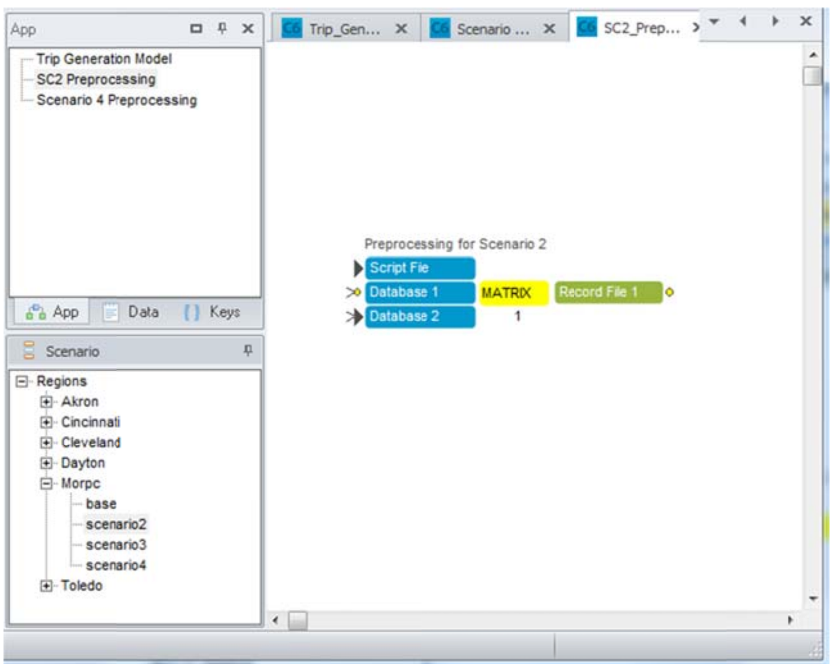


Figure A- 10: Scenario 2 Preprocessing Screen

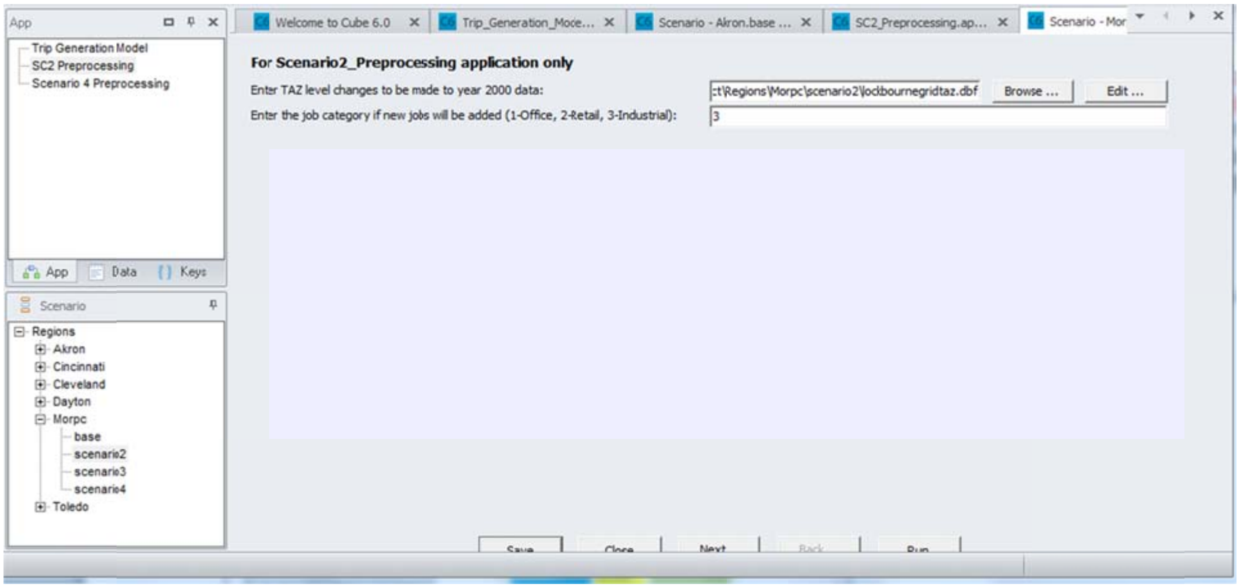


Figure A- 11: Specifying the Input Dataset and Job Category Change

Scenario 3 Preprocessing

Scenario 3 represents a demonstration of the use of the model to provide alternative forecasts based on changes in the input values for cells and/or the regional forecasts used to define future changes in households and jobs. Our instructions thus use scenario 3 as an example that can be used to create any number of future scenarios which can be given any name.

There are two types of changes that can be made with the preprocessing application. Changes can be made to one or more subsets of cells to their future land use code, their household or job scores, and/or their future growth/decline scores. Changes can also be made to the regional control totals for households and jobs by category used in making land use allocations. The script is divided into two parts allowing the user to decide which combination of changes to include in a given scenario. The only important restriction is that changes to the cell values, if any, should be made first, then changes to the control totals, if any, to prepare for a run of the land allocation model.

The first part of the script is designed to allow a series of changes to the values of the cells used in the land allocation model. The script requires the preparation of a file with a list of the cells that are to undergo changes. The changes to each set of cells must be the same. Multiple sets of cells can be changed by running this part of the script multiple times, once for each subset of changes. The most straightforward way of creating a subset is by using the GIS files to identify groups of cells by their existing attributes or their spatial location. That subset can then be saved as a new file to be used as input to the script.

Start the script process by creating a scenario3 (or any name you want to call it. But you have to remember it is for scenario 3 preprocessing, so it's better to be 3a, 3b, etc. child for the region in question in CUBE. Then create a preprocessing child directory in scenario3 directory in the operating system window.

The input dataset for the list of cells should be a dbf file with the field names in the first row and must include the field PAGENUMBER which represents the cell numbers in the existing input dataset. The dataset should then be copied to the preprocessing folder. Start the cell changes section of the script by double clicking on SC3 Preprocessing –GridData in **App** pane (Figure A-12), then double clicking on scenario3 for the region in **Scenario** pane and filling in the file name for the cell changes. You will also be prompted for the changes to be made to the cell values. Fill in the appropriate values and then run the script (Figure A- 13).

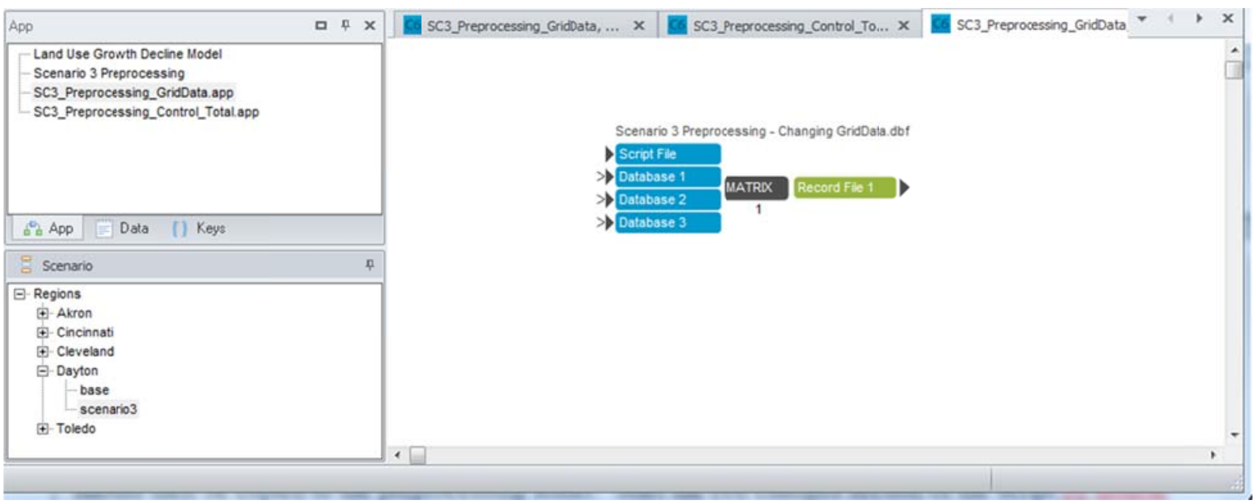


Figure A- 12: Scenario Preprocessing Screen

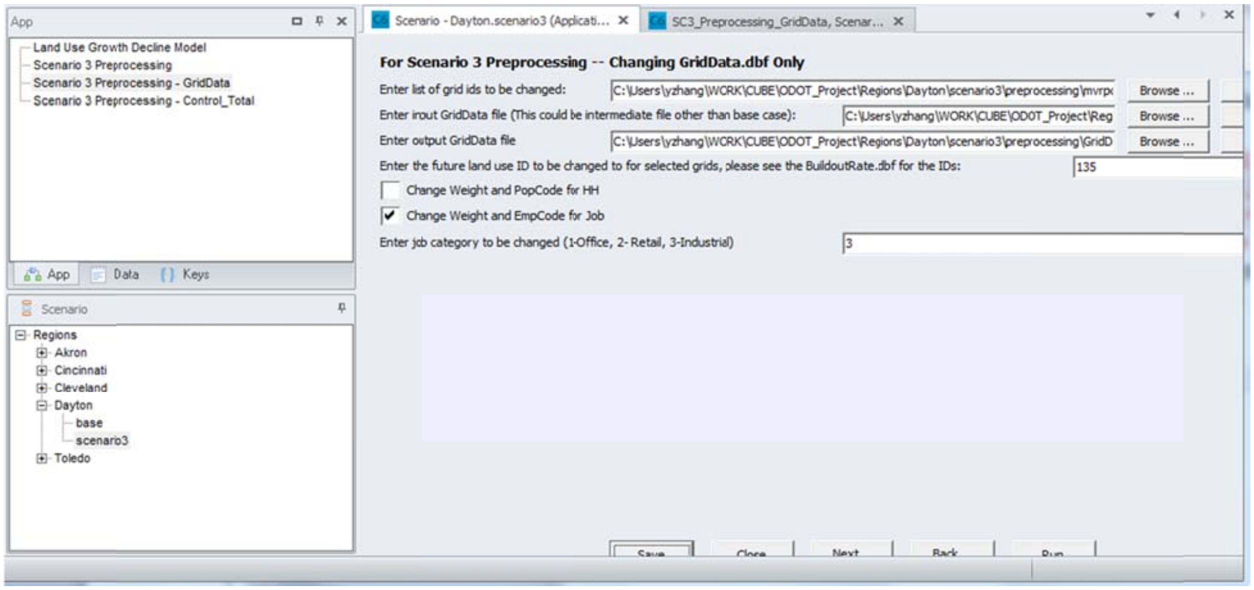


Figure A- 13: Entering Filenames and Value Changes for Scenario 3 Preprocessing

The output from the script will be a new version of the GridData.dbf file called GridData_1.dbf with changes made to the cells designated in the input file. If you have additional sets of changes to make, repeat the process with a new input file. The script will use GridData_1.dbf as the input file and output GridData_2.dbf with the accumulated changes. Repeat as many times as necessary. When you are done with this part of the pre-processing, copy the final GridData_n.dbf file to the Scenario 3 directory and rename it as Grid_Data.dbf.

