Central Indiana Suburban Transportation and Mobility Study

Transportation and Land Use Assessment

draft

report

prepared for

Indiana Department of Transportation

prepared by

Cambridge Systematics, Inc.

with

IUPUI Center for Urban Policy and the Environment

and

HNTB Corporation

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Parsons Brinckerhoff Quade & Douglas, Inc.

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1.0 Introduction

1.0 Introduction

This document describes potential transportation and land use outcomes associated with two network alternatives that represent a range of highway improvements intended to address long-range suburban mobility needs in Central Indiana. The results of an analysis that combines travel demand forecasting with land use modeling to assess interactions between transportation system changes and real estate development patterns are presented in six main sections.

- Section 1.0 provides an overview of the study, some background on regional growth trends, a description of the transportation alternatives under study, and a summary of the transportation-land use analysis approach.
- Section 2.0 documents the existing demographic conditions in the study area and presents assumptions about future growth.
- Section 3.0 describes the development of the travel demand model and presents the forecast transportation impacts of the alternatives on travel patterns, highway traffic volumes, and congestion.
- Section 4.0 describes the development of the land use model and presents the forecast patterns of urban growth under each alternative.
- Section 5.0 presents the results of a sensitivity analysis that evaluates the effects of various alternative assumptions about growth patterns, timeframe of impacts, and development patterns on the findings.
- Section 6.0 presents overall conclusions from the analysis of alternatives.

This document summarizes the results of Tasks 2 and 4 in the scope of work for the Central Indiana Suburban Transportation and Mobility Study, referred to as “CISTMS” and pronounced “systems.”

■ 1.1 Purpose of Study

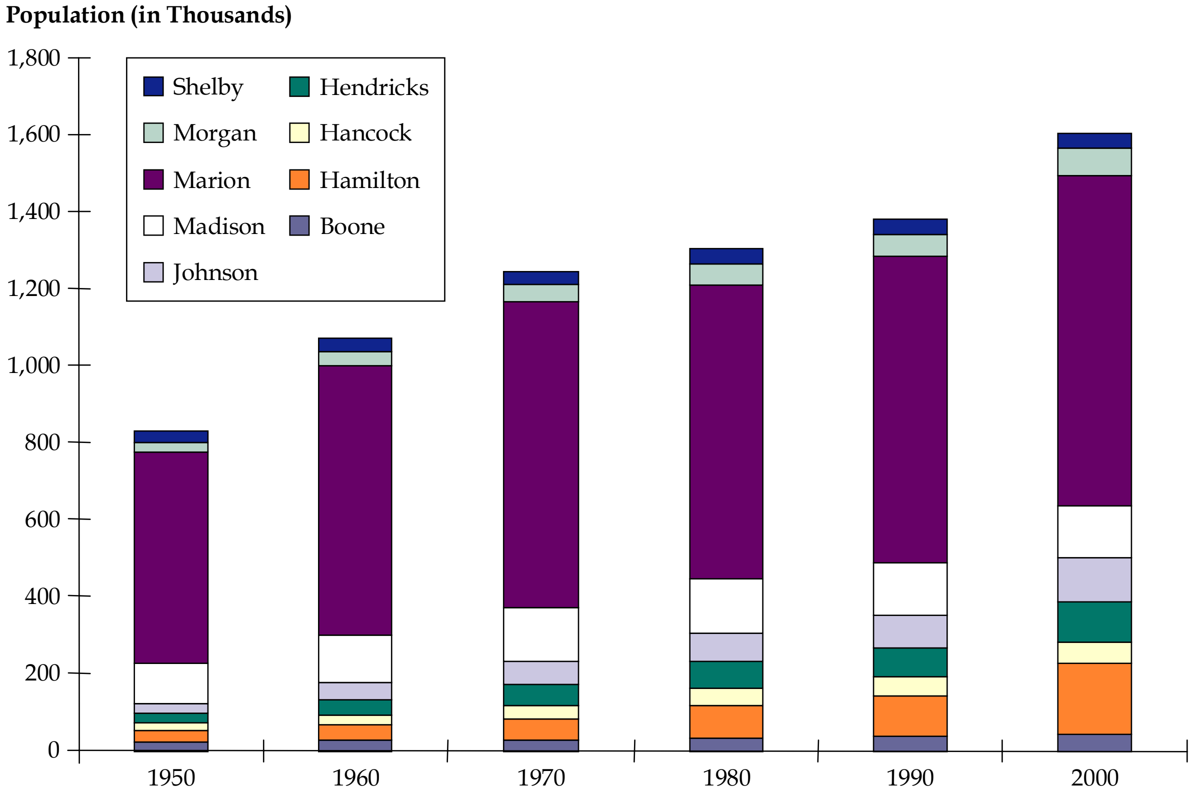
The Indiana Department of Transportation (INDOT) has retained the consulting team of HNTB Corporation, Cambridge Systematics, and Parsons Brinckerhoff to conduct CISTMS. The main purpose of the study is to identify key issues and problems pertaining to suburb-to-suburb mobility in the nine-county Central Indiana region and to determine how those can best be addressed from a transportation planning perspective. The study area includes Marion County and its surrounding counties: Boone, Hamilton, Madison, Hancock, Shelby, Johnson, Morgan, and Hendricks.

The focus is primarily on the area outside I-465 and includes the following state route corridors: SR 32/38 on the north, SR 9 on the east, SR 44/144 on the south, and SR 267/39 on the west. Parallel routes (such as 146th Street in Hamilton County, the proposed North-South Corridor in Hendricks County, and the proposed East-West Corridor in Johnson County) will also be examined as appropriate. The study will provide an analysis of the transportation needs for the suburban areas and a series of recommendations on how to improve the overall transportation system in Central Indiana.

■ 1.2 Historical Population and Employment Growth

This section describes how the nine counties of the study area have grown since 1950 and presents population and employment forecasts through the study planning horizon of 2025. Between 1950 and the present, Central Indiana has experienced continuous population growth at both county and regional levels, as shown in Figure 1.1.

Figure 1.1 Population Growth in Central Indiana by County
1950 – 2000



Source: U.S. Census.

Table 1.1 summarizes the growth in population and households in Central Indiana between 1990 and 2000. Though Marion County remains the most populous county in the region, between 1990 and 2000 it experienced only an eight percent growth while Hamilton and Hendricks Counties experienced 68 percent and 38 percent increases, respectively (Table 1.1). That is, while the region's population continues to grow, the most aggressive recent growth has occurred in the counties surrounding Indianapolis. Another regional trend is the decline in average household size, reflected in the number of persons per household. Both statistics follow broader national trends in decentralization and family size.

Table 1.1 Population Growth in Central Indiana by County
1990-2000

	1990		2000		Percent Change	
County	**Population**	**Households**	**Population**	**Households**	**Population**	**Households**
Boone	38,304	13,986	46,425	17,210	21%	23%
Hamilton	110,348	39,018	185,459	66,991	68	72
Hancock	45,686	16,022	55,664	20,856	22	30
Hendricks	76,107	26,233	105,400	37,792	38	44
Johnson	88,615	31,489	116,041	42,794	31	36
Madison	130,922	50,038	133,336	53,142	2	6
Marion	800,138	321,310	860,209	352,377	8	10
Morgan	56,215	19,677	66,953	24,571	19	25
Shelby	40,383	14,820	43,581	16,635	8	12
Region Total	**1,386,718**	**532,593**	**1,613,068**	**632,368**	**16%**	**19%**
Average Household Size		2.60		2.55		

Source: Woods and Poole (2003).[1]

As with population, Central Indiana has experienced enduring employment growth at both the county and regional levels since 1950. This trend is illustrated in Figure 1.2.

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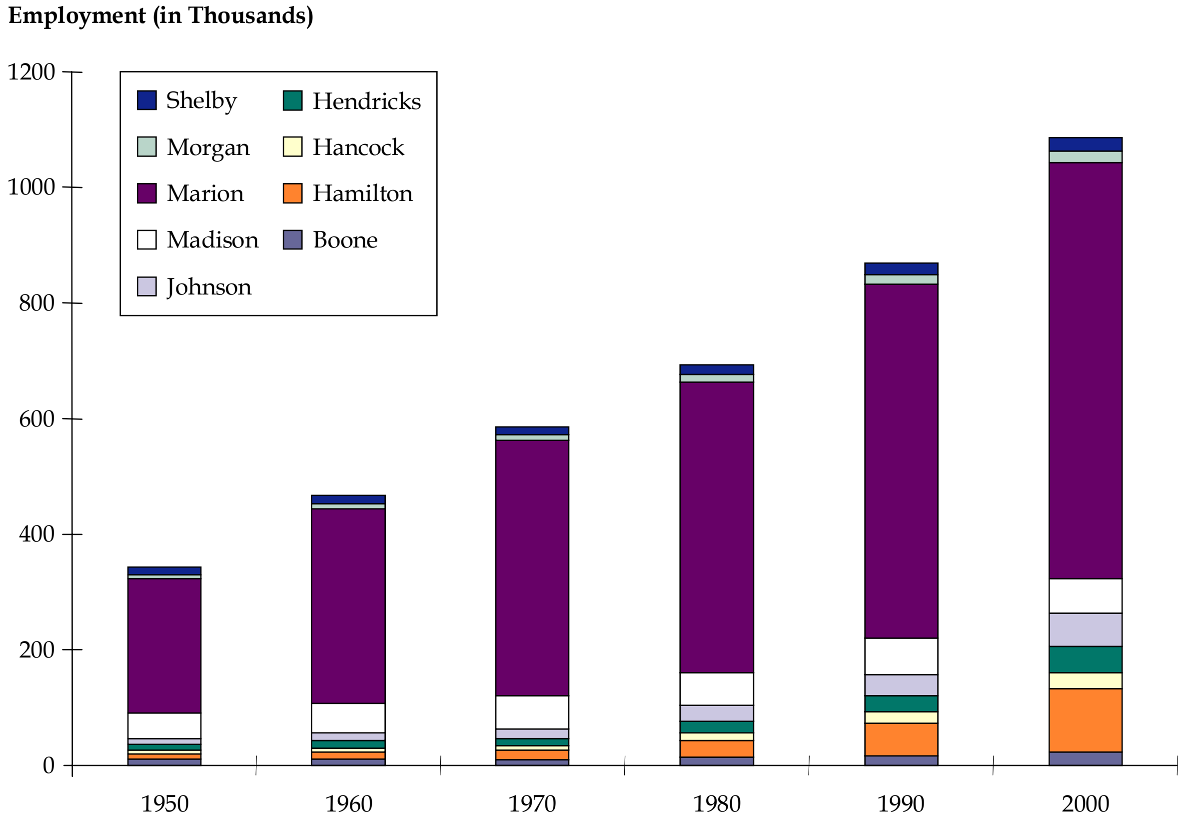
[1] Because of minor discrepancies between forecasts prepared by the Indianapolis Metropolitan Planning Organization (MPO), INDOT, and national county-level forecasts prepared by Woods and Poole, county and subcounty population, household, and employment statistics are presented as MPO county forecasts adjusted to meet the regional total established by Woods and Poole. The national forecasts were considered to provide the most consistent basis for future-year forecasts. 1990 and 2000 values are adjusted to match county totals published by Woods and Poole. 2025 values are adjusted by a uniform regional scale factor that preserves the MPO's subregional allocation while matching the regional total forecast by Woods and Poole. These values serve as inputs to the transportation and land use modeling processes described in this report.

Figure 1.2 County-Level Employment for Central Indiana Region



Note: 1960 data was interpolated.
Source: U.S. Census.

Table 1.2 shows total employment by county in 1990 and 2000. On the whole, the region's growth in employment has been more rapid than its population growth. Similar to population growth trends, recent employment growth has been more aggressive in the counties surrounding Marion than in Marion County itself. The only exception has been Madison County, where employment has declined slightly.

1.2.1 Population Forecast

CISTMS involves the assessment of regional mobility needs for the more than 20-year period between now and 2025. One of the major factors driving mobility needs will be increasing population. Table 1.3 presents forecasts of population and number of households for each county in 2025.

Table 1.2 Employment Growth in Central Indiana by County
1990-2000

	1990	2000	Percent Change
Boone	17,114	23,510	37%
Hamilton	57,748	107,100	85
Hancock	17,463	24,141	38
Hendricks	27,888	45,947	65
Johnson	38,039	55,428	46
Madison	60,817	60,020	-1
Marion	612,994	724,743	18
Morgan	18,249	21,037	15
Shelby	19,506	22,981	18
Region Total	**869,818**	**1,084,907**	**25%**

Source: Woods and Poole (2003).

Table 1.3 Population and Household Forecasts by County
2000-2025

	2000		2025		Percent Change	
County	**Population**	**Households**	**Population**	**Households**	**Population**	**Households**
Boone	46,425	17,210	67,851	25,808	46%	50%
Hamilton	185,459	66,991	354,102	126,736	91	89
Hancock	55,664	20,856	86,285	32,060	55	54
Hendricks	105,400	37,792	165,385	64,275	57	70
Johnson	116,041	42,794	180,652	68,646	56	60
Madison	133,336	53,142	141,266	58,477	6	10
Marion	860,209	352,377	1,003,833	413,737	17	17
Morgan	66,953	24,571	93,072	34,212	39	39
Shelby	43,581	16,635	53,614	21,105	23	27
Region Total	**1,613,068**	**632,368**	**2,146,061**	**845,055**	**33%**	**34%**
Average Household Size		2.55		2.54		

Source: 2000 values from Woods and Poole (2003). 2025 values from Indianapolis MPO, adjusted to Woods and Poole regional control totals.