If you also want to make changes to the regional control totals, you can now use the second part of the script (Figure A- 14 and Figure A- 15). If you don't wish to make any such changes, you can skip to the instructions for running Land Allocation Model for the new scenario. It is up to the analyst to define a scenario with consistent changes to the cell and regional control data files as appropriate. For example, it may not make sense to make many changes to cells to force them into growth categories without also adding to the amount of growth in an otherwise declining region.

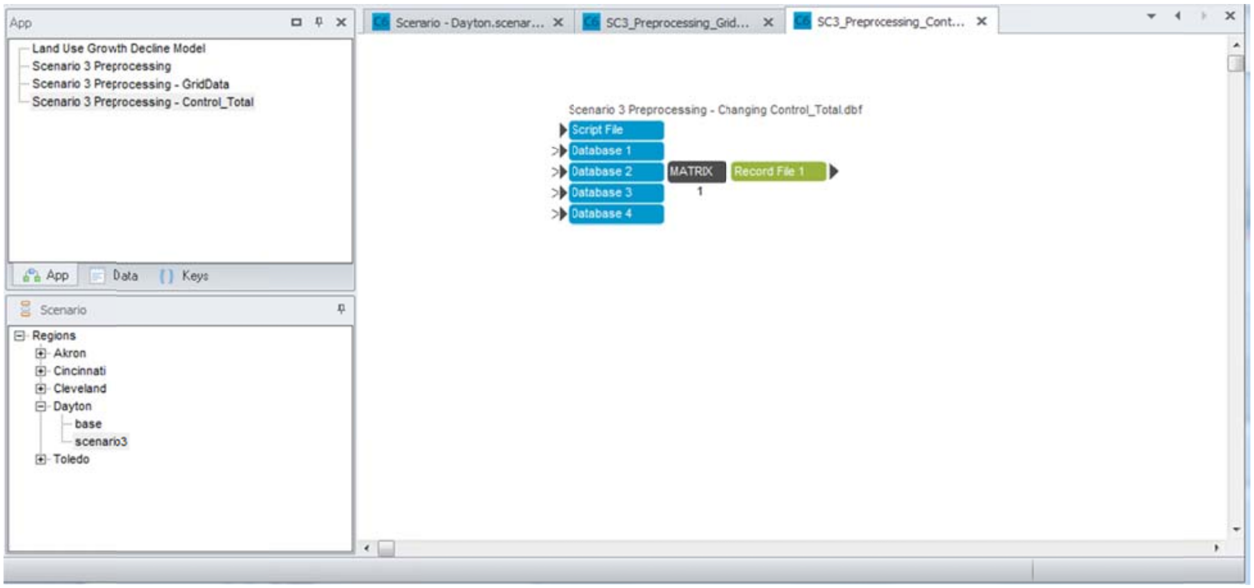


Figure A- 14: Scenario 3 Control Total Changes Script

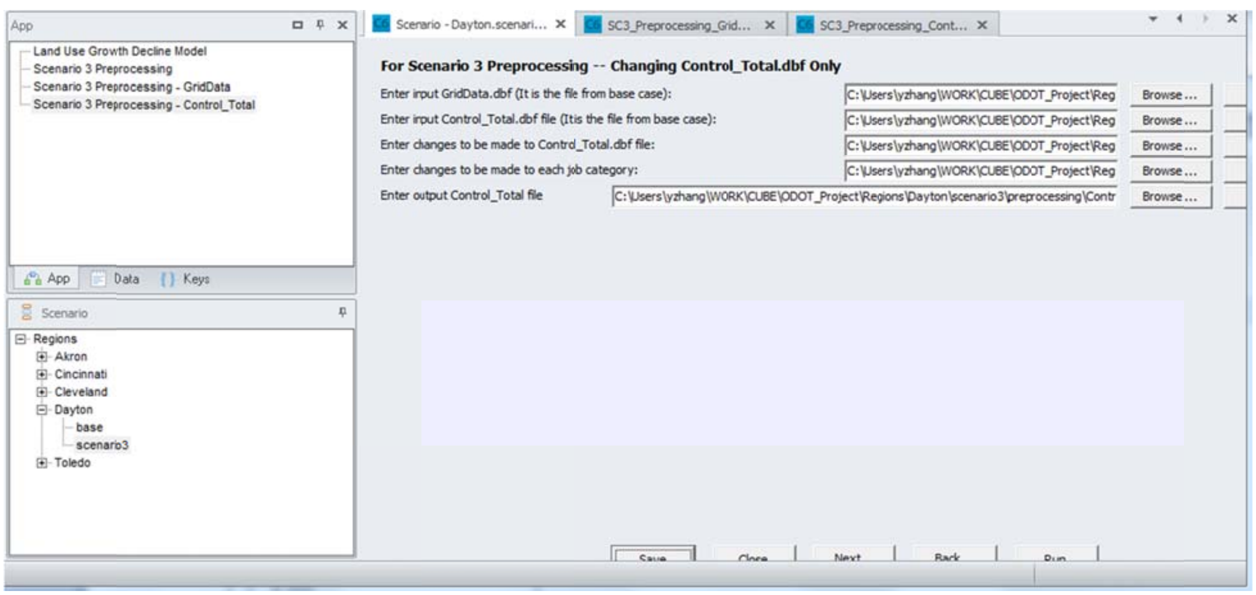


Figure A- 15: Parameters for the Control Total Changes

For this script, you will need to prepare a table showing the county codes and the shares of forecast changes in jobs and households that will be made to the control total table. An example is shown as Table A- 3. The control totals may change for households or jobs and may be distributed across the region in various ways. The table is needed to make the calculations of changes.

Table A- 3: Share of Household and Job Changes by County

CNTY	SHARE_HH	SHARE_JOB
37	0	0
57	0	50
109	0	0
113	0	50
135	0	0

Changes for households and jobs will then require other data. For households, you will need to specify the percentage growth in the households for the region. That number will be used along with the percentage distributions to calculate the new values for each county.

For jobs, you will need both the percentage growth and the job category or categories in which that growth may occur. Table A-4 shows the job categories. Table A-5 shows the data table required for job growth calculations. The growth numbers are then used to calculate the new control totals for jobs and households by county and produce a new table Control_Total_1.dbf. Execute the script and copy that file to the scenario 3 directory and rename it Control_Total.dbf.

Table A- 4: Codes for Job Types

Code	Job Type
1	Office Jobs
2	Retail Jobs
3	Industry Jobs

Table A- 5: Designating Changes in Jobs by Type

Job Type	Percent change
1	5
2	0
3	10

Now you have all of the files needed to run the new land allocation scenario so you can start the Land Allocation Growth and Decline script and use the data in the Scenario 3 folder to generate a new land allocation.

Scenario 4 Preprocessing

The input for scenario 4 is a dbf table with the list of TAZs where the presence of transit dummy variable should be set to 1 to reflect the presence of transit services. We used the cell change dataset that created in scenario 3 joined to the TAZ dataset to get a list of TAZs that we wanted to change in this way. The table only needs to have a field named TAZ_ID and then the list of those IDs in a dbf format.

Create a child for Scenario 4 in **Scenario** pane and the corresponding directory is created automatically in the region directory. Copy your TAZ_ID table to the directory. Double click on Scenario 4 Preprocessing in **App** pane (Figure A- 16), then double click on scenario4 in **Scenario** pane, and fill in the values in the popped up window (Figure A- 17), then click on **Save** and **Run** to run the script. A new version of the TAZ characteristic file TAZ_characteristics_Sc4.dbf will be created with the appropriate change in scenario4 directory. You can then run the Trip model using the revised data.

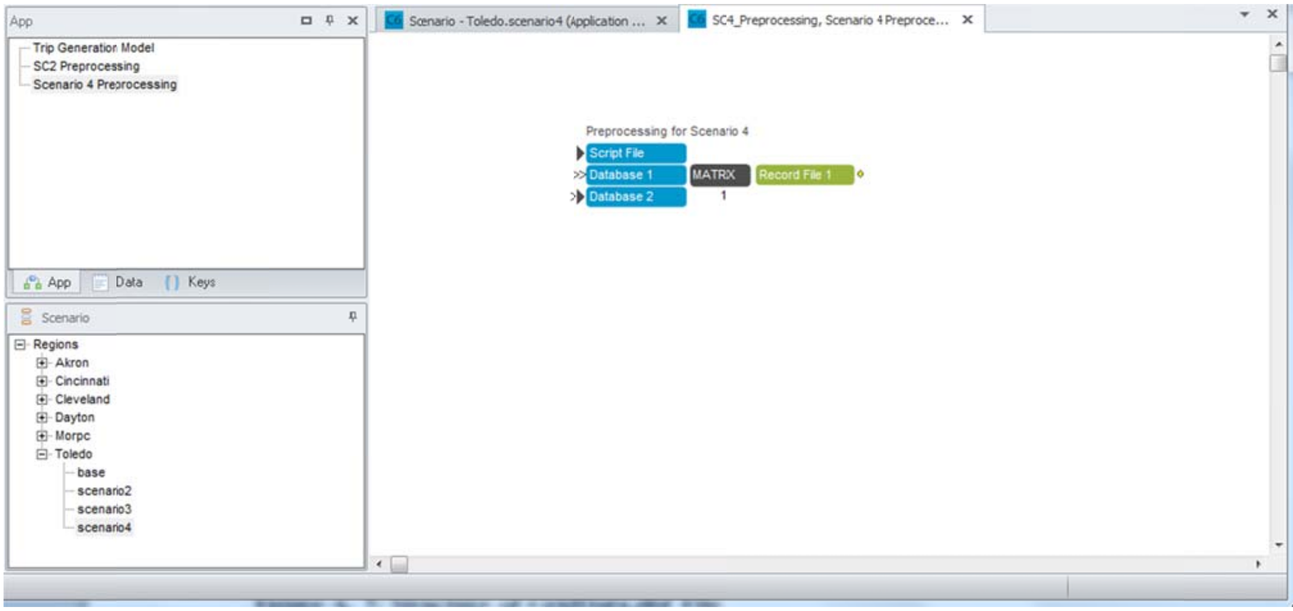


Figure A- 16: Scenario 4 Preprocessing Screen

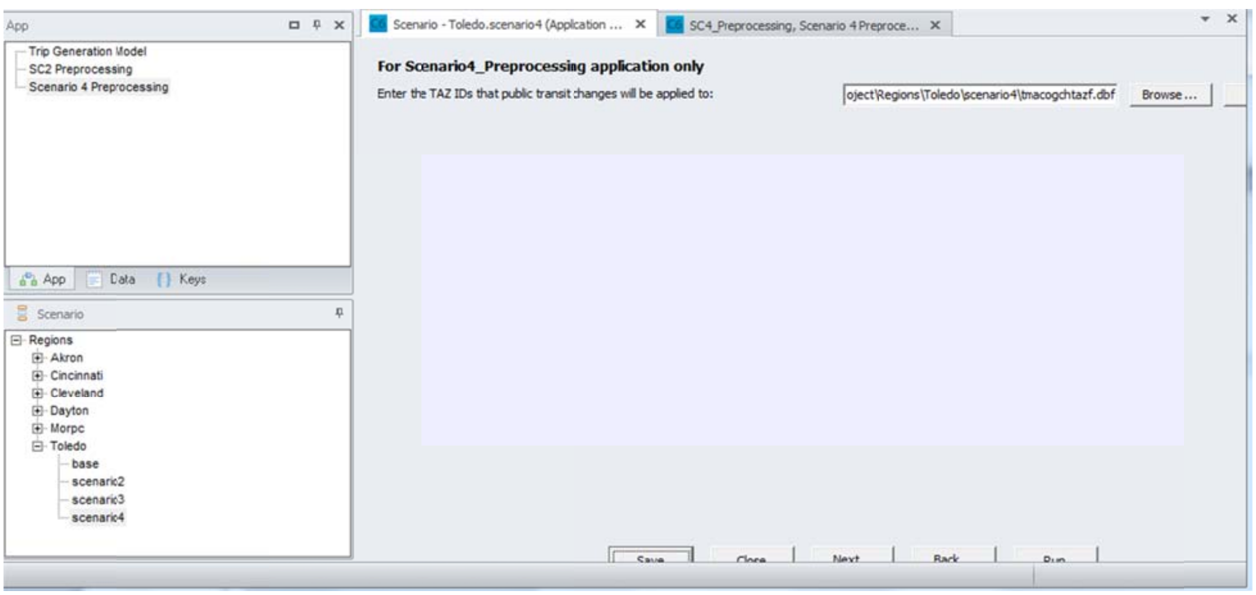


Figure A- 17: Scenario 4 File Reference

Data Structure and Data Preparation

Datasets are provided on a companion DVD and are indexed in Appendix C of this report. This section provides a brief overview of the major input datasets and guidance on future updates to data. For each region, we created a grid overlay and then generated data at the grid scale from available GIS information. The exception was the data for Central Ohio which was provided directly by MORPC.

Figure A- 18 shows the structure of the GridData.dbf file that is the basis for the land use allocation models.The first field is Grid_ID which is equivalent to the PAGENUMBER field in the GIS datasets. The county code, name, and TAZ ID fields are next. When we created the grid data, we assigned grids to one and only one of these larger units. If the grid was on a boundary, the unit with the largest percentage of the area was used as the decide reference location. The current file can be used as a model for any updated versions of the information.

The second major file used in the Land Allocation model is the Control_Total.dbf. Its structure is shown in Figure A- 19. The current values are based on forecasts provided by MORPC and statewide regional forecasts of population and employment growth.

Name	Type	Width	Decimals	Label
GRID_ID	Numeric	12	0	Grid ID (pagenumber)
COUNTY	Numeric	12	0	County Code
CNTY_NAME	String	7	0	County
TAZ	Numeric	12	0	TAZ ID for Cell
WEIGHTHH	Numeric	12	0	Household Weight
WEIGHTJOB	Numeric	12	0	Job Weight
NOBUILD	Numeric	12	4	Percent area no build
EXISTINGID	Numeric	12	0	Existing Land Use ID
FUTUREID	Numeric	12	0	Future Land Use ID
POP1000_SD	Numeric	12	0	Population growth-decline score
IND1004_SD	Numeric	12	0	Industry growth-decline score
OFF1004_SD	Numeric	12	0	Office growth-decline score
RET1004_SD	Numeric	12	0	Retail growth-decline score
HH	Numeric	12	4	Households 2000
INDUSTRIAL	Numeric	12	4	Industrial Jobs 2000
RETAIL	Numeric	12	4	Retail Jobs 2000
OFFICE	Numeric	12	4	Office Jobs 2000
OTHER	Numeric	12	4	Other Jobs 2000
JOB	Numeric	12	4	Total Jobs 2000

Figure A- 18: Structure of GridData.dbf File

Name	Type	Width	Decimals	Label
D_R	String	1	0	
county	Numeric	12	0	County code
cnty_name	String	7	0	County Name
controlhh	Numeric	12	4	Total Households
controljob	Numeric	12	4	Total Jobs
ctjoboffic	Numeric	12	4	Office Jobs
ctjobretai	Numeric	12	4	Retail Jobs
ctjobindus	Numeric	12	4	Industrial Jobs
ctjobother	Numeric	12	4	Othe Jobs

Figure A- 19: Control Total Data Structure

The numbers represent the totals for the year 2035 for each category in each county in the region. The other datasets used by the model are constant across regions and are used as development limits for different land use types and as inputs for the trip model.

Future Data Updates

The values and available variables for the regional models outside of Central Ohio were limited by the availability of publically available GIS data. If the model is to be used by other regional transportation agencies, they will likely wish to update the information with more recent local data and may also wish to add other criteria that they believe impacts land use changes in their region.

Making these changes will require the overlay of the cell structure with any updated layers and assigning values to the cells using GIS functions. Once the values are assigned, they can be assembled into a new master database that can be used to generate new values for the household and job weights, current land use codes, and current jobs.

Once the updated data are assembled, they can be used to alter the values of the codes in the allocation model input files and then used with the model using the instructions given earlier.

APPENDIX B: Additional Model Comparisons – Urban/Rural TAZs

These tables are companion to the summary tables of forecasts presented within the body of the report. They report separate forecasts for urban (with and without transit accessibility) and rural TAZs in the regions.

Comparison Tables for Year 2000 vs. Year 2035 Base Case

Table B- 1: Akron – Nonmetropolitan

	2000	**2035**	**Change**	**% change**
Number of households	31,428.40	35,403.40	3,975.00	12.65
Number of jobs	49,696.10	57,454.10	7,758.00	15.61
Office jobs	6,200.10	12,616.10	6,416.00	103.48
Retail jobs	12,344.30	8,616.30	-3,728.00	-30.20
Industry jobs	15,153.20	25,800.20	10,647.00	70.26
Other jobs	16,001.00	10,424.00	-5,577.00	-34.85
Number of trips	225,608.52	238,191.49	12,582.98	5.58
VMT	1,560,738.24	1,671,019.88	110,282.64	7.07
Trip distance	6.92	7.02	0.10	1.41

Table B- 2: Akron- Urban No Transit

	2000	2035	Change	% change
Number of households	31,428.40	35,403.40	3,975.00	12.65
Number of jobs	49,696.10	57,454.10	7,758.00	15.61
Office jobs	6,200.10	12,616.10	6,416.00	103.48
Retail jobs	12,344.30	8,616.30	-3,728.00	-30.20
Industry jobs	15,153.20	25,800.20	10,647.00	70.26
Other jobs	16,001.00	10,424.00	-5,577.00	-34.85
Number of trips	1,497,806.89	1,452,899.47	-44,907.43	-3.00
VMT	9,267,489.34	9,184,356.28	-83,133.07	-0.90
Trip distance	6.19	6.32	0.13	2.17

Table B- 3: Akron - Urban with Transit

	2000	2035	Change	% change
Number of households	142,286.30	147,146.30	4,860.00	3.42
Number of jobs	218,261.40	181,697.40	-36,564.00	-16.75
Office jobs	41,935.50	83,506.50	41,571.00	99.13
Retail jobs	47,730.10	15,028.10	-32,702.00	-68.51
Industry jobs	49,821.40	66,102.40	16,281.00	32.68
Other jobs	78,771.20	17,057.20	-61,714.00	-78.34
Number of trips	1,276,973.62	1,192,634.16	-84,339.46	-6.60
VMT	7.592,664.20	7,099,433.18	-493,231.02	-6.50
Trip distance	5.95	5.95	0.01	0.12

Table B- 4: Cincinnati - Urban No Transit

	2000	2035	Change	% change
Number of households	328,266.70	318,607.70	-9,659.00	-2.94
Number of jobs	391,434.40	501,296.40	109,862.00	28.07
Office jobs	43,887.80	130,528.80	86,641.00	197.42
Retail jobs	93,635.60	70,704.60	-22,931.00	-24.49
Industry jobs	90,140.50	174,062.50	83,922.00	93.10
Other jobs	163,770.50	126,000.50	-37,770.00	-23.06
Number of trips	1,608,838.85	1,618,602.90	9,764.05	0.61
VMT	11,749,162.71	11,941,818.10	192,655.40	1.64
Trip distance	7.30	7.38	0.07	1.03

Table B- 5 Cincinnati - Urban with Transit

	2000	2035	Change	% change
Number of households	263,587.90	222,706.90	-40,881.00	-15.51
Number of jobs	597,160.40	384,905.40	-212,255.00	-35.54
Office jobs	104,475.90	166,192.90	61,717.00	59.07
Retail jobs	118,731.50	37,388.50	-81,343.00	-68.51
Industry jobs	107,065.90	102,591.90	-4,474.00	-4.18
Other jobs	266,887.20	78,732.20	-188,155.00	-70.50
Number of trips	2,245,933.24	1,693,774.62	-552,158.61	-24.58
VMT	13,010,248.06	10,099,036.81	-2,911,211.25	-22.38
Trip distance	5.79	5.96	0.17	2.93

Table B- 6: Cleveland- Urban No Transit

	2000	2035	Change	% change
Number of households	323,505.40	355,299.40	31,794.00	9.83
Number of jobs	448,760.70	377,696.70	-71,064.00	-15.84
Office jobs	59,464.00	83,911.00	24,447.00	41.11
Retail jobs	104,307.50	64,038.50	-40,269.00	-38.61
Industry jobs	124,799.20	145,656.20	20,857.00	16.71
Other jobs	160,190.10	84,091.10	-76,099.00	-47.51
Number of trips	1,773,842.17	1,750,181.72	-23,660.45	-1.33
VMT	12,701,314.07	12,254,085.14	-447,228.93	-3.52
Trip distance	7.16	7.00	-0.16	-2.22

Table B- 7: Cleveland - Urban with Transit

	2000	2035	Change	% change
Number of households	529,656.30	472,680.30	-56,976.00	-10.76
Number of jobs	902,868.10	607,253.10	-295,615.00	-32.74
Office jobs	174,336.40	193,569.40	19,233.00	11.03
Retail jobs	171,927.90	67,958.90	-103,969.00	-60.47
Industry jobs	169,864.30	154,796.30	-15,068.00	-8.87
Other jobs	386,739.50	190,928.50	-195,811.00	-50.63
Number of trips	3,640,873.73	2,903,225.23	-737,648.51	-20.26
VMT	18,753,683.77	15,599,433.19	-3,154,250.58	-16.82
Trip distance	5.15	5.37	0.22	4.32