Total growth in the nine-county Indianapolis region is projected to be more than 530,000 people, or 33 percent in comparison to the 2000 population of 1.6 million. Continuing the trend through the 1990s, the fastest growth is expected to occur in on the periphery of the region. Hamilton County is expected to nearly double in population by 2025, absorbing approximately 32 percent of total regional population growth. Boone, Johnson, Hancock, Hendricks, and Morgan Counties are projected to experience moderate growth. Madison County is projected to experience a slight increase in population. The population forecast assumes a continued decline in average household size through 2025. The Indianapolis MPO forecasts assume an even greater decline (to 2.44 persons per household) than shown in the table.

Table 1.4 presents this growth at a township level of detail. The individual townships with the highest amounts of projected growth are listed. This forecast was prepared by the Indianapolis MPO through a semi-automated process based on historic population growth trends from 1970 through 2000, availability of land for development, and other local factors. It also incorporates input from local jurisdictions.

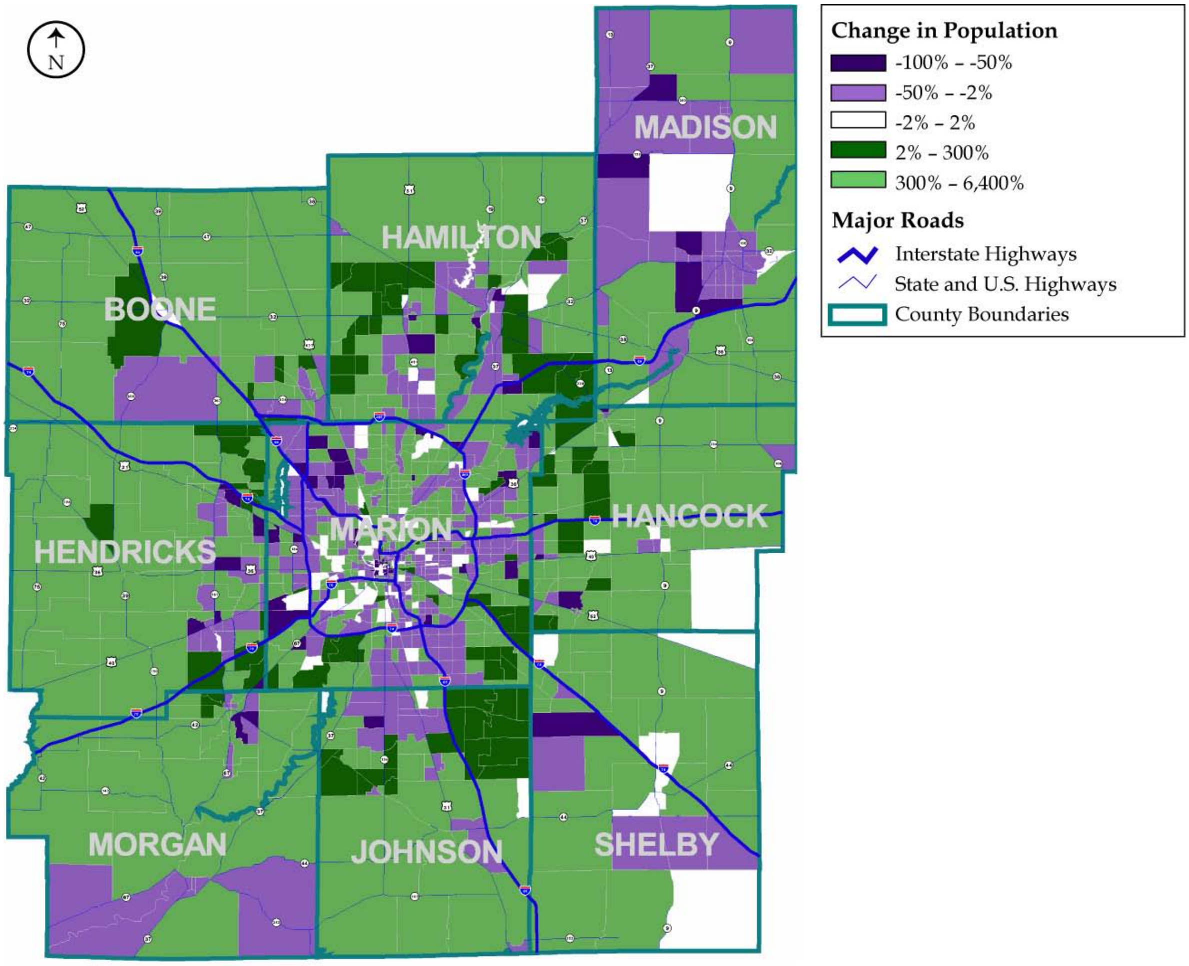
Table 1.4 Townships with High Forecast Population Growth
2000-2025

Forecast Population Growth	Townships
More than 30,000	Hamilton County: Clay, Fall Creek
20,000 to 30,000	Hamilton County: Delaware, Noblesville Hendricks County: Washington Johnson County: White River
10,000 to 20,000	Hamilton County: Washington Hendricks County: Guilford, Lincoln Johnson County: Pleasant Marion County: Franklin

Source: Indianapolis MPO.

Figure 1.3 shows the forecasted change in population between 2000 and 2025 at a finer level of geographic detail than the counties or townships summarized above. The Indianapolis MPO maintains a regional travel demand model that divides the region into 1,285 zones. The model includes disaggregated demographic data for each of these traffic analysis zones (TAZs). The TAZ-level changes generally suggest that the most rapid population growth is projected to occur in the parts of the surrounding counties that are closest to Indianapolis.

Figure 1.3 Forecast Change in Population by Traffic Analysis Zone
2000-2025



Source: Indianapolis MPO.

1.2.2 Employment Forecast

Employment growth is projected to continue the trend of the 1990s and exceed population growth. More than 425,000 new jobs are expected to be created in the nine-county Indianapolis region between now and 2025. This represents a 39 percent increase, in comparison to 2000 employment of approximately 1.1 million. As shown in Table 1.5, the fastest growth is projected in Hancock County, which is expected to absorb approximately 21,000 new jobs. Other fast growing counties include Hendricks, Johnson, Morgan, and Shelby counties, each increasing total jobs by approximately one-half by 2025. Marion County is expected to add 268,000 jobs, or more than one-half of the projected regional increase.

Table 1.5 Employment Forecasts by County
2000-2025

County	2000 Employment	2025 Employment	Percent Change
Boone	23,510	31,645	35%
Hamilton	107,100	145,674	36
Hancock	24,141	45,071	87
Hendricks	45,947	71,140	55
Johnson	55,428	83,524	51
Madison	60,020	75,046	25
Marion	724,743	992,442	37
Morgan	21,037	31,061	48
Shelby	22,981	34,744	51
Region Total	**1,084,907**	**1,510,347**	**39%**

Source: 2000 values from Woods and Poole (2003). 2025 values from Indianapolis MPO, adjusted to Woods and Poole regional control totals.

Table 1.6 lists the townships that are projected by the Indianapolis MPO to experience the greatest change in the total number of jobs.

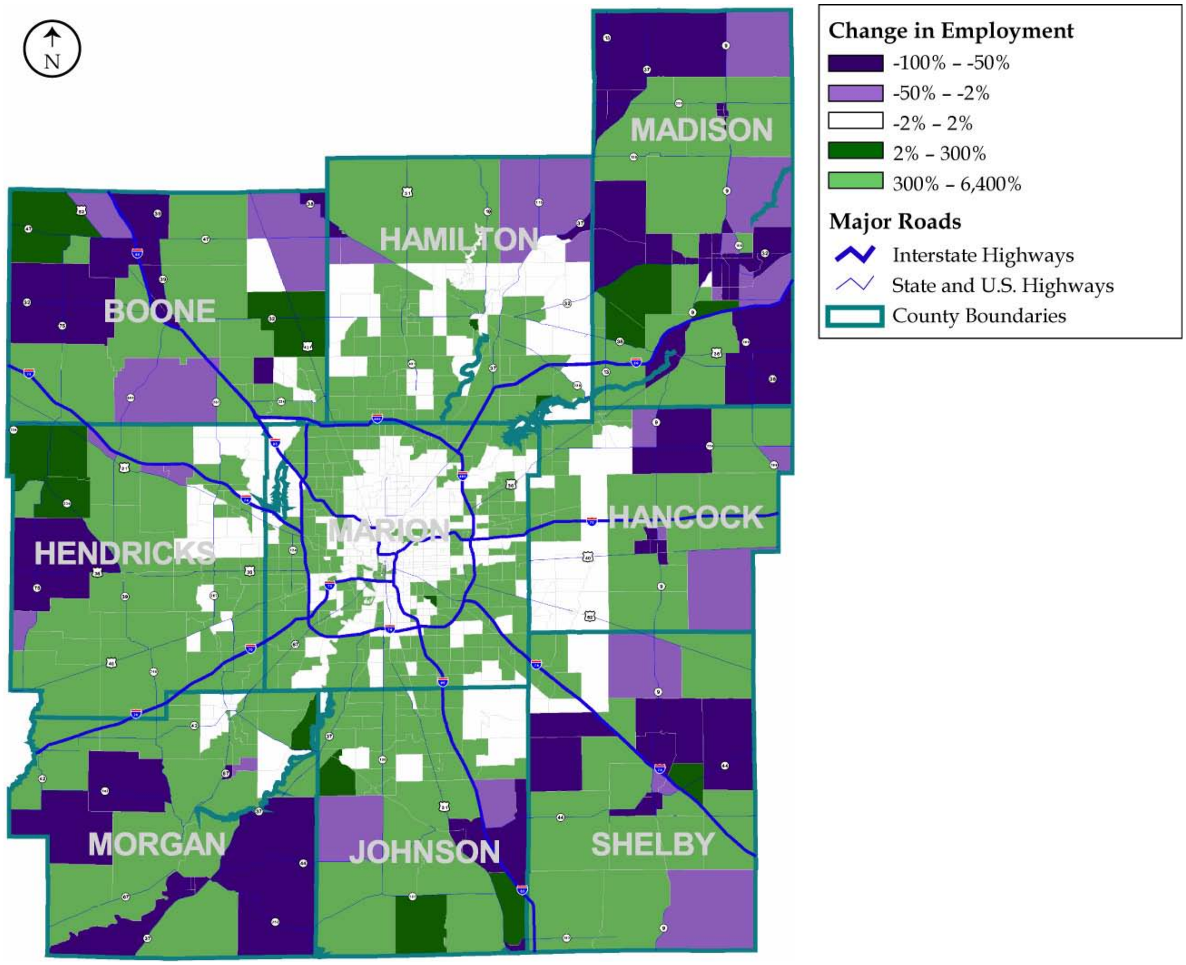
Table 1.6 Townships with High Forecast Employment Growth
2000-2025

Forecast Employment Growth	Townships
More than 20,000	Hamilton County: Clay
10,000 to 20,000	Hendricks County: Guilford
5,000 to 10,000	Boone County: Center Hamilton County: Noblesville Hancock County: Center Hendricks County: Lincoln, Center Johnson County: Pleasant Marion County: Franklin Shelby County: Addison

Source: Indianapolis MPO.

Figure 1.4 shows the forecast change in employment between 2000 and 2025 using data from the regional travel demand model. This forecast is based on county-level employment forecasts, with each township in a county experiencing the same percentage growth rate. Generally, the MPO forecast places the areas of most rapid employment growth on the periphery of the study area.

Figure 1.4 Forecast Change in Employment by Traffic Analysis Zone, *2000-2025*

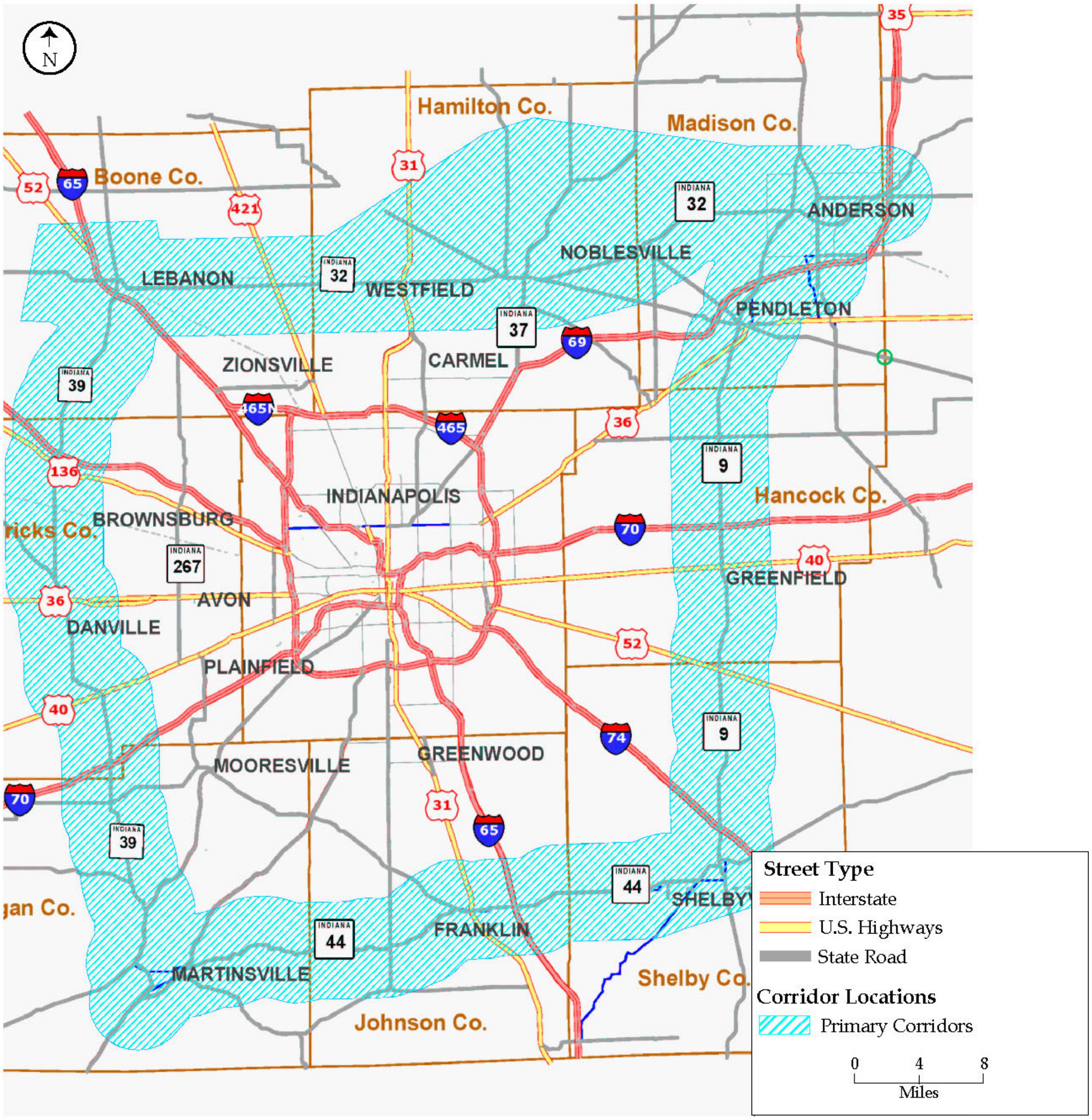


Source: Indianapolis MPO.