Table B- 8: Dayton – Nonmetropolitan				
	2000	**2035**	**Change**	**% change**
Number of households	33,194.10	35,005.10	1,811.00	5.46
Number of jobs	32,957.60	30,598.60	-2,359.00	-7.16
Office jobs	4,625.30	7,013.30	2,388.00	51.630
Retail jobs	8,673.10	5,160.10	-3,513.00	-40.50
Industry jobs	7,189.70	10,619.70	3,430.00	47.71
Other jobs	12,469.40	7,805.40	-4,664.00	-37.40
Number of trips	207,562.09	198,305.04	-9,257.06	-4.46
VMT	1,553,121.86	1,501,274.12	-51,847.74	-3.34
Trip distance	7.48	7.57	0.09	1.17

Table B- 9: Dayton - Urban No Transit				
	2000	**2035**	**Change**	**% change**
Number of households	146,348.50	162,312.50	15,964.00	10.91
Number of jobs	185,204.40	152,642.40	-32,562.00	-17.58
Office jobs	41,155.10	43,973.10	2,818.00	6.85
Retail jobs	48,443.90	33,944.90	-14,499.00	-29.93
Industry jobs	33,323.20	47,246.20	13,923.00	41.78
Other jobs	62,282.30	27,478.30	-34,804.00	-55.88
Number of trips	639,973.93	634,549.33	-5,424.61	-0.85
VMT	4,477,850.42	4,313,816.52	-164,033.90	-3.66
Trip distance	7.00	6.80	-0.20	-2.84

Table B- 10: Dayton - Urban with Transit				
	2000	**2035**	**Change**	**% change**
Number of households	179,861.00	170,075.00	-9,786.00	-5.44
Number of jobs	318,651.30	206,265.30	-112,386.00	-35.27
Office jobs	60,290.70	74,255.70	13,965.00	23.16
Retail jobs	66,001.60	28,207.60	-37,794.00	-57.26
Industry jobs	64,749.30	69,906.30	5,157.00	7.97
Other jobs	127,609.80	33,895.80	-93,714.00	-73.44
Number of trips	1,448,067.94	1,248,853.12	-199,214.82	-13.76
VMT	8,195,272.65	6,952,750.95	-1,242,521.70	-15.16
Trip distance	5.66	5.57	-0.09	-1.63

Table B- 11: Mid-Ohio - Urban No Transit				
	2000	2035	Change	% change
Number of households	402,840.00	561,905.00	159,065.00	39.49
Number of jobs	394,384.00	567,644.00	173,260.00	43.93
Office jobs	144,524.00	204,870.00	60,346.00	41.76
Retail jobs	98,007.00	139,519.00	41,512.00	42.36
Industry jobs	86,465.00	121,025.00	34,560.00	39.97
Other jobs	65,388.00	88,593.00	23,205.00	35.49
Number of trips	1,516,707.28	2,283,327.87	766,620.59	50.55
VMT	11,464,089.18	18,462,854.73	6,998,765.56	61.05
Trip distance	7.56	8.09	0.53	6.98

Table B- 12: Mid-Ohio - Urban with Transit				
	2000	**2035**	**Change**	**% change**
Number of households	303,869.00	336,488.00	32,619.00	10.74
Number of jobs	472,831.00	551,266.00	78,435.00	16.59
Office jobs	220,656.00	246,064.00	25,408.00	11.52
Retail jobs	99,716.00	117,790.00	18,074.00	18.13
Industry jobs	72,297.00	84,896.00	12,599.00	17.42
Other jobs	80,162.00	95,704.00	15,542.00	19.39
Number of trips	2,732,334.95	3,167,273.15	434,938.20	15.92
VMT	15,382,523.46	19,173,314.19	3,790,790.72	24.64
Trip distance	5.63	6.05	0.42	7.53

Table B- 13: Toledo – Nonmetropolitan				
	2000	**2035**	**Change**	**% change**
Number of households	63,711.50	66,540.50	2,829.00	4.44
Number of jobs	83,906.60	75,992.60	-7,914.00	-9.43
Office jobs	13,786.10	17,727.10	3,941.00	28.59
Retail jobs	20,173.90	11,926.90	-8,247.00	-40.88
Industry jobs	25,857.70	31,719.70	5,862.00	22.67
Other jobs	24,088.80	14,618.80	-9,470.00	-39.31
Number of trips	435,573.03	405,765.48	-29,807.55	-6.84
VMT	3,094,343.00	2,866,682.61	-227,660.38	-7.36
Trip distance	7.10	7.06	-0.04	-0.55

Table B- 14: Toledo - Urban No Transit				
	2000	**2035**	**Change**	**% change**
Number of households	68,982.30	72,220.30	3,238.00	4.69
Number of jobs	98,482.50	84,823.50	-13,659.00	-13.87
Office jobs	10,080.90	15,390.90	5,310.00	52.67
Retail jobs	26,932.60	19,246.60	-7,686.00	-28.54
Industry jobs	20,261.60	25,682.60	5,421.00	26.76
Other jobs	41,207.40	24,503.40	-16,704.00	-40.54
Number of trips	362,070.10	349,381.08	-12,689.02	-3.50
VMT	2,368,076.50	2,230,286.65	-137,789.85	-5.82
Trip distance	6.54	6.38	-0.16	-2.40

Table B- 15: Toledo - Urban with Transit				
	2000	**2035**	**Change**	**% change**
Number of households	150,992.90	138,347.90	-12,645.00	-8.38
Number of jobs	222,090.70	140,172.70	-81,918.00	-36.89
Office jobs	48,357.80	61,067.80	12,710.00	26.28
Retail jobs	59,566.60	22,167.60	-37,399.00	-62.79
Industry jobs	33,908.80	42,800.80	8,892.00	26.22
Other jobs	103,882.80	37,761.80	-66,121.00	-63.65
Number of trips	1,073,647.65	861,044.80	-212,602.85	-19.80
VMT	5,089,762.37	4,114,829.06	-974,933.32	-19.15
Trip distance	4.74	4.78	0.04	0.81

Comparison of Base Case and Scenario 3

Table B- 16: Akron - Nonmetropolitan

	2035 - Base	Scenario 3	Change	% change
Number of households	35,403.40	35501.36	98.000	0.28
Number of jobs	57,454.10	57115.13	-339.000	-0.59
Office jobs	12,616.10	12176.12	-440.000	-3.49
Retail jobs	8,616.30	8659.29	43.000	0.50
Industry jobs	25,800.20	26264.18	464.000	1.80
Other jobs	10,424.00	10018.03	-406.000	-3.90
Number of trips	238,191.49	237,276.54	-914.95	-0.38
VMT	1,671,019.88	1,661,267.20	-9,752.68	-0.58
Trip distance	7.02	7.00	-0.01	-0.20

Table B- 17: Akron - Urban No Transit

	2035 - Base	Scenario 3	Change	% change
Number of households	35,403.40	321596.69	286,193.33	808.38
Number of jobs	57,454.10	434568.03	377,113.90	656.37
Office jobs	12,616.10	115493.07	102,876.95	815.44
Retail jobs	8,616.30	58388.66	49,772.37	577.65
Industry jobs	25,800.20	177095.52	151,295.34	586.41
Other jobs	10,424.00	83592.4	73,168.37	701.92
Number of trips	1,452,899.47	1,529,299.96	76,400.49	5.26
VMT	9,184,356.28	9,564,165.53	379,809.25	4.14
Trip distance	6.32	6.25	-0.07	-1.07

Table B- 18: Akron - Urban with Transit				
	2035 - Base	**Scenario 3**	**Change**	**% change**
Number of households	147,146.30	150023.30	2,877.00	1.96
Number of jobs	181,697.40	197959.37	16,262.00	8.95
Office jobs	83,506.50	86586.51	3,080.00	3.69
Retail jobs	15,028.10	15471.07	443.00	2.95
Industry jobs	66,102.40	79681.35	13,579.00	20.54
Other jobs	17,057.20	16217.18	-840.00	-4.93
Number of trips	1,192,634.16	1,233,346.45	40,712.29	3.41
VMT	7,099,433.18	7,344,785.77	245,352.59	3.46
Trip distance	5.95	5.96	0.00	0.04

Table B- 19: Cincinnati - Urban No Transit				
	2035- Base	**Scenario 3**	**Change**	**% change**
Number of households	318,607.70	332026.74	13,419.00	4.21
Number of jobs	501,296.40	533994.42	32,698.00	6.52
Office jobs	130,528.80	136419.84	5,891.00	4.51
Retail jobs	70,704.60	69881.64	-823.00	-1.16
Industry jobs	174,062.50	197618.49	23,556.00	13.53
Other jobs	126,000.50	130074.45	4,074.00	3.23
Number of trips	1,618,602.90	1,670,806.31	52,203.41	3.23
VMT	11,941,818.10	12,268,158.10	326,340.00	2.73
Trip distance	7.38	7.34	-0.04	-0.48

Table B- 20: Cincinnati - Urban with Transit				
	2035- Base	Scenario 3	Change	% change
Number of households	222,706.90	258820.92	36,114.00	16.22
Number of jobs	384,905.40	407528.44	22,623.00	5.88
Office jobs	166,192.90	160301.86	-5,891.00	-3.55
Retail jobs	37,388.50	36705.48	-683.00	-1.83
Industry jobs	102,591.90	120907.91	18,316.00	17.85
Other jobs	78,732.20	89613.19	10,881.00	13.82
Number of trips	1,693,774.62	1,890,362.53	196,587.91	11.61
VMT	10,099,036.81	10,736,626.38	637,589.57	6.31
Trip distance	5.96	5.68	-0.28	-4.74

Table B- 21: Cleveland- Urban No Transit				
	2035	Scenario 3	Change	% change
Number of households	355,299.40	356,228.40	929.00	0.26
Number of jobs	377,696.70	388,312.70	10,616.00	2.811
Office jobs	83,911.00	83,919.00	8.00	0.010
Retail jobs	64,038.50	64,054.50	16.00	0.03
Industry jobs	145,656.20	150,765.20	5,109.00	3.51
Other jobs	84,091.10	89,574.10	5,483.00	6.52
Number of trips	1,750,181.72	1,752,504.26	2,322.54	0.13
VMT	12,254,085.14	12,272,353.69	18,268.55	0.15
Trip distance	7.00	7.00	0.00	0.02

Table B- 22: Cleveland - Urban with Transit				
	2035	**Scenario 3**	**Change**	**% change**
Number of households	472,680.30	490,773.30	18,093.00	3.83
Number of jobs	607,253.10	651,298.10	44,045.00	7.25
Office jobs	193,569.40	193,568.40	-1.00	-0.00
Retail jobs	67,958.90	68,062.90	104.00	0.15
Industry jobs	154,796.30	183,610.30	28,814.00	18.61
Other jobs	190,928.50	206,056.50	15,128.00	7.92
Number of trips	2,903,225.23	3,020,786.81	117,561.59	4.05
VMT	15,599,433.19	16,084,663.09	485,229.90	3.11
Trip distance	5.37	5.32	-0.05	-0.90

Table B- 23: Dayton - Nonmetropolitan				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	35,005.10	35033.12	28.00	0.08
Number of jobs	30,598.60	30755.57	157.00	0.51
Office jobs	7,013.30	7098.31	85.00	1.21
Retail jobs	5,160.10	5158.14	-2.00	-0.04
Industry jobs	10,619.70	10692.72	73.00	0.69
Other jobs	198,305.04	198,648.20	343.17	0.17
Number of trips	1,501,274.12	1,505,876.89	4,602.77	0.31
VMT	7.57	7.58	0.01	0.13
Trip distance	7.817	7.813	-0.004	-0.055

Table B- 24: Dayton - Urban No Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	162,312.50	177163.52	14,851.00	9.15
Number of jobs	152,642.40	161064.4	8,422.00	5.52
Office jobs	43,973.10	45201.09	1,228.00	2.80
Retail jobs	33,944.90	34318.85	374.00	1.10
Industry jobs	47,246.20	50163.15	2,917.00	6.17
Other jobs	27,478.30	31381.31	3,903.00	14.20
Number of trips	634,549.33	668,544.65	33,995.33	5.36
VMT	4,313,816.52	4,523,787.67	209,971.15	4.87
Trip distance	6.80	6.77	-0.03	-0.47

Table B- 25: Dayton - Urban with Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	170,075.00	190447.00	20,372.00	11.98
Number of jobs	206,265.30	223466.27	17,201.00	8.34
Office jobs	74,255.70	74812.65	557.00	0.75
Retail jobs	28,207.60	27834.55	-373.00	-1.32
Industry jobs	69,906.30	80784.27	10,878.00	15.56
Other jobs	33,895.80	40034.80	6,139.00	18.11
Number of trips	1,248,853.12	1,382,996.80	134,143.69	10.74
VMT	6,952,750.95	7,535,154.42	582,403.46	8.38
Trip distance	5.57	5.45	-0.12	-2.14

Table B- 26: Mid-Ohio - Urban No Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	561,905.00	577180.00	15,275.00	2.72
Number of jobs	567,644.00	567369.00	-275.00	-0.05
Office jobs	204,870.00	204919.00	49.00	0.02
Retail jobs	139,519.00	139580.00	61.00	0.04
Industry jobs	121,025.00	121041.00	16.00	0.01
Other jobs	88,593.00	87515.00	-1,078.00	-1.22
Number of trips	2,283,327.87	2,335,365.33	52,037.46	2.28
VMT	18,462,854.73	17,824,300.37	-638,554.36	-3.46
Trip distance	8.09	7.63	-0.45	-5.61

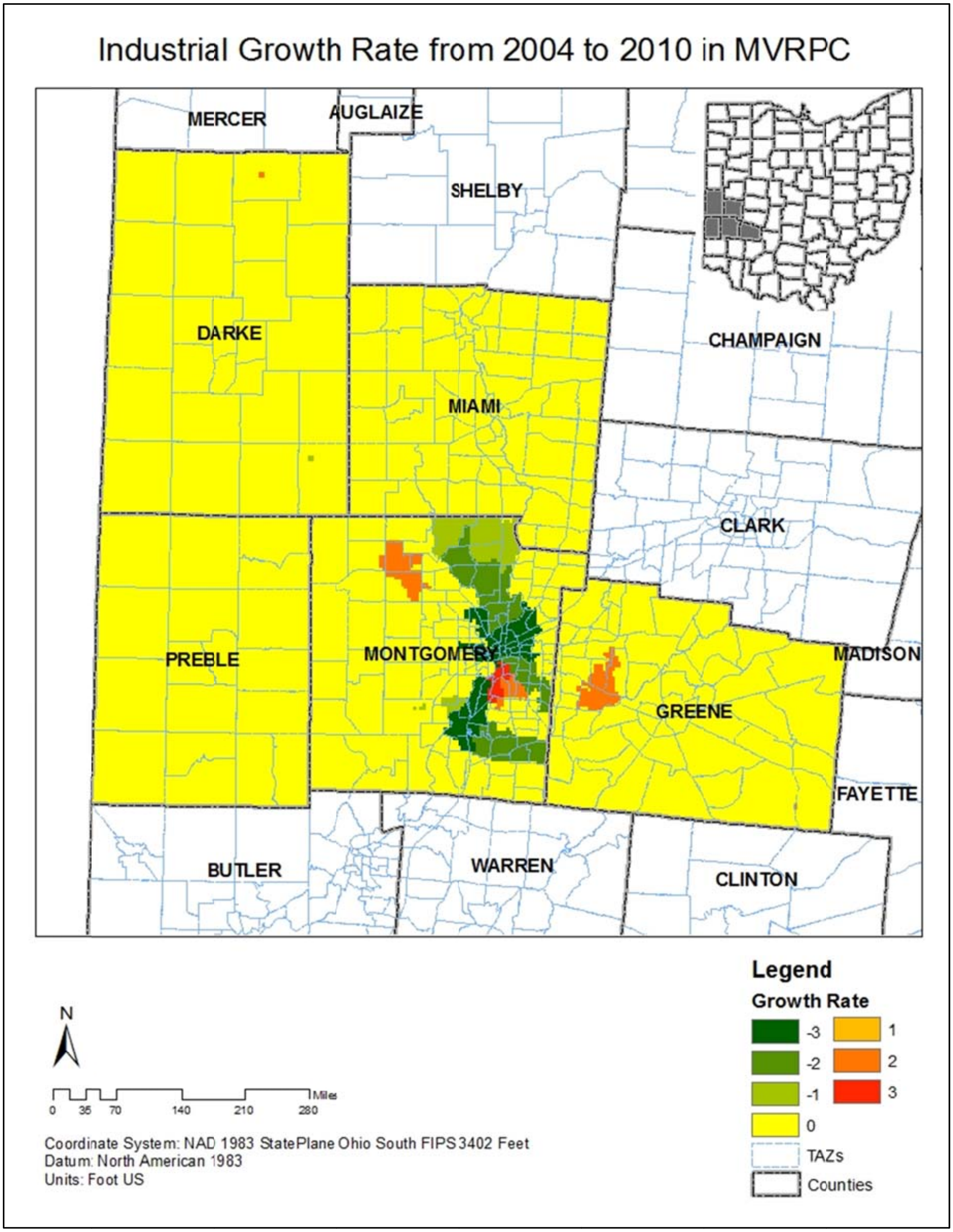
Table B- 27: Mid-Ohio - Urban with Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	336,488.00	356444.00	19,956.00	5.93
Number of jobs	551,266.00	551083.00	-183.00	-0.03
Office jobs	246,064.00	245637.00	-427.00	-0.17
Retail jobs	117,790.00	117522.00	-268.00	-0.23
Industry jobs	84,896.00	84398.00	-498.00	-0.59
Other jobs	95,704.00	96811.00	1,107.00	1.16
Number of trips	3,167,273.15	3,292,126.95	124,853.80	3.94
VMT	19,173,314.19	17,865,568.75	-1,307,745.44	-6.82
Trip distance	6.05	5.43	-0.63	-10.35

Table B- 28: Toledo - Nonmetropolitan				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	66,540.50	67918.54	1,378.00	2.07
Number of jobs	75,992.60	75623.55	-369.00	-0.49
Office jobs	17,727.10	17922.12	195.00	1.10
Retail jobs	11,926.90	11917.92	-9.00	-0.08
Industry jobs	31,719.70	31736.70	17.00	0.05
Other jobs	14,618.80	14046.81	-572.00	-3.91
Number of trips	405,765.48	408,965.49	3,200.01	0.79
VMT	2,866,682.61	2,884,784.35	18,101.74	0.63
Trip distance	7.06	7.05	-0.01	-0.16

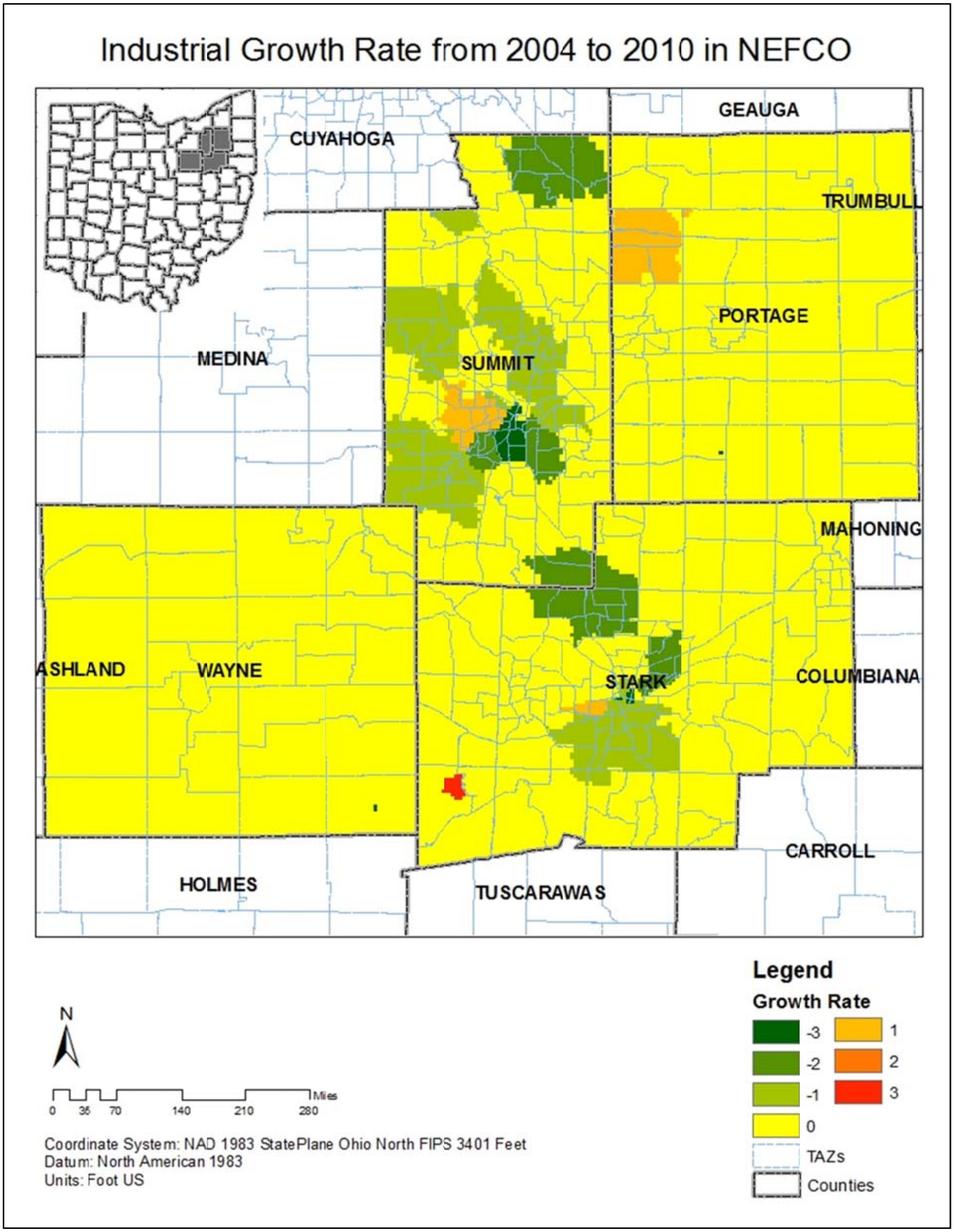
Table B- 29: Toledo - Urban No Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	72,220.30	81655.25	9,435.00	13.064
Number of jobs	84,823.50	104522.49	19,699.00	23.224
Office jobs	15,390.90	16141.90	751.00	4.880
Retail jobs	19,246.60	19436.64	190.00	0.987
Industry jobs	25,682.60	41971.56	16,289.00	63.424
Other jobs	24,503.40	26972.39	2,469.00	10.076
Number of trips	349,381.08	398,407.29	49,026.21	14.03
VMT	2,230,286.65	2,559,305.49	329,018.84	14.75
Trip distance	6.38	6.42	0.04	0.63