1.3 Description of Alternatives

Significant growth has occurred and will continue to occur in the outlying areas of Central Indiana surrounding Marion County, which suggests an increasing demand for travel between suburban areas. To address this need, this study explores potential transportation improvements, primarily along state route corridors outside of I-465, including SR 32/38 on the north, SR 9 on the east, SR 44/144 on the south, and SR 267/39 on the west. The general area of potential improvements is shown in Figure 1.5.

Figure 1.5 CISTMS Study Area



The study will evaluate a broad range of options for meeting existing and future transportation needs in the study area. This report describes the results of an analysis of two alternatives that represent extremes along the range of potential solutions. These "bookend" alternatives include:

- **Minimum Change Alternative.** This alternative includes minor improvements to the existing facilities listed above or parallel facilities to improve safety and traffic operations. Changes could include improving intersections, adding turning lanes, enhancing roadside safety features, and removing on-street parking. Because this alternative includes only relatively small projects, many of which are already listed in local transportation improvement programs, this alternative is considered to be equivalent to a No-Build Alternative for the purposes of this analysis.

- **Maximum Change Alternative.** This alternative entails the development of limited access roadways (including freeways) on new alignment or in combination with portions of existing roadways. As the most extensive improvement option being evaluated, this alternative consists of a new freeway "outer-loop" similar to I-465, but located five to 15 miles outside of I-465, depending on conditions in each corridor area.

Within this range of alternatives, the type of improvement alternative proposed for each of the four corridor areas (north, south, east, and west) could be different. For example, a new terrain freeway could be located parallel to SR 9, while other corridors receive only minor improvements to existing facilities. By focusing on the bookends alternatives, it may be possible to estimate the impacts of some intermediate improvement alternatives through interpolation or other comparative techniques.

1.4 Peer Cities Analysis

Recognizing the potential relationship between roadway construction and urban development patterns, one task of this study was the examination of other cities' experiences with the development of "outer belts" (freeways or limited access roadways) that were built outside an initial freeway "ring" surrounding an urban area. A summary report was prepared to address the experience of other communities with outer belts and to review related topics associated with urban bypasses. The evaluation included a literature review of research intended to address the experience of a large number of metropolitan areas, and a more detailed review of the direct experience of four "peer" cities.

The conclusions of the Peer City Report are as follows:

1. The national trend of urban growth and economic expansion, combined with a trend favoring decentralized development, has prompted a concern for urban sprawl that is found virtually nationwide. These trends were noted in all of the cities surveyed.

   In areas where growth is occurring, the research findings were inconclusive regarding whether the presence of a beltway contributed to the overall expansion of the area and urban sprawl. Rather, land use planning was found to be a key factor. In areas where land use planning was emphasized and coordinated, the growth was more orderly and focused.

2. Beltways (and radial freeways) do impact the location of development and may contribute to some loss of marginal retail and service operations, but research is inconclusive regarding the causal relationship of beltways and urban sprawl. Experience of peer cities clearly indicates, however, that local and regional land use effects (and policies) should be a major part of beltway planning.

3. Since land use policies are determined locally (in Indiana and in all of the peer cities reviewed), coordinated planning among jurisdictions is essential for effective beltway planning. Objectives to be served may be regional, but land use impacts are local. Beltway segments need to be integrated with local comprehensive plans.

4. Beltways are not a panacea for improving congestion on existing routes. Linking suburban centers by improved arterial routes rather than a suburban freeway or beltway may best satisfy local needs. The key is to clearly identify the objectives being served through regional studies, local impact reviews and public involvement.

5. Coordinated planning by jurisdictions being served can be effective in reducing the negative land use impacts of beltways (freeway or arterial) and establishing common design standards. Principles and guidelines should be project specific and should reflect state-of-the-art knowledge of the potential development impacts of transportation facilities. A three-step process should be used:

   - *Visioning* to identify the purpose of the project;
   - *Design and Location Studies* to fit the plan to the context; and
   - *Zoning and Land Use Controls* prior to construction to control development.

As a part of the CISTMS study, the relationship of land use and transportation has been explored through a local expert panel, public involvement, and state-of-the art modeling. Subsequent sections of this report provide the results of the expert panel and transportation land use modeling.

1.5 Summary of Transportation-Land Use Methodology

This study employs an integrated forecasting approach that attempts to capture the interactions between transportation investment and land development. The methodology includes a combination of quantitative statistical modeling, using the MPO travel demand model and a regional land use model (the LUCI/T model), and quantitative and qualitative assessment by an expert panel. The travel demand modeling process uses a modified version of the regional travel demand model developed by the Indianapolis MPO, which is described in more detail in Section 3.0. The land use forecasting process uses a modified version of the Land Use in Central Indiana (LUCI) model developed by Indiana University Purdue University Indianapolis (IUPUI), which is described in more detail in Section 4.0. An expert panel was asked to refine MPO forecasts and to estimate employment shifts that could occur following the construction of the Maximum Change alternative. Their work is described in Section 2.0.

There were three main scenarios of land use forecasts that were conducted. They include: the 2000 Baseline, the 2025 Minimum Change Alternative, and the 2025 Maximum Change Alternative. The 2000 Baseline alternative was used to calibrate models to existing conditions. The 2025 Minimum Change alternative applies future-year socioeconomic forecasts to the existing transportation network, with various programmed improvements. The 2025 Maximum Change alternative applies the same socioeconomic forecasts to the future network with the circumferential freeway described above.

As seen in Figures 1.6 through 1.8, the modeling process for each scenario was very similar, with variations in the transportation network and employment allocation inputs. As seen in Figure 1.8, the 2025 Maximum Change alternative has additional feedback steps to measure the sensitivity of modeled transportation improvements on modeled land use.

The following sections of this report detail the work that was completed with respect to the Expert Panel Employment Allocation Exercise, the MPO Travel Demand Model, the regional land use model (LUCI), and Sensitivity Analyses.

Figure 1.6 Modeling Process for 2000 Baseline

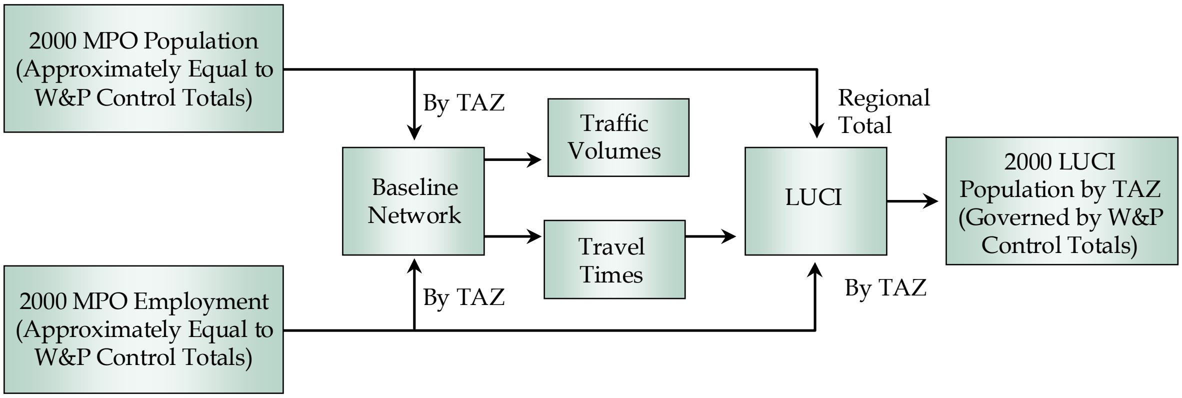


Figure 1.7 Modeling Process for 2025 Minimum Change Alternative

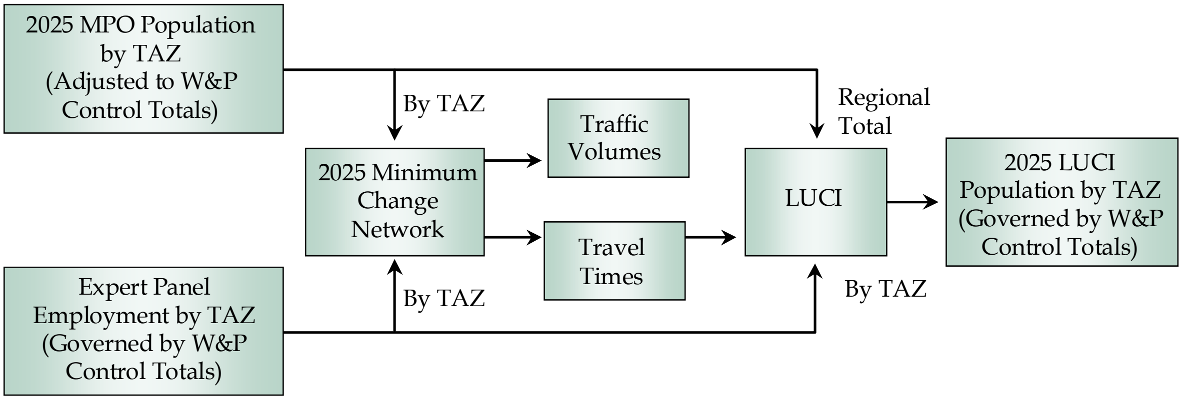
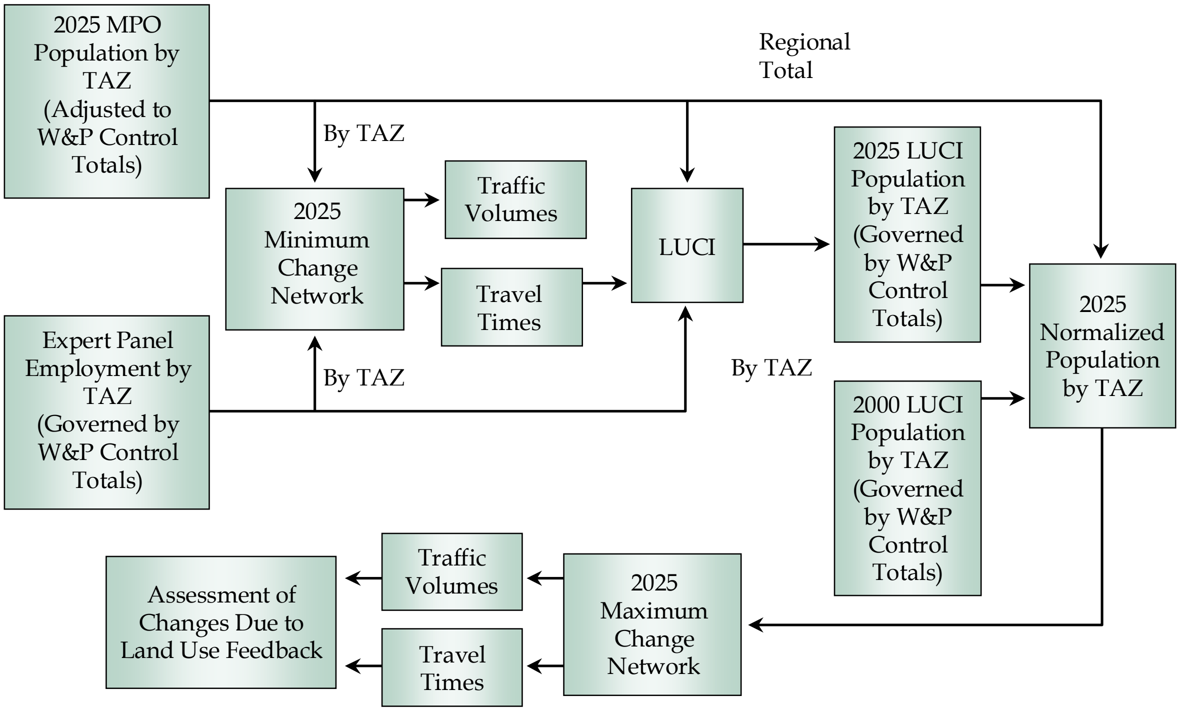


Figure 1.8 Modeling Process for 2025 Maximum Change Alternative



2.0 Existing Conditions and Future Assumptions

2.0 Existing Conditions and Future Assumptions

2.1 Expert Panel Employment Allocation Exercise

Because the regional land use model (LUCI) does not currently have an employment allocation module that is sensitive to network travel times, an expert panel was consulted to provide employment forecasts as input to the model. The expert panel was composed of local officials, developers, and others familiar with the greater Indianapolis real estate market and planning conditions. These experts were primarily charged with the task of identifying how the location of employment would be affected by transportation project alternatives, specifically roadway improvements in the four study corridors.

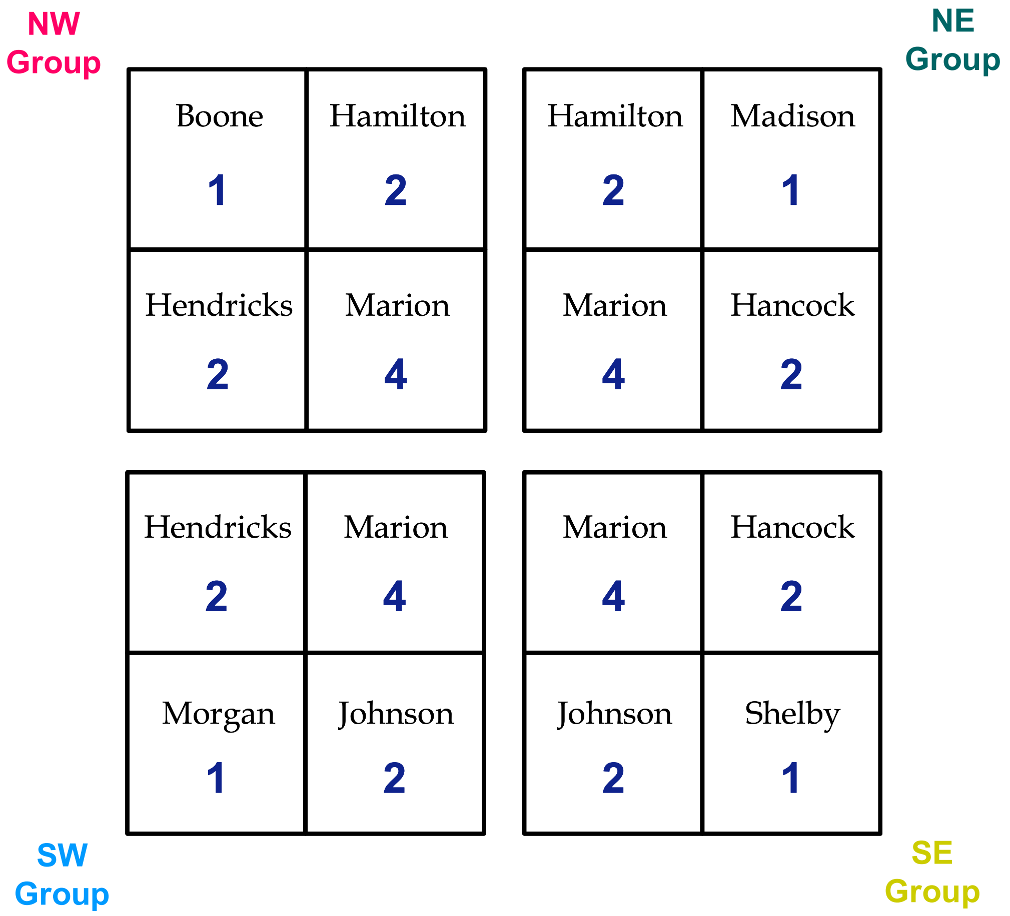
The workshop included an employment allocation exercise in which participants were divided into four groups and asked to estimate changes in workplace location and associated employment at the township level for the Minimum Change and Maximum Change alternatives.

The nine-county Indianapolis region was divided into four quadrants. As shown in Figure 2.1, there was overlap between groups for Hamilton, Hancock, Johnson, and Hendricks Counties. Marion County was included in all four quadrants. Each group was asked to specifically discuss impacts that would occur in its assigned quadrant.

The first phase involved a discussion of the impacts of minor safety and operational improvements made within the existing rights-of-way of the four corridors, such as intersection changes, additional turning lanes, or roadside safety improvements. Reflecting only slightly more changes than are already programmed by INDOT and the Indianapolis MPO, this alternative was referred to as the Minimum Change Alternative. Given that such changes are generally not considered to have significant impacts on employment location or land use, this phase essentially provided participants with an opportunity to apply their knowledge of recent trends and development plans to refine the Indianapolis MPO's baseline forecast for 2025 employment, which was prepared more than five years ago.

The second phase involved isolating the impacts of upgrading all four corridors to a high-type facility, such as a limited-access freeway with significant segments on new terrain alignments, and forecasting how this facility would impact the allocation of employment growth. This alternative was referred to as the Maximum Change Alternative.

Figure 2.1 Quadrants used in Employment Allocation Exercise



4 Number of groups considering county

The exercise was in essence a reallocation of employment *growth*. Because the region is expected to experience a 39 percent increase in employment by 2025 (more than 425,000 new jobs), all of the employment redistributed by the groups represents growth that has not yet occurred. As a result, the exercise did not necessarily move existing jobs from one place to another, but rather suggested locations where faster or slower growth would likely occur if the transportation alternatives were implemented.

Because the objective of the exercise was to determine how a fixed amount of projected regional growth between now and 2025 will be distributed around the region, the activity was intended to be a zero-sum game. The fixed amount of growth is based on regional economic growth forecasts by Woods and Poole that reflect the Indianapolis region's projected competitive position in the national and global economies. While the participants were permitted to reallocate employment from county to county in the nine-county region, economic impacts of the proposed highway improvements that could result in the relative growth of the Indianapolis region in comparison to other regions were considered beyond the scope of this exercise and the CISTMS study. Under the constraint of regional control totals, if a given township gained 100 employees, those 100 employees were subtracted from the anticipated growth in another township or combination of townships.

Figure 2.2 exhibits each group's estimate of township-level employment changes under the Minimum Change Alternative, in comparison to the baseline forecast. Figure 2.3 exhibits employment changes under the Maximum Change Alternative.

Figure 2.2 Township-level Adjustments to Forecast Employment Growth Estimates by Each Group under the Minimum Change Alternative

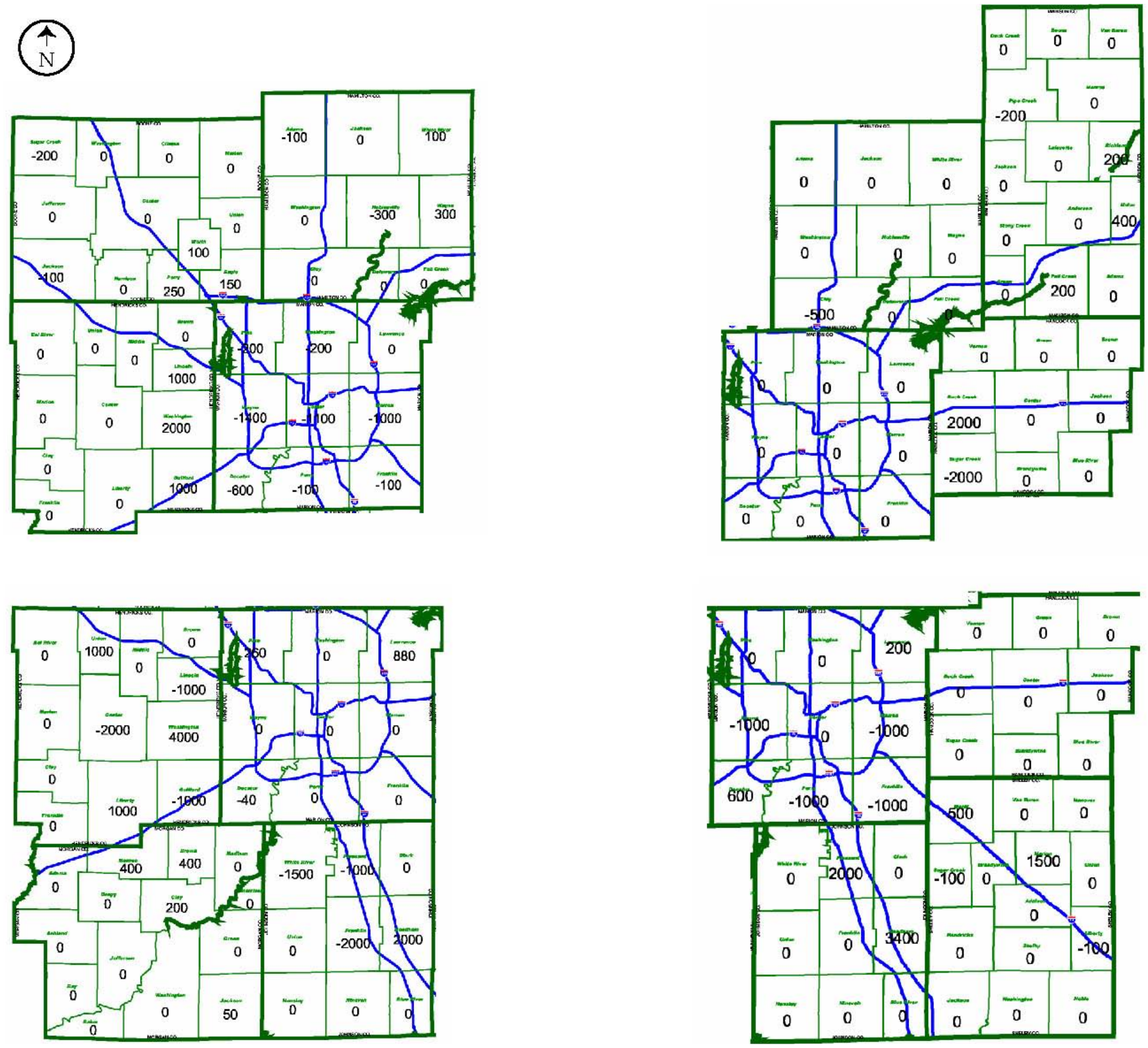
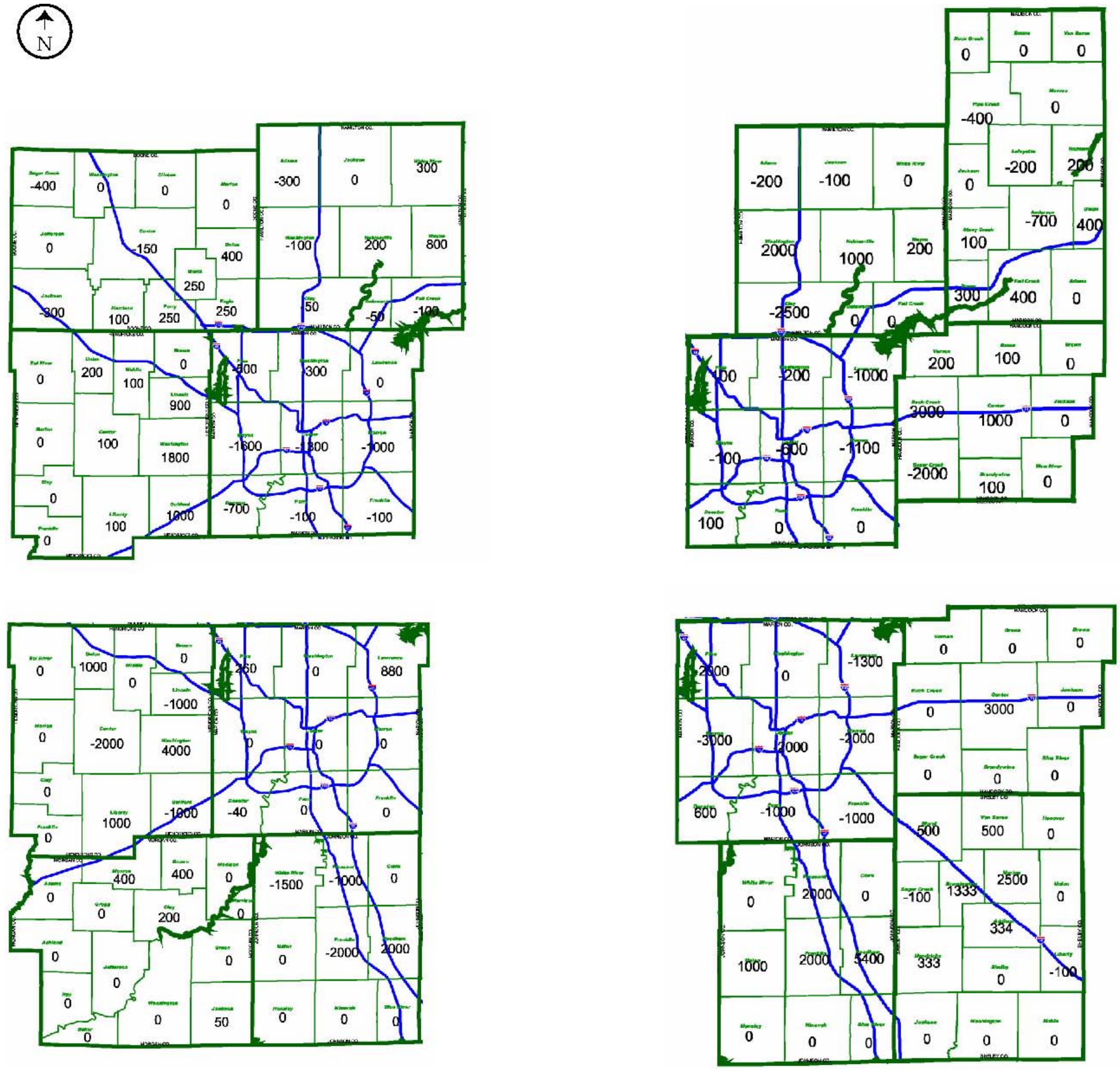


Figure 2.3 Township-level Adjustments to Forecast Employment Growth Estimates by Each Group under the Maximum Change Alternative