Table B- 30: Toledo - Urban with Transit				
	2035 Base	**Scenario 3**	**Change**	**% change**
Number of households	138,347.90	163151.89	24,804.00	17.93
Number of jobs	140,172.70	177797.65	37,625.00	26.84
Office jobs	61,067.80	60261.80	-806.00	-1.32
Retail jobs	22,167.60	22000.64	-167.00	-0.75
Industry jobs	42,800.80	77458.75	34,658.00	80.98
Other jobs	37,761.80	41701.82	3,940.00	10.43
Number of trips	861,044.80	1,008,986.09	147,941.29	17.18
VMT	4,114,829.06	4,696,825.75	581,996.69	14.14
Trip distance	4.78	4.65	-0.12	-2.59

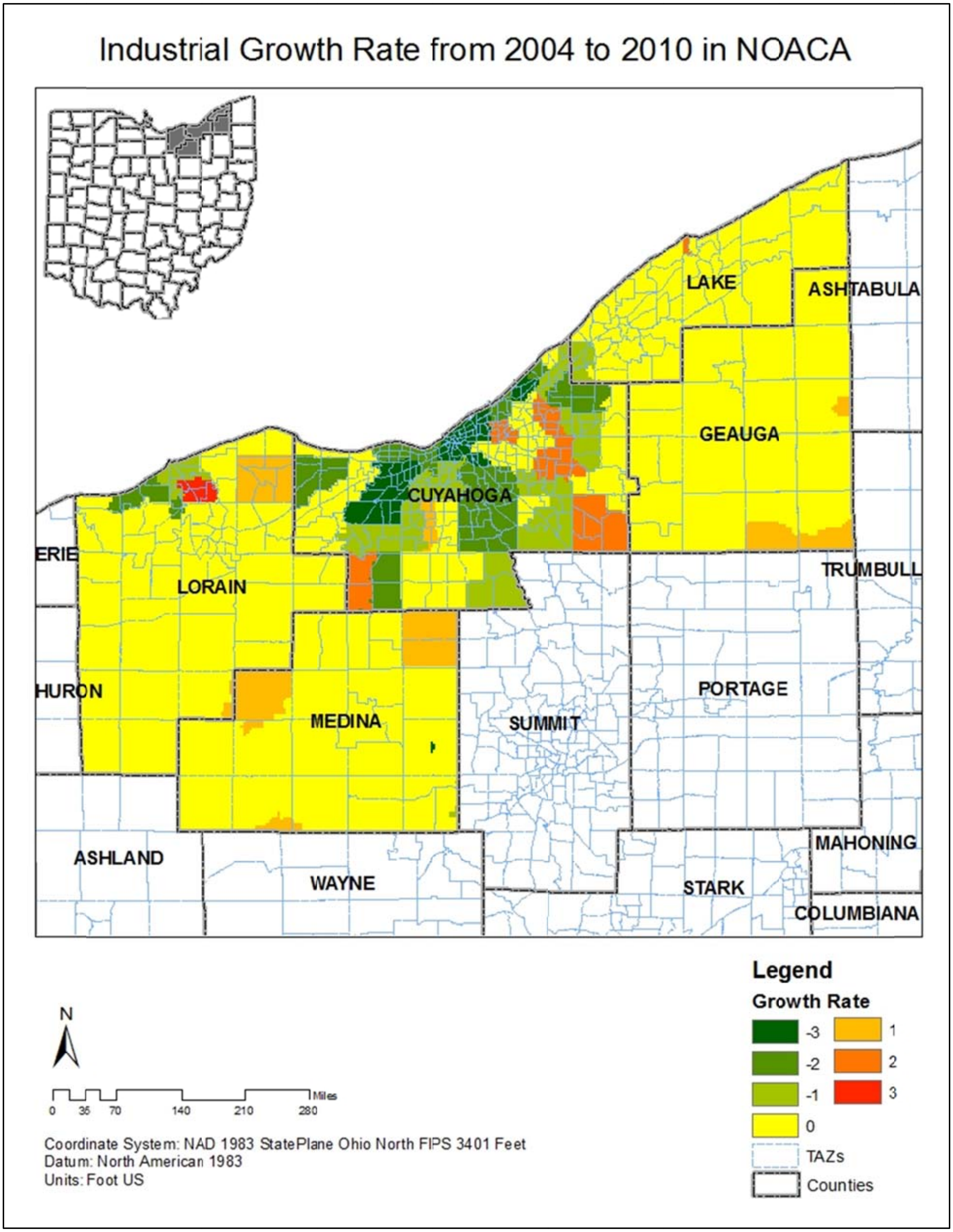
APPENDIX C



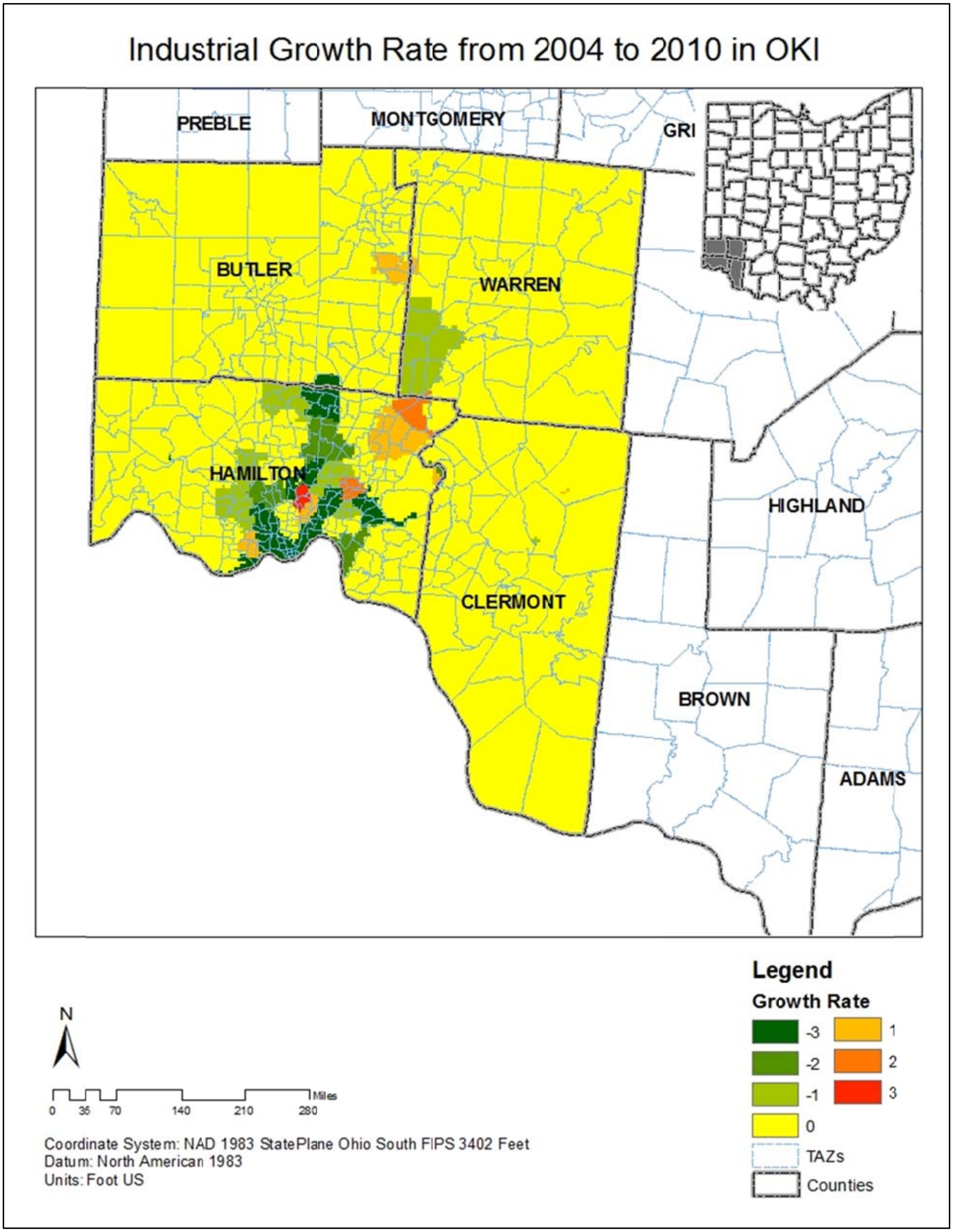
Map C- 1: Industrial Growth Rate MVRPC Region