To derive a unified estimate of what would happen under each bookend alternative for the entire region, rules were developed and applied to each county based on the number of groups that considered the effects of transportation improvements there. Corner counties, each considered by only one group, assumed the employment adjustments as suggested by their respective groups. For intermediate counties, the employment adjustments that were made by the two overlapping groups were averaged. For townships in Marion County where the groups either agreed on more rapid employment growth or disagreed over the rate of growth, the employment adjustments made by the four groups for each township were averaged. Keeping in mind that this exercise was intended to be a zero-sum game, the excess in employment growth in all of the other counties were distributed among the

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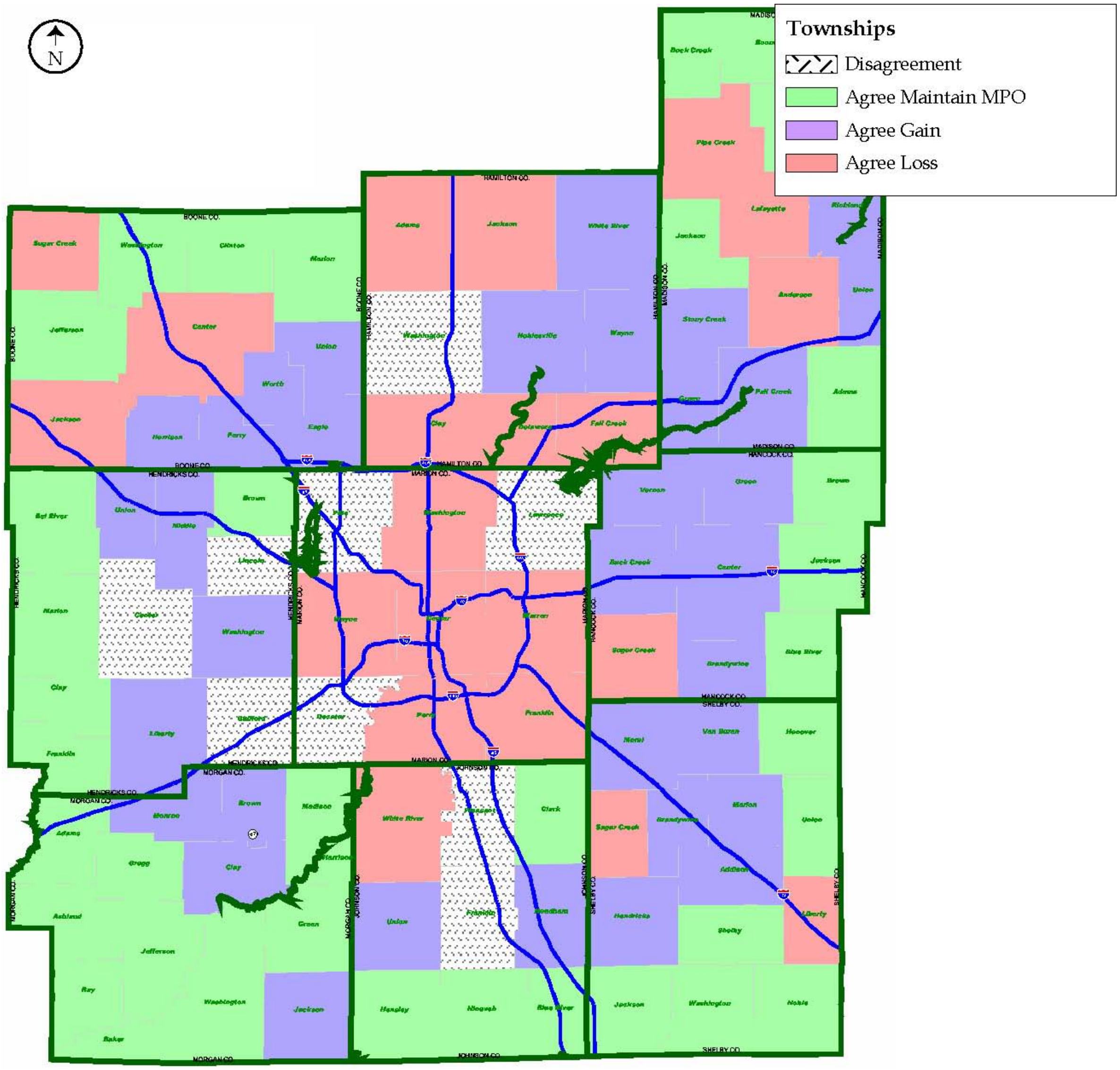
remaining Marion County townships – the townships where all groups agreed upon slower growth. The excess growth was distributed on a weighted basis using the cumulative loss in job growth as forecasted by all four groups.

For the Maximum Change Alternative, Figure 2.4 illustrates the townships where there was an overall agreement of where job growth would be sustained at the MPO forecast level, would vary either upward or downward from the MPO forecast, or where groups had opposing views.

Figure 2.4 Level of Agreement between Groups on Effects of Maximum Change Alternative



The combined absolute change in employment growth for each alternative was then adjusted to reflect Woods and Poole regional control totals. Because the expert panel was asked to reallocate growth between counties, a uniform regional scale factor was used to adjust the expert panel suggestions for each township.

Figure 2.5 shows the results of the balancing and adjustment exercises for the Minimum Change Alternative. Figure 2.6 shows the corresponding results for the Maximum Change Alternative.

Figure 2.5 Combined Change in Employment Growth for Minimum Change Alternative

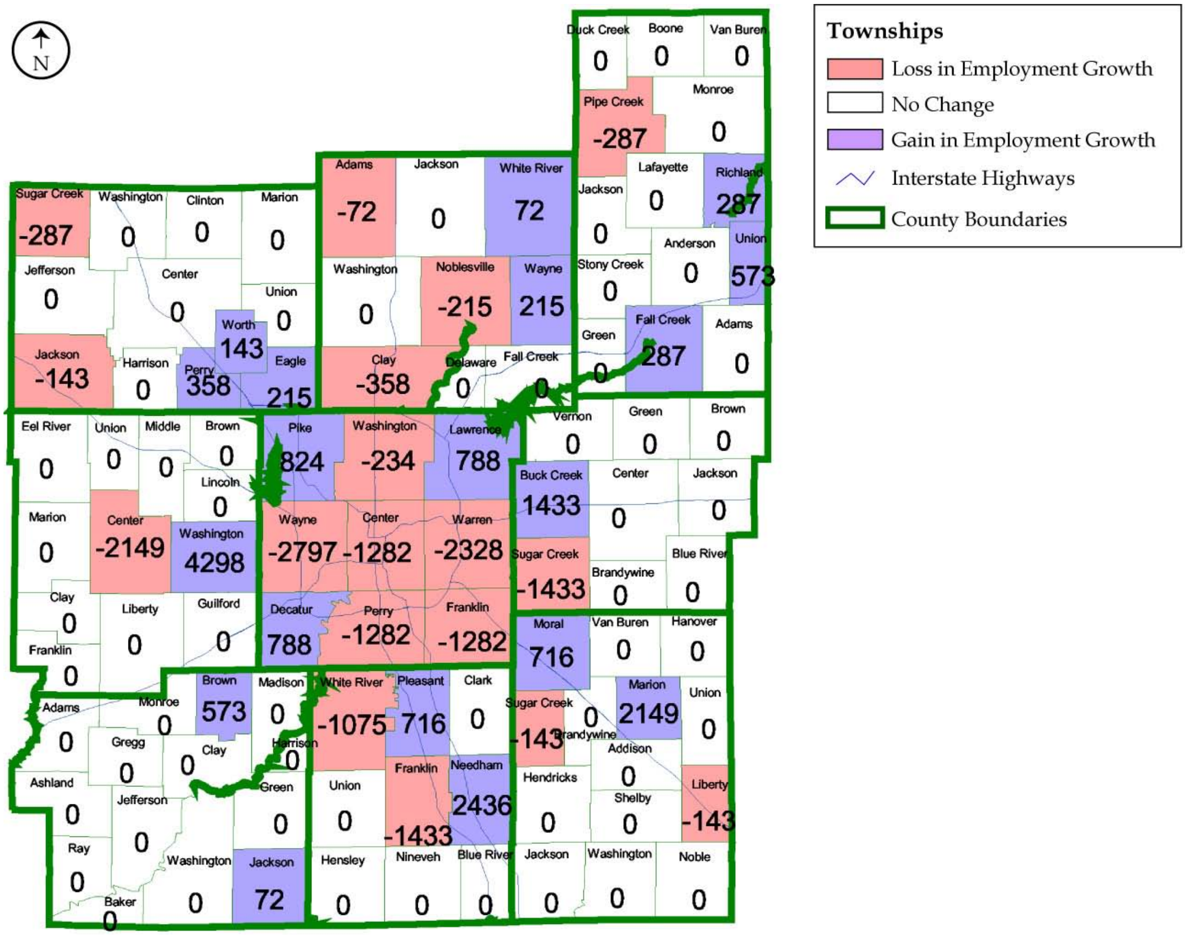
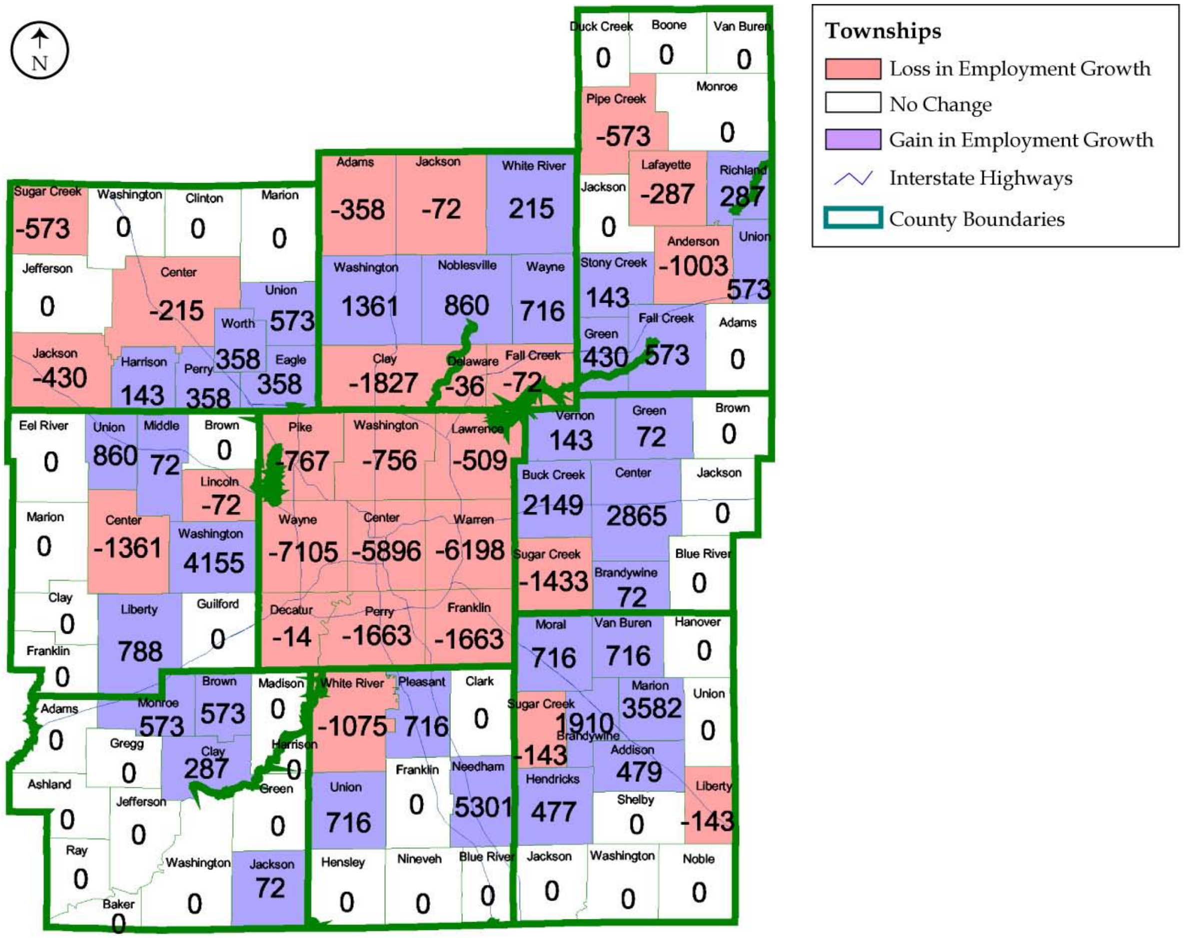


Figure 2.6 Combined Change in Employment Growth for Maximum Change Alternative



Overall, the groups re-distributed a combined 16,942 and 34,242 new jobs in the Minimum Change and Maximum Change alternatives, respectively. These reallocations constitute 4.0 percent and 8.0 percent, respectively, of the region's overall employment growth as forecast by Woods and Poole. As a result, it is reasonable to assume that the majority of changes in employment location suggested by the experts reflect shifts in growth that have not yet occurred rather than movements of current employees from one place to another.

The results by township are summarized in Appendix A. The Maximum Change Alternative is predicted to draw small amounts of employment growth from established areas – predominantly Indianapolis and its immediate surroundings. Simultaneously, a ring of enhanced growth is expected to form along the Maximum Change Alternative corridors. Marion County's estimated shift in future employment of approximately 24,500 jobs amounts to approximately 10 percent of its projected employment growth between now and 2025. In other words, the expert panel predicted that the transportation improvements associated with the Maximum Change Alternative would cause Marion County to grow about 10 percent more slowly than if no improvements were made.

These combined results were used as inputs to the evaluation and comparison of alternatives in the travel demand forecasting and land use forecasting processes. Township results were disaggregated to TAZs based on the proportion of MPO-forecast township total employment in each zone.

3.0 Transportation Impacts

3.0 Transportation Impacts

This section describes the travel demand forecasting methodology and results for the study. The analysis was based on the nine-county version of the regional travel demand model developed by the Indianapolis MPO, modified to reflect the needs of this study.

■ 3.1 Indianapolis MPO Nine-County Model

The Indianapolis Nine-County Model is an update of the earlier MPO model. The earlier model was validated for 1996, and had 1,025 internal TAZs and 1,070 total TAZs. The Nine-County Model, as its name implies, covers the nine Central Indiana counties in their entirety, with Indianapolis/Marion County at the center, and has 1,285 internal zones and 1,343 total zones including external stations and extra dummy zones.

The Nine-County Model is a traditional four-step model, which produces transit trip estimates plus average daily highway traffic volumes on each roadway link in the network. It was calibrated to 2000 traffic counts, and 2000 population was taken from the 2000 Census at the block level. Households for 2000 were estimated using 2000 population and occupancy rates from earlier studies, as the 2000 Census had not yet reported information on households. Employment data were not available from 2000 sources. For zones that were in the 1996 modeling area, employment was interpolated by TAZ between the 1996 zonal data and the 2006 employment estimate that was used for the recent air quality conformity analysis. For TAZs that were outside the 1996 modeling area, employment totals, by TAZ, were taken from INDOT's Indiana Statewide Model. Traffic count data were obtained from INDOT and county sources. All highway network and zonal data for the model were assembled as databases using TransCAD® software.

■ 3.2 Changes for this Study

During the initial stages of this study, a full model review was undertaken to assess the sensitivity of the travel demand model to the analysis needs of this study. The following changes to the model were made:

- Socioeconomic data was updated to provide a consistent base with the LUCI land use model;
- Procedures to estimate external truck and auto traffic were adjusted to incorporate the regional dynamics from INDOT's Statewide Model;

- The addition of roadways to the base networks representing facilities from the long-range plan that are not yet programmed but can be expected to be in place by 2025, including I-69 toward Evansville, the upgrading of U.S. 31 in Hamilton County, the widening of I-465, and other facilities identified in coordination with INDOT; and
- The addition of existing roadways in outlying areas not currently well represented in the base networks.

3.2.1 Base-Year Socioeconomic Data

The MPO model's population statistics were updated based on data from the 2000 Census and its employment estimates were based on data from INDOT's Statewide Model. In the interest of developing a set of consistent future-year socioeconomic datasets, 2000 population, households, and employment numbers were adjusted by applying a county-specific factor to the MPO 2000 numbers to match the Woods and Poole county control total. Employment values reflect the results of the expert panel process described in Section 2.0. Because Woods and Poole was considered to be the most appropriate source of regional forecasts, the use of the Woods and Poole control totals for the base year enables the development of future-year forecasts in a consistent manner.

Table 3.1 Changes to County-Level Population
2000 Base Year

	MPO	CISTMS	Percent Difference
Boone	46,100	46,425	0.7%
Hamilton	182,700	185,459	1.5
Hancock	55,400	55,664	0.5
Hendricks	104,100	105,400	1.2
Johnson	115,200	116,041	0.7
Madison	133,400	133,336	0.0
Marion	860,500	860,209	0.0
Morgan	66,700	66,953	0.4
Shelby	43,400	43,581	0.4
Region Total	**1,607,500**	**1,613,068**	**0.3%**

Table 3.2 Changes to County-Level Total Employment
2000 Base Year

	MPO	CISTMS	Percent Difference
Boone	21,400	23,510	9.9%
Hamilton	105,000	107,100	2.0
Hancock	25,900	24,141	-6.8
Hendricks	43,400	45,947	5.9
Johnson	56,700	55,428	-2.2
Madison	65,700	60,020	-8.6
Marion	700,300	724,743	3.5
Morgan	23,800	21,037	-11.6
Shelby	22,800	22,981	0.8
Region Total	**1,065,000**	**1,084,907**	**1.9%**

3.2.2 External Auto and Truck Traffic Modeling Updates

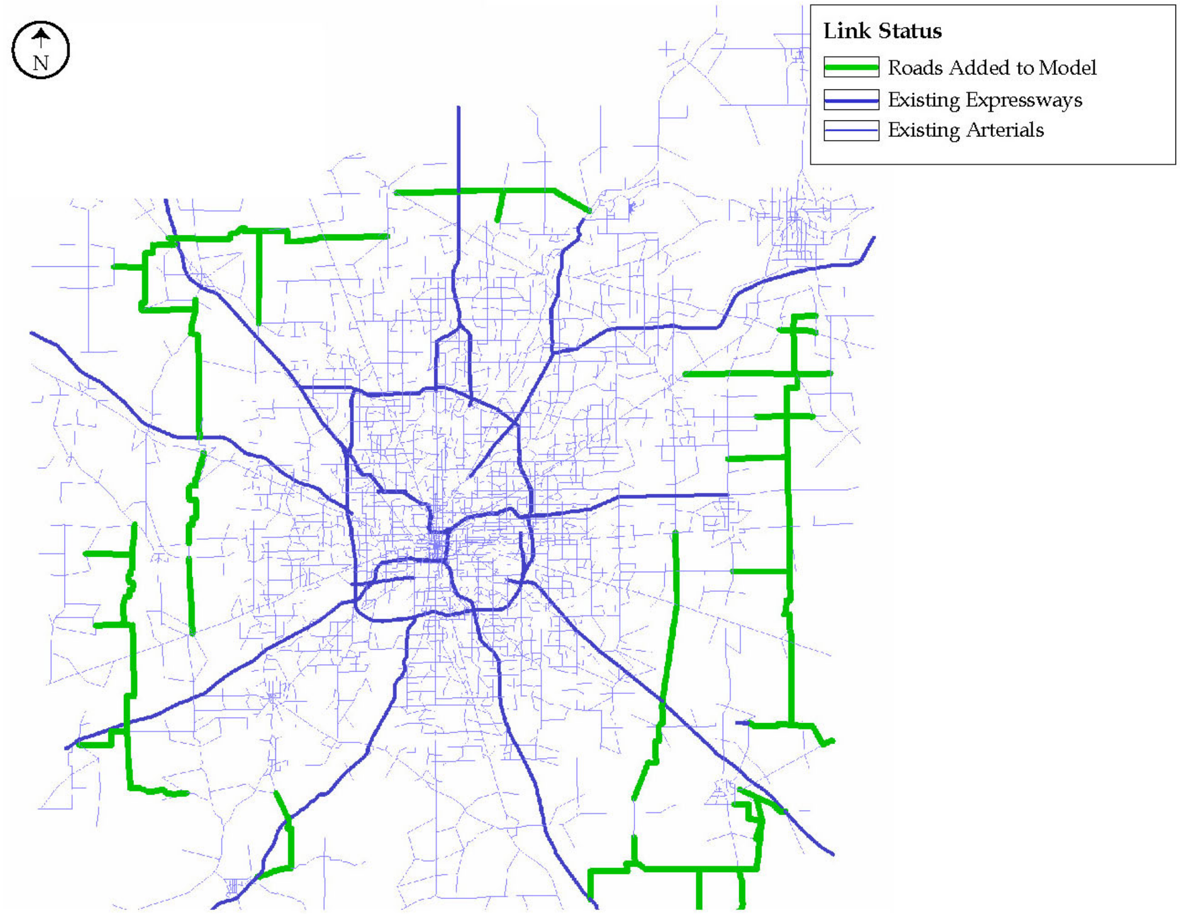
Because of the regional emphasis of the CISTMS study and more specifically the inclusion of I-69 toward Evansville, there was a desire to integrate the more regional breadth of the INDOT Statewide Model with the more local MPO Nine-County Model. Ideally, the approach would maintain the level of detail associated with the Nine-County Model with respect to truck trip ends while incorporating the more regionally based characteristics of the Statewide Model, including trip distribution patterns outside the study area. After some review of the two models, the following approach to external trip modeling was adopted and implemented for both the 2000 base-year and 2025 future-year models:

- Run the Statewide Model's subarea analysis procedure for the nine-county study area;
- Convert the subarea analysis trip tables from the Statewide Model to the nine-county zone system and zero out the internal-to-internal (I-I) portion;
- Develop trip-end targets for the external-to-internal (E-I) and external-to-external (E-E) portions of the Nine-County Model from the Nine-County Model and from the Statewide Model subarea external volumes; and
- Use the Fratar procedure to adjust the subarea trip tables to fit the trip-end targets in the previous step.

3.2.3 Network Updates: Existing County Roads added to Base Networks

Roads in the outlying areas that are not under INDOT jurisdiction but were considered to be significant to the study were added next. Figure 3.1 shows the location of these roadways.

Figure 3.1 Increased Network Detail in Study Area



3.2.4 Mode Choice Model

An update of the mode choice element of the Nine-County Model is currently underway to address several issues with regard to the park-and-ride portion of the module. For the CISTMS study, it was decided that these issues were not relevant because transit is typically focused on the Indianapolis central area and is not readily available as a travel option for trips between points in the study corridors.

3.3 Base-Year Model Validation Results

The Nine-County Model was re-run for the base year with the above-mentioned changes. The ability of the model to estimate base-year traffic volumes was checked. Parameters were adjusted and the model was re-run until an acceptable "fit" was reached. The results showing the model "fit" appear in Tables 3.3 and 3.4. These tables compare the original version of the model to the adjusted version with respect to facility type and screenlines, respectively. The CISTMS version reflects only the adjustments to 2000 socioeconomic data, truck traffic, and county road network detail described above.

Table 3.3 shows that in most cases there is very little change in the traffic assignments between the two versions of the model. Overall, links with traffic counts had a ratio of estimated link vehicle miles of travel (VMT) to count-based VMT of 98 percent for the MPO version and 100 percent with the updated socioeconomic data and new truck trip procedures. However, on individual facility types there are differences among the three, most noticeably the improvement for the one-way arterial links from a ratio of 1.18 in the MPO version to within the target 15 percent at 1.01 of the count-based VMT in the updated version with both changes. There are very few such highways in the vicinity of CISTMS improvements, however.

Table 3.3 Estimated VMT to Count VMT Ratio by Facility Type
2000 Base Year

Facility Type	MPO Version	CISTMS Version
Freeways	0.95	0.98
Expressways	1.01	1.03
Arterials with Parking	1.02	1.03
One-Way Arterials	1.18	1.01
Arterials without Parking	0.99	1.00
Freeway Ramps	0.99	1.02
All Types	**0.98**	**1.00**

Individual screenline results comparing total screenline-estimated volume to count-based volume are more varied as well. Figure 3.2 shows the location of each of the screenlines used for this analysis.

Figure 3.2 Screenline Link Locations

Table 3.4 shows the comparison between the MPO model and the CISTMS model at each screenline. One of the comments received as part of the model review process during the initial stages of this study were that some of the outlying screenlines where the model needs to be more sensitive because of the focus of this study were not as accurate as they could be. The implementation of the changes has improved some of these areas including:

- 86th Street Cutline from 0.72 in the MPO version to 0.81 in the updated version;
- Hancock-Shelby from 1.16 in the MPO version to 1.07 in the updated version;
- Johnson-Morgan from 1.26 in the MPO version to 1.17 in the updated version; and
- Boone-Hendricks from 1.30 in the MPO version to 1.11 in the updated version.

Table 3.4 Estimated to Actual Traffic Volumes for Select Screenlines and Cutlines
2000 Base Year

Screenline	No.	MPO Version	CISTMS Version
1996 External Stations	1	1.00	1.03
38th Street	10	0.99	0.99
National Road	11	1.00	1.02
Lynnhurst/65-67	12	0.90	0.92
White River	13	0.95	0.98
Emerson/65-69	14	0.95	0.98
I-465 Cordon	15	1.09	1.12
Southport Cutline	16	1.02	1.01
City Center Cordon	16	1.02	1.01
Raymond Street Cutline	18	0.96	1.00
16th Street Cutline	19	1.05	1.06
116th Street Cutline	20	0.90	0.97
Northwestern Avenue Cutline	21	0.96	1.00
Keystone Avenue Cutline	22	1.04	1.09
German Church Cutline	23	0.98	1.01
Madison Cutline	24	0.77	0.84
86th Street Cutline	32	0.72	0.81
Madison-Hancock Cutline	33	1.03	1.06
Madison-Hamilton Cutline	34	1.12	1.16
Hancock-Shelby Cutline	35	1.16	1.07
Johnson-Shelby Cutline	36	1.08	1.06
Johnson-Morgan Cutline	37	1.26	1.17
Hendricks-Morgan	38	1.24	1.25
Boone-Hendricks	39	1.30	1.11
Boone-Hamilton Cutline	40	0.84	0.89

3.4 Minimum Change Alternative Traffic Impacts

This section describes the network and land use assumptions used to develop forecasts of future-year traffic volumes and describes the changes in travel characteristics associated with the 2025 Minimum Change (baseline) alternative.

3.4.1 Network Updates: Future-Year Projects Coded in the Network

A comprehensive review and update process was undertaken with regard to the future-year network assumptions to ensure the appropriate representation of existing and committed (E+C) projects in the future-year Minimum Change network for the Indianapolis nine-county region. Other future projects that are reflected in the Indianapolis MPO's Long-Range Plan (LRP projects) were also included. The preferred alternative alignment for the proposed new I-69 known as "Alternative 3C" from the *I-69 Evansville to Indianapolis Tier I Final Environmental Impact Statement (FEIS*), was added to the 2025 Minimum Change network.

3.4.2 2025 Baseline Socioeconomic Forecasts

Population and employment data at the TAZ level were adjusted as described in Sections 1.0 and 2.0 of this document. Total population growth for the nine-county Indianapolis region is projected to be about 2.1 million in 2025, 33 percent above the 2000 population of 1.6 million. Total employment growth is projected to increase by about 39 percent from 1.1 million in 2000 to about 1.5 million jobs in 2025.