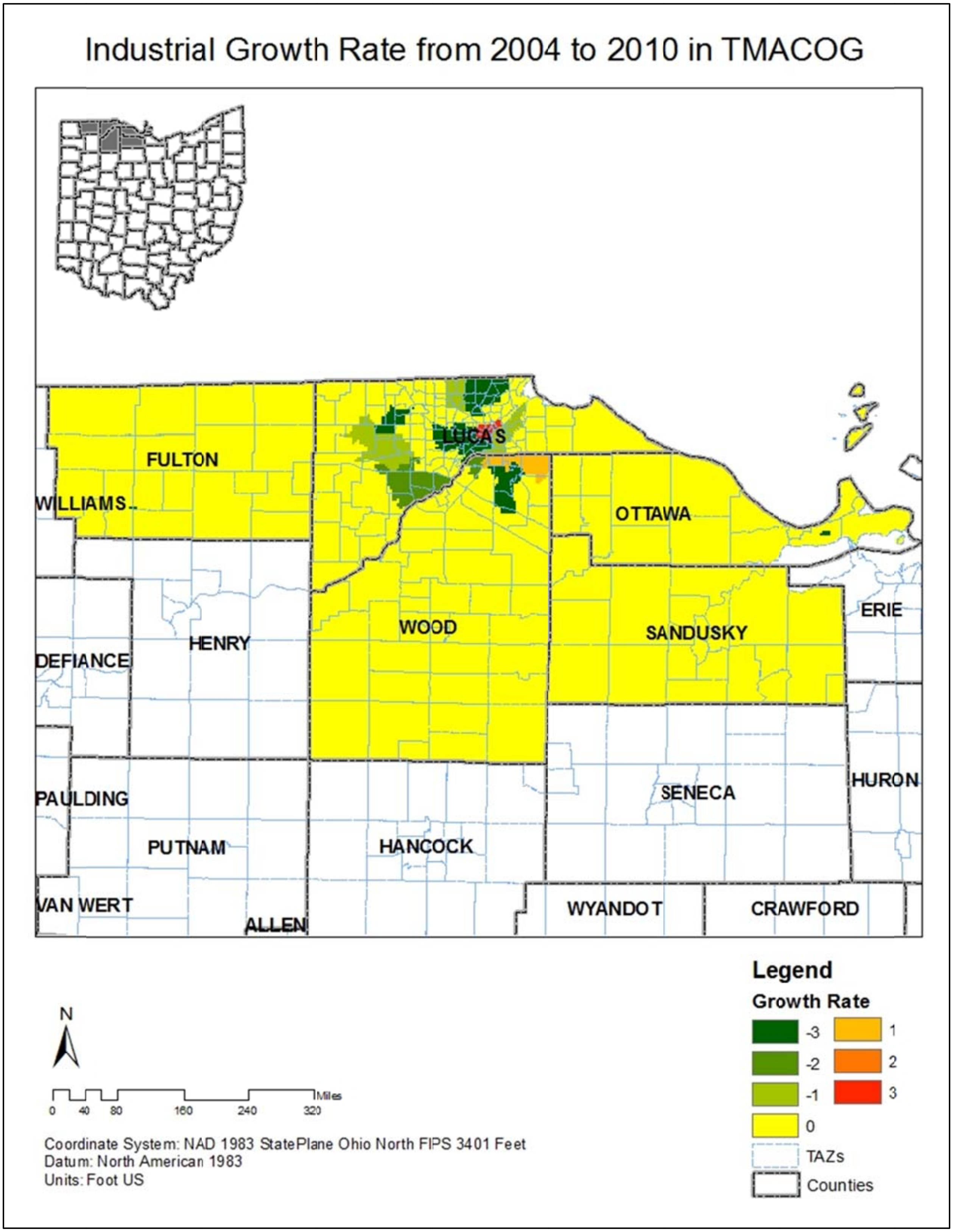
Map C- 2: Industrial Growth Rate NEFCO Region



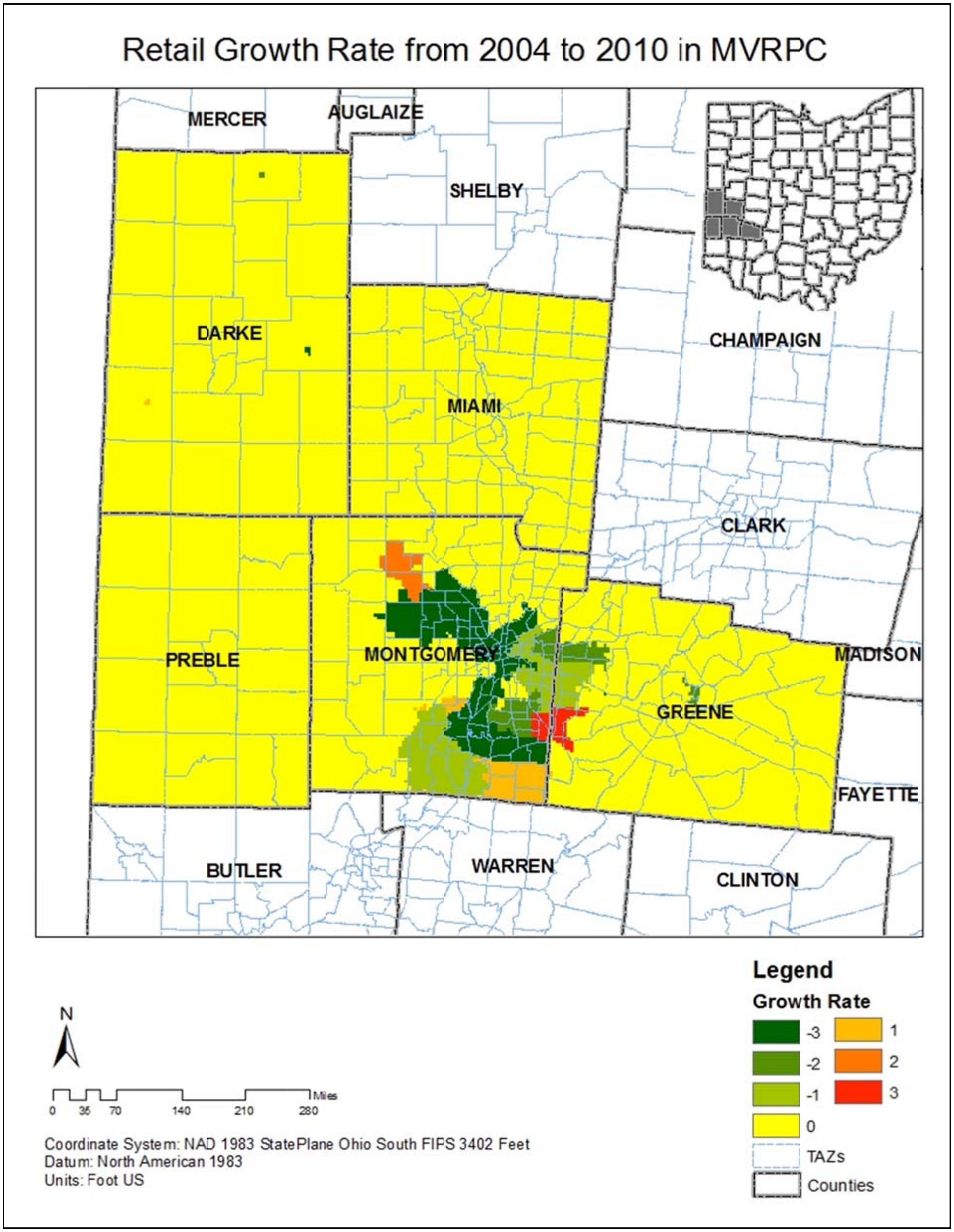
Map C- 3: Industrial Growth Rate NOACA Region



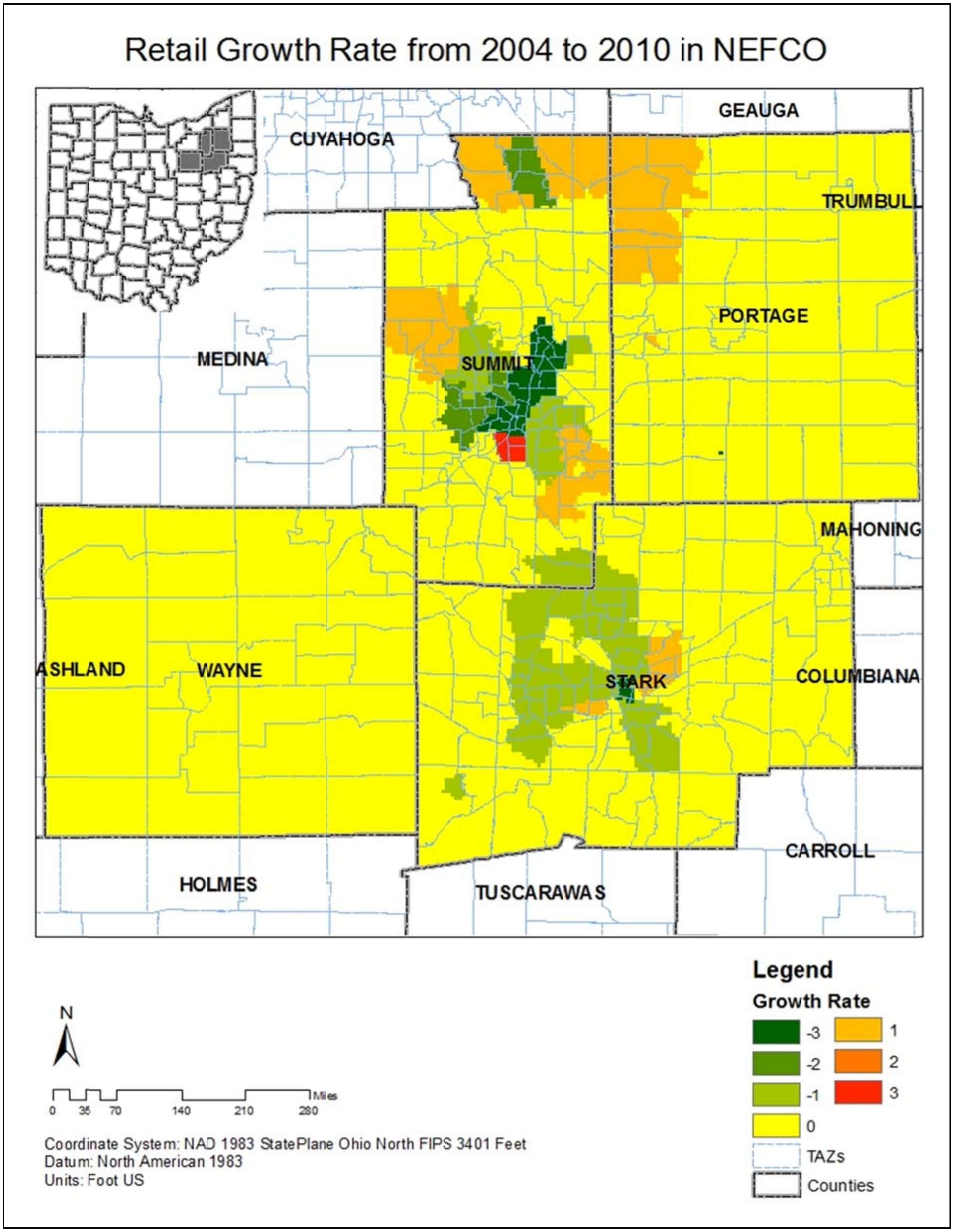
Map C- 4: Industrial Growth Rate OKI Region