3.4.3 2025 Baseline Traffic Impacts

The updated Network and Land Use information described above was used to develop forecasts for the 2025 Baseline condition. The following describes the changes in travel characteristics estimated by the travel model between the 2000 Baseline condition and the 2025 Minimum Change condition.

Table 3.5 shows the changes in person trips generated within the study area from the base year 2000 to 2025. Overall person trips increase by about 34 percent, somewhat more than the estimated population growth and somewhat less than the estimated growth in employment as shown in Tables 1.3 and 1.5. This translates into slight increases in the rate of trip making over the 25-year period from about 3.56 daily trips per person in 2000 to about 3.59 daily trips per person in 2025. Increases in trip making for the internally produced trips are fairly consistent with the changes in land use and range from 33 to 36 percent. External trips, on the other hand, are estimated to increase by about 70 percent over the 25-year period.

Table 3.6 shows the estimated change in vehicle trips. Similar increases in auto vehicle trips of about 36 percent from 2000 to 2025 are estimated as mode shares remain relatively constant. Truck trips, on the other hand, are estimated to increase by about 43 percent over the same time period. Although truck trips only represent about 12 percent of the total number of vehicles on the roadway system, they account for about 16 percent of the VMT. Consequently, the differences among vehicle types become even more pronounced when changes in estimated VMT by vehicle type are considered. Auto VMT is expected to increase by about 51 percent and truck VMT by as much as 63 percent. These differences are related to changes in average trip lengths as well. Trip lengths are estimated to increase for all trip types but the largest percentage increases are expected from truck trips.

Table 3.5 Changes in Estimated Person Trips by Trip Purpose
2000 Baseline – 2025 Minimum Change

	2000	2025	2000-2025
Home-Based Work	1,419,750	1,881,483	33%
Home-Based Shopping	755,375	1,007,226	33
Home-Based School	564,304	766,027	36
Home-Based Other	1,580,413	2,114,570	34
Non-Home-Based	1,441,208	1,936,625	34
External	297,536	501,743	69
All Purposes	**6,058,586**	**8,207,674**	**35%**

Table 3.6 Changes in Estimated Vehicle Trip Patterns by Vehicle Type
2000 Baseline – 2025 Minimum Change

	2000	2025	Percent Change
Vehicle Trips			
Passenger Autos	4,650,596	6,302,583	36%
Trucks	595,977	849,855	43
All Vehicle	*5,246,573*	*7,152,438*	*36%*
VMT (1,000s)			
Passenger Autos	39,263	59,253	51%
Trucks	7,245	11,839	63
All Vehicle	*46,508*	*71,092*	*53%*
Average Trip Length (Miles)			
Passenger Autos	8.44	9.40	11%
Trucks	12.16	13.93	15
All Vehicle	*8.86*	*9.94*	*12%*

Table 3.7 helps to illustrate where the increases in trip making are occurring. This table shows changes in VMT between 2000 and 2025 classified by Area Type for each roadway Facility Type. The largest projected increases occur on freeways and especially freeways in rural areas. Links within areas designated as the central business district (CBD) show the lowest percentage increases.

Table 3.7 Percent Change in VMT by Facility Type and Area Type
2000 Baseline – 2025 Minimum Change

	Area Type					
Facility Type	**CBD**	**CBD Fringe**	**Residential**	**Outlying Business District**	**Rural**	**All**
Freeways	22%	45%	70%	N/A	114%	73%
Expressways	N/A	25	41	61	73	43
Arterials	38	26	56	27	79	51
All Types	**30%**	**34%**	**61%**	**32%**	**96%**	**60%**

Note: Totals do not include centroid connectors.

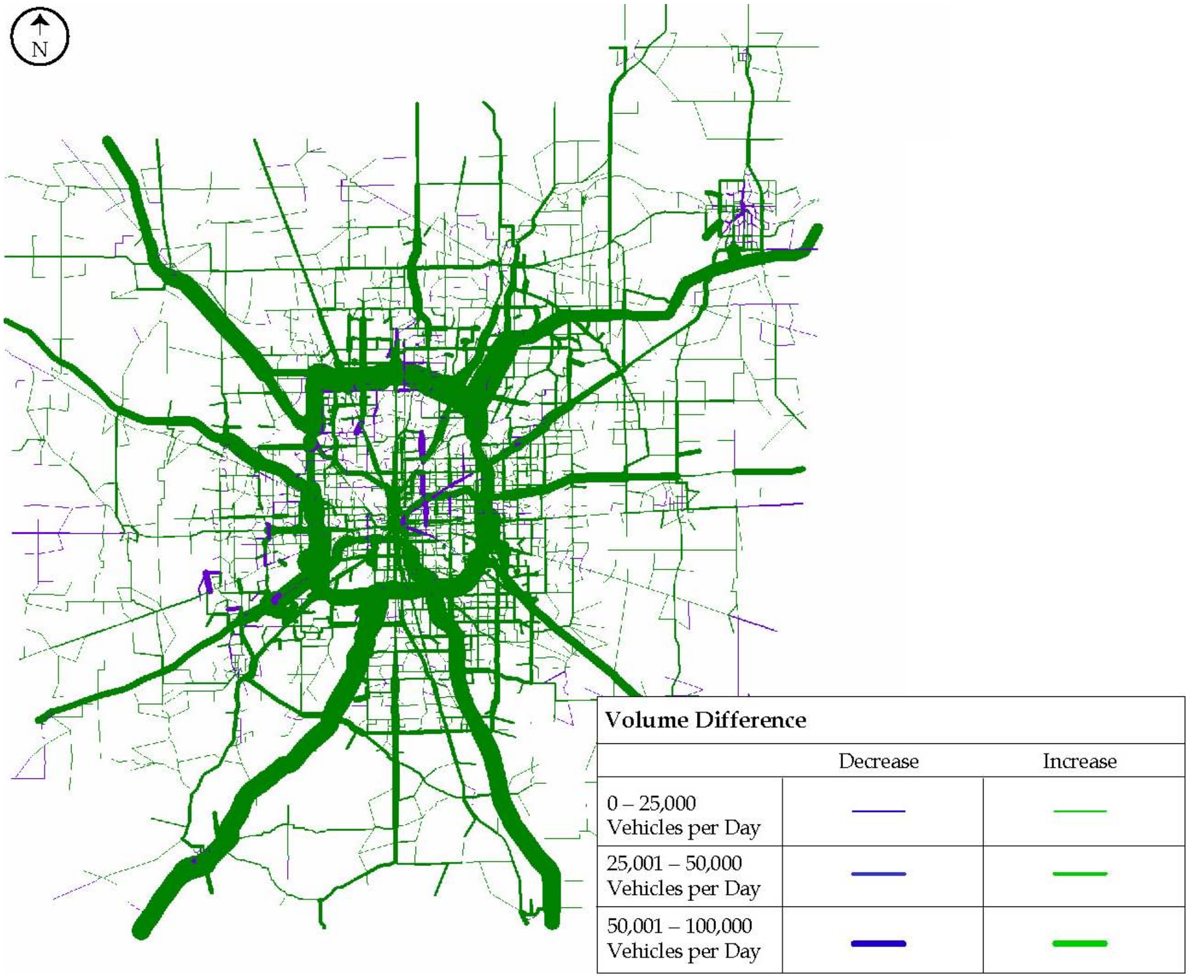
A review of changes in estimated VMT by county further pinpoints the location of travel increases. Table 3.8 lists estimated VMT by county for the base and future year. The greatest changes in traffic are outside of Marion County. VMT in Boone and Morgan Counties is estimated to more than double. These findings are consistent with the location of growth in the outlying areas as estimated by the land use model and the expert panel exercise.

Table 3.8 Change in Estimated VMT by County (1,000s)
2000 Baseline – 2025 Minimum Change

	2000	**2025**	**Percent Change**
Marion	23,400	33,239	42%
Hamilton	4,589	7,622	66
Johnson	2,552	5,016	97
Hendricks	2,334	3,981	70
Hancock	1,600	2,840	78
Shelby	1,387	2,510	81
Boone	1,608	3,378	110
Morgan	1,517	3,290	117
Madison	2,102	3,724	77
Region Total	**41,089**	**65,601**	**60%**

Figure 3.3 provides additional insight regarding the location of significant volume changes occurring between 2000 and 2025 by graphically depicting forecast changes in estimated traffic volumes. Some of the largest increases are on regional interstates entering and leaving the study area, which indicates the large impact that externally generated traffic has on the study area roadways. In particular, growth in traffic related to the proposed new I-69 corridor significantly affects travel patterns in the nine-county region.

Figure 3.3 Changes in Estimated Traffic Volumes from 2000 to 2025

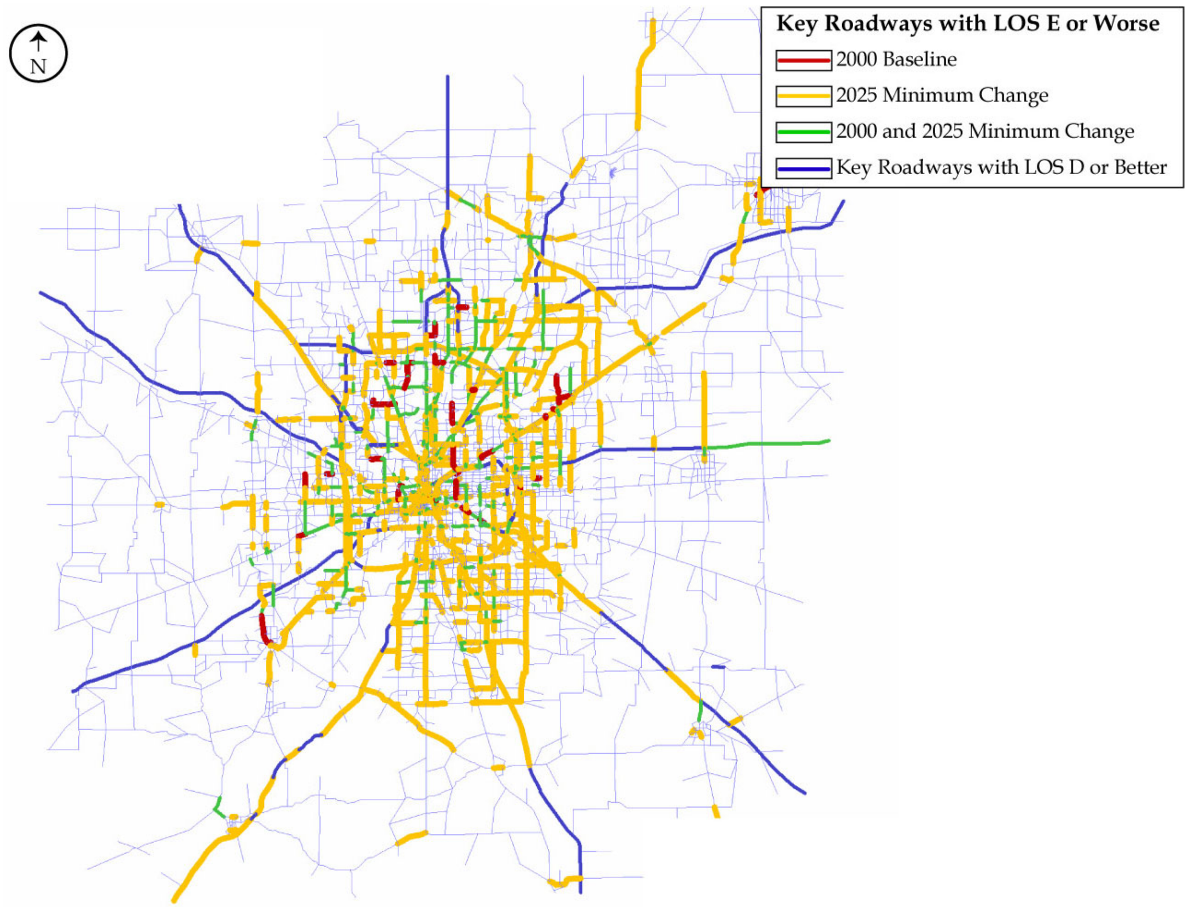


Increases in traffic volumes from 2000 to 2025 translate into increased roadway congestion. Table 3.9 shows the estimated miles of roadway approaching capacity or at capacity as denoted by the label Level of Service (LOS) E conditions or worse. This designation should be viewed as an indicator of links that are approaching or at their capacities from a planning perspective. This designation is not based on operations analysis. Overall, the miles of roadway at LOS E or worse more than double from about 414 miles to more than 876 miles between 2000 and 2025, with the majority of the increases occurring on non-freeway or expressway links. Figure 3.4 shows where roadways experiencing capacity problems are located for the 2000 and 2025 scenarios.