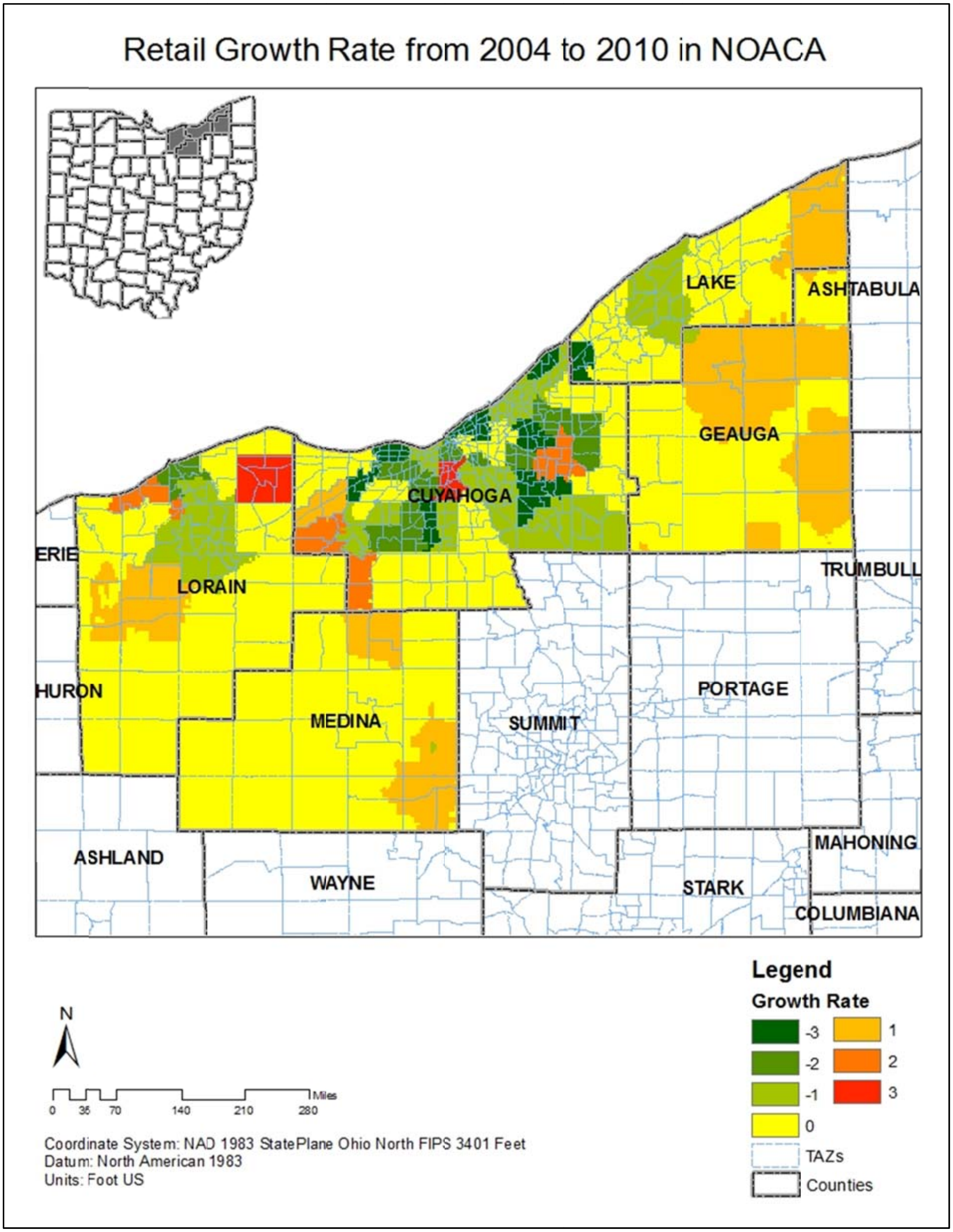
Map C- 5: Industrial Growth Rate TMACOG Region



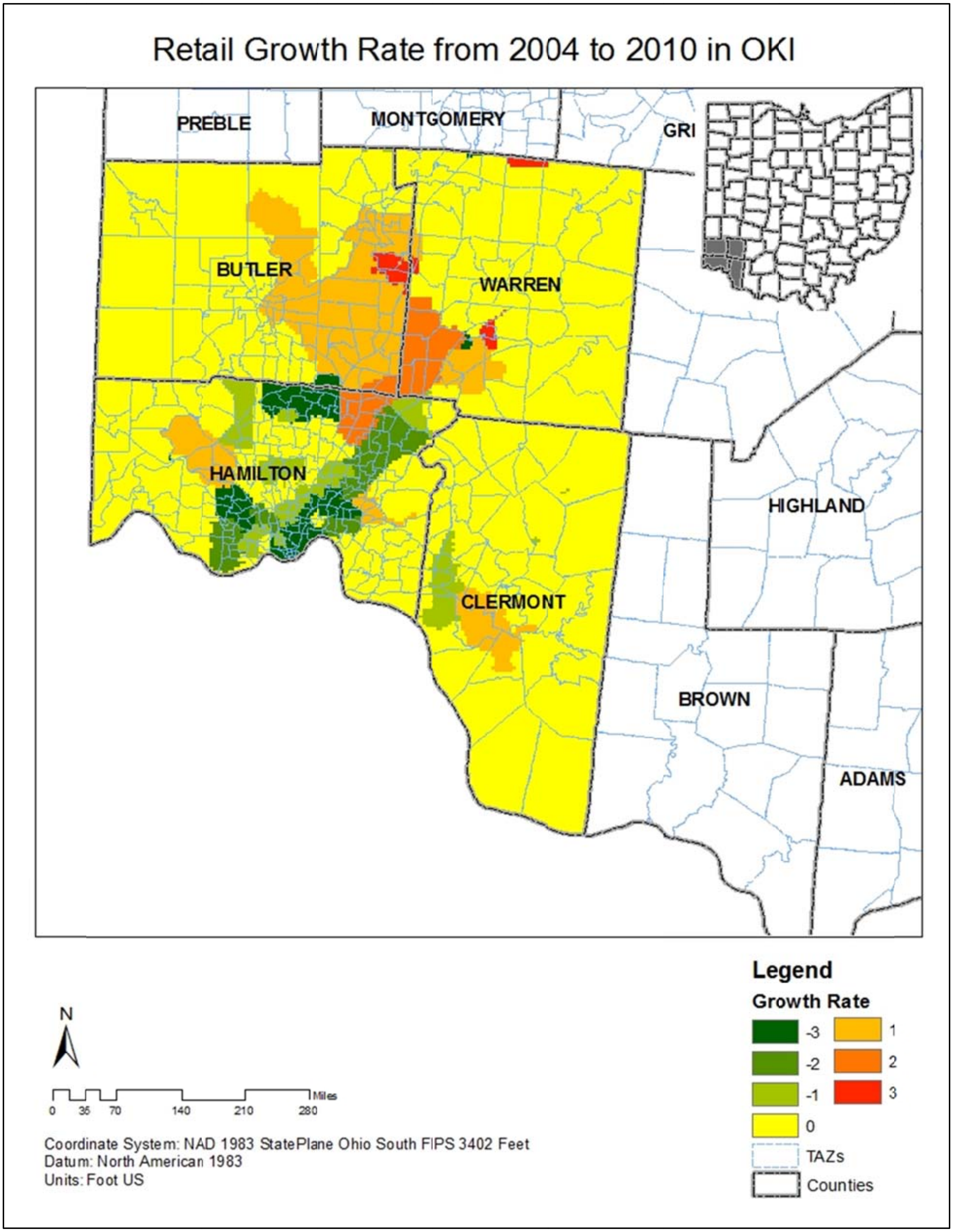
Map C- 6: Retail Growth Rate MVRPC Region



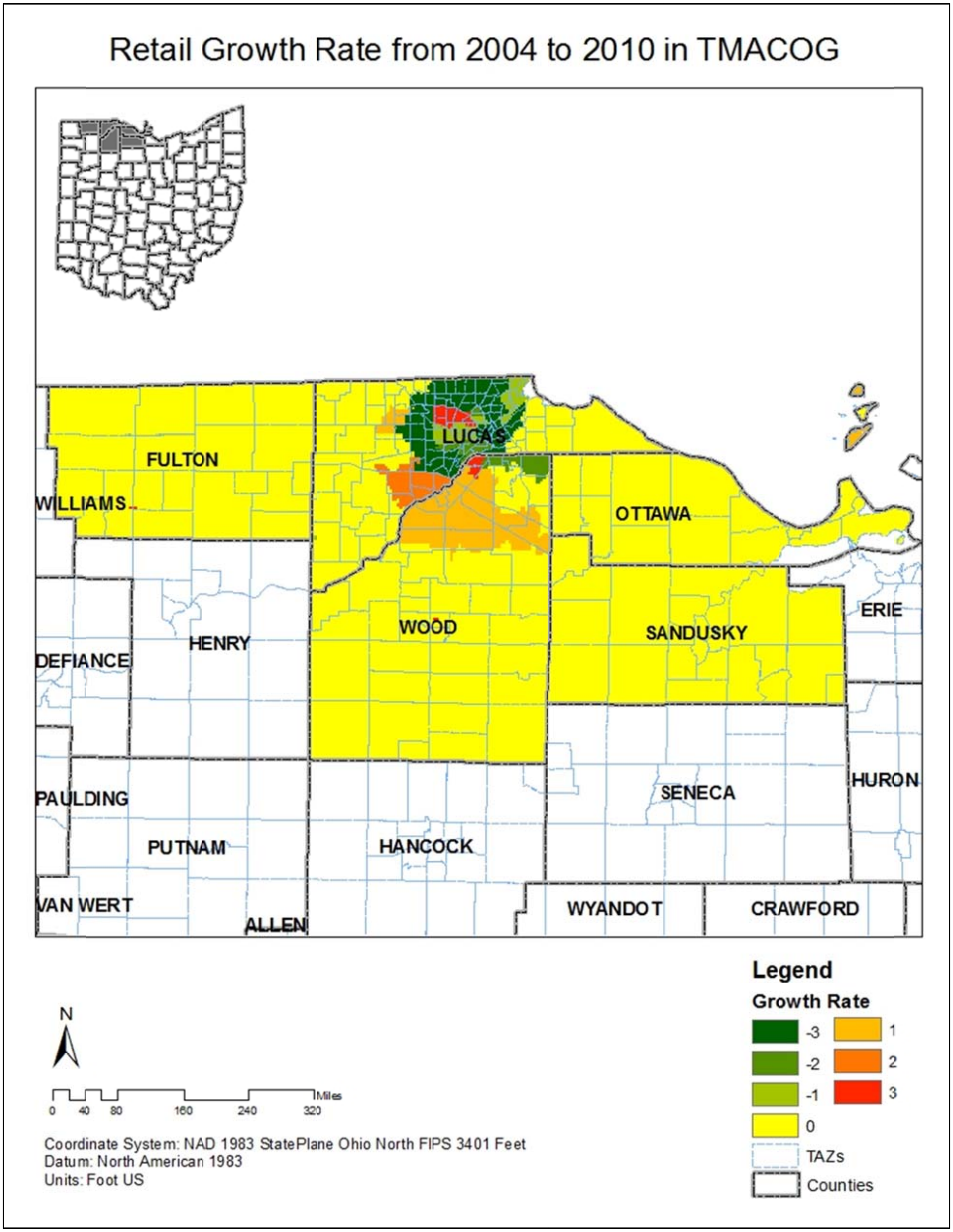
Map C- 7: Retail Growth Rate NEFCO Region



Map C- 8: Retail Growth Rate NOACA Region



Map C- 9: Retail Growth Rate OKI Region



Map C- 10: Retail Growth Rate TMACOG Region

APPENDIX D

Appendix D includes the datasets created and used in this study and is provided as a DVD.