Table 3.9 Estimated Miles of Roadway at LOS E or Worse
2000 Baseline – 2025 Minimum Change

Facility Type	2000	2025	Percent Change
Freeways and Expressways	141	219	55.3%
Other	273	657	140.7
All Facilities	**414**	**876**	**111.6%**

Figure 3.4 Roadways Experiencing LOS E Conditions or Worse
2000 Base and 2025 Baseline Alternatives



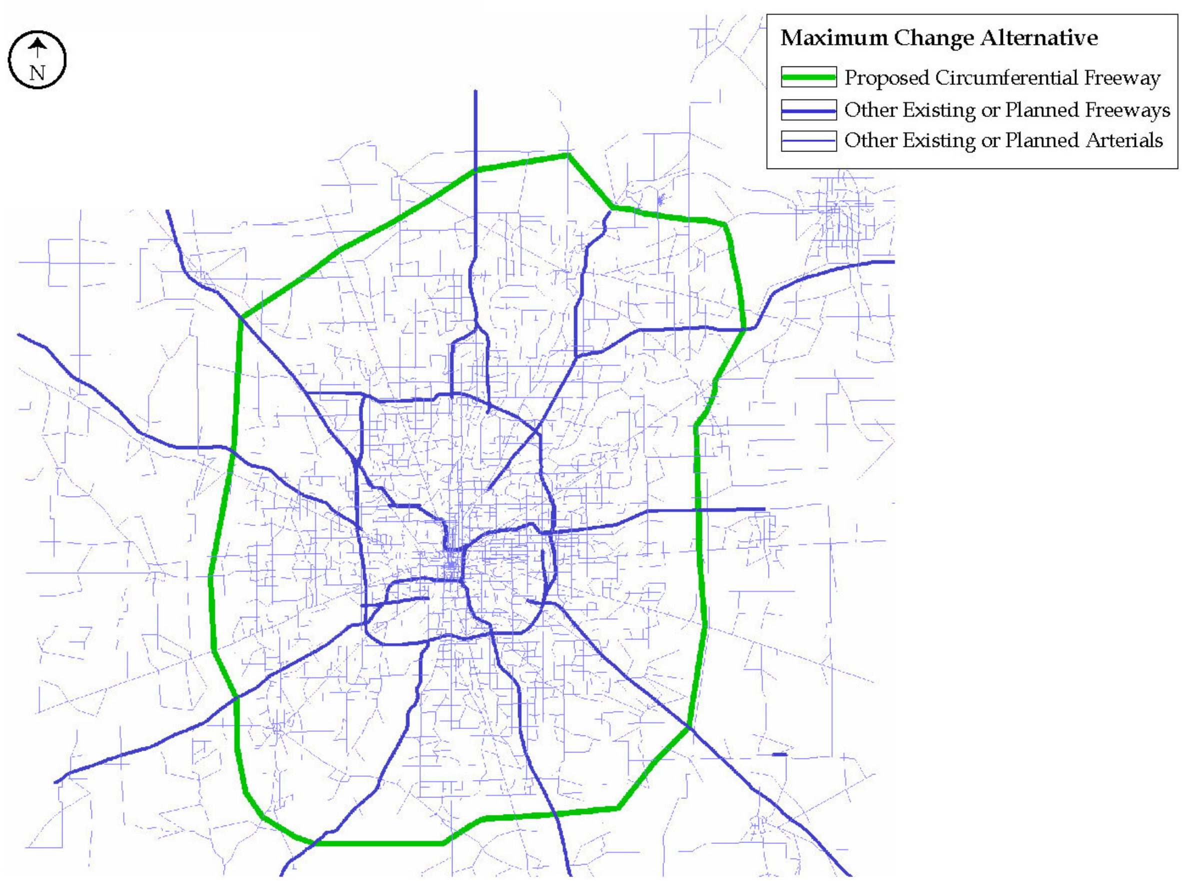
■ 3.5 Maximum Change Alternative Traffic Impacts

This section describes the network and land use assumptions used to develop the forecasts for the Maximum Change alternative and summarizes the impacts of the alternative on traffic.

3.5.1 Network Updates: Circumferential Highway

To capture the maximum impact associated with the construction of a major new facility within the study area corridor, an "outer-loop" freeway was coded into the 2025 Baseline network. The facility was assumed to be an interstate with four lanes of traffic with interchanges at all arterial State Route highways, Interstate highways, or other limited-access highways. Figure 3.5 shows the alignment of the new facility.

Figure 3.5 Assumed Alignment of Circumferential Highway



3.5.2 2025 Maximum Change Socioeconomic Inputs

Population and employment data at the TAZ level were adjusted as described in Sections 1.0 and 2.0 of this document. As discussed in those sections, overall regional control totals were maintained between the 2025 Baseline and Maximum Change alternatives while the distribution of growth areas were adjusted. Differences at the TAZ level were therefore sometimes quite significant.

3.5.3 2025 Maximum Change Traffic Impacts

The updated network and land use information described above was used to develop forecasts for the 2025 Maximum Change condition. This section describes the changes in travel characteristics between the 2025 Minimum Change and 2025 Maximum Change alternatives.

Although the number of vehicle trips is estimated to remain fairly constant between the two future-year alternatives, overall systemwide VMT is estimated to increase for the Maximum Change alternative from about 71.1 million to about 72.4 million miles per day, a two percent increase. Most of the increase is estimated to be related to changes in auto traffic (2.1 percent increase) as truck VMT stays relatively constant (0.6 percent increase). These changes are directly related to increases in the average distance of vehicle trips from approximately 9.9 miles per trip in the Minimum Change alternative to approximately 10.1 miles per trip in the Maximum Change alternative. Table 3.10 summarizes these changes.

Table 3.10 Changes in Estimated Vehicle Trip Patterns by Vehicle Type
2025 Minimum Change -2025 Maximum Change

	Minimum Change	Maximum Change	Percent Change
Vehicle Trips			
Passenger Autos	6,302,583	6,297,940	-0.1%
Trucks	849,855	848,418	-0.2
All Vehicle	*5,246,573*	*7,152,438*	*-0.1%*
VMT (1,000s)			
Passenger Autos	59,253	60,509	2.1%
Trucks	11,839	11,912	0.6
All Vehicle	*71,092*	*72,421*	*1.9%*
Average Trip Length (miles)			
Passenger Autos	9.40	9.61	2%
Trucks	13.93	14.04	1
All Vehicle	*9.94*	*10.13*	*2%*

A closer look at average trip lengths in terms of travel time reveals that all trip lengths for all trip purposes decrease slightly. This indicates that average travel speeds have increased for the Maximum Change Alternative with the availability of the proposed circumferential highway, as shown in Table 3.11.

Table 3.11 Changes in Average Trip Lengths (Minutes) by Trip Purpose
2025 Minimum Change – 2025 Maximum Change

Average Trip Lengths (minutes)	Minimum Change	Maximum Change	Percent Change
Home-Based Work	22.25	21.79	-2.1%
Home-Based Shopping	13.35	13.00	-2.6
Home-Based School	12.68	12.41	-2.1
Home-Based Other	15.96	15.50	-2.9
Non-Home-Based	15.12	14.79	-2.2
External – Drive Alone	63.81	61.51	-3.6
External – Shared Ride 2	70.48	67.57	-4.1
External – Shared Ride 3+	70.26	67.22	-4.5
Truck	32.06	31.26	-2.5%

A more detailed review of VMT by county provides additional information about how the distribution of growth in land use and the addition of a major facility in the four study corridors affect traffic growth. The addition of the new facility tends to divert traffic away from the established inner core (Marion County) to the surrounding counties (especially Hancock, Hendricks, and Shelby Counties). Table 3.12 shows estimated changes in VMT for each of the nine counties.

Table 3.12 Change in Estimated VMT by County (1,000s)
2025 Minimum Change – 2025 Maximum Change

	Minimum Change	Maximum Change	Percent Change
Marion	33,328	31,816	-5%
Hamilton	7,222	6,969	-4
Johnson	5,161	5,540	7
Hendricks	3,944	4,695	19
Hancock	2,888	3,763	30
Shelby	2,428	2,774	14
Boone	3,570	3,688	3
Morgan	3,593	3,821	6
Madison	3,661	3,973	2
Region Total	**65,601**	**66,904**	**2%**

Figure 3.6 illustrates this pattern more clearly. As indicated by the large increases on the "outer ring" and large decreases on I-69 and I-70 inside the proposed new facility, the circumferential highway provides an alternative path for regional traffic, especially I-69 traffic, that is traveling to the inner core or through the study area. Table 3.13 shows the roadway links exclusive of the proposed "outer loop" with the largest change in volume between the 2025 Baseline and 2025 Maximum Change alternatives. The locations of these sections of roadway are indicated in Figure 3.6.

Figure 3.6 Traffic Volume Changes Between 2025 Baseline and Maximum Change Alternative

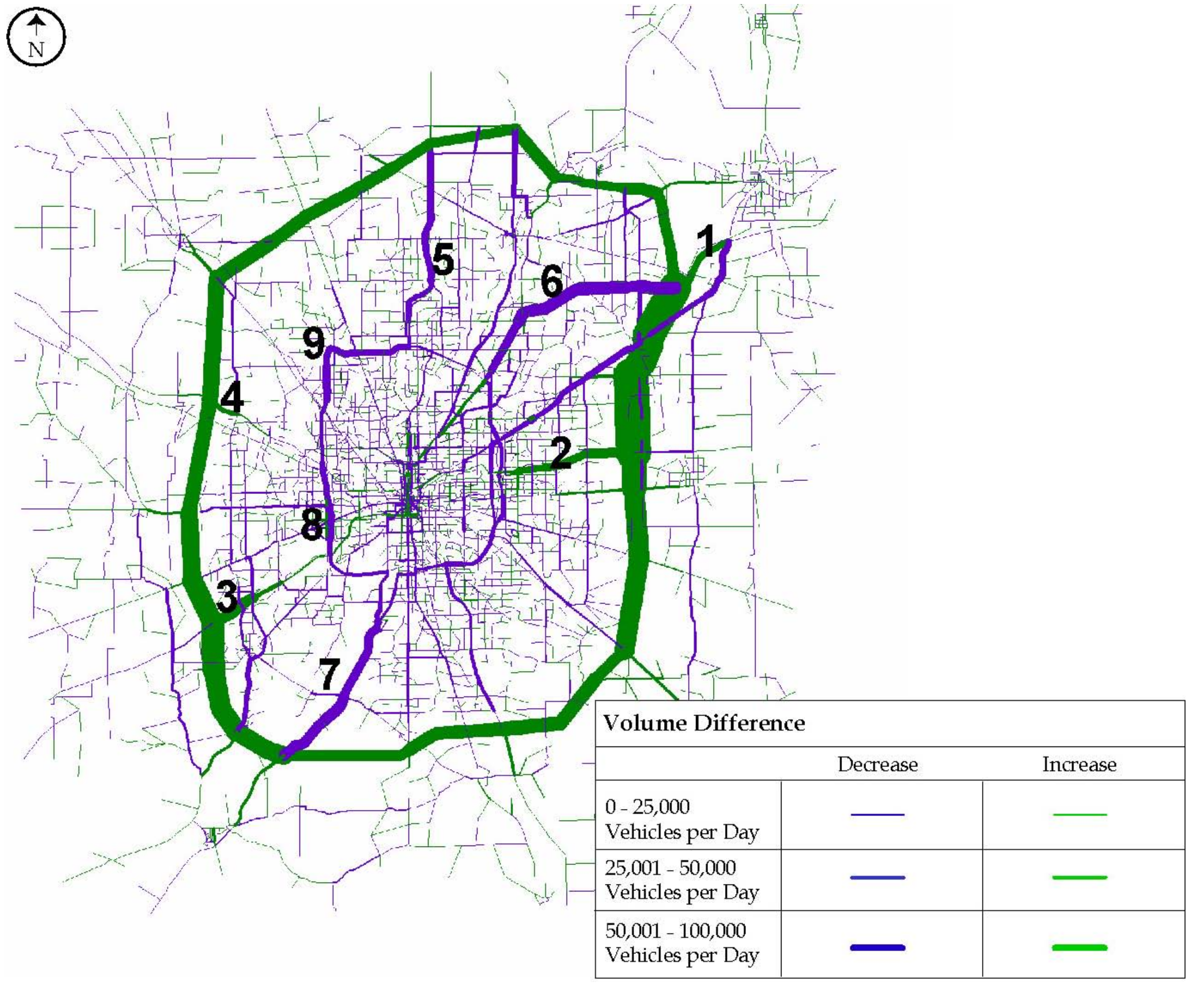


Table 3.13 Comparison of Estimated Traffic Volumes
2025 Minimum Change – 2025 Maximum Change

Location	Roadway Link	Minimum Change	Maximum Change	Difference
1	I-69 North – SR 9 to "Outer Loop"	82,000	99,200	17,200
2	I-70 East – I-465 to "Outer Loop"	87,000	108,700	21,700
3	I-70 West – SR 267 to "Outer Loop"	59,300	83,100	23,800
4	I-74 West – SR 267 to "Outer Loop"	52,200	63,300	11,100
5	U.S. 31 North – SR 431 to SR 38	68,900	53,800	-15,100
6	I-69 North – I-465 to "Outer Loop"	127,100	103,600	-23,500
7	I-69 South – Johnson Ctyline to "Outer Loop"	85,100	69,500	-15,600
8	I-465 – Airport Road to U.S. 40	167,100	150,300	-16,800
9	I-465 near I-865	132,200	116,400	-15,800

The changes in traffic volumes between the Minimum Change and Maximum Change alternatives impact roadway operating conditions. Table 3.14 shows the estimated miles of roadway experiencing LOS E conditions or worse. Overall, the miles of roadway operating at LOS E or worse decrease by about 15 percent with the relocation of land use development and the addition of a major regional facility. Figure 3.7 shows where roadways experiencing capacity problems are located for the 2025 Baseline and Maximum Change scenarios. The operating conditions of many of the roadways inside the proposed "outer loop" facility are estimated to improve under the Maximum Change alternative as indicated by the links identified as "Baseline LOS E+ Only" and portrayed in red. Most noticeable among these are sections of the proposed new I-69 interstate south of Indianapolis and U.S. 36 from about I-465 all the way to Anderson. On the other hand, many of the major roadways that feed the proposed new facility are estimated to experience increasing congestion. These include:

- I-70 on both the east and west sides of the proposed facility;
- I-74 on both the east and west sides of the proposed facility;
- U.S. 36 near Danville;
- U.S. 421 to the north;
- State Highway 234 near Eden; and
- State Highway 32 west of Anderson.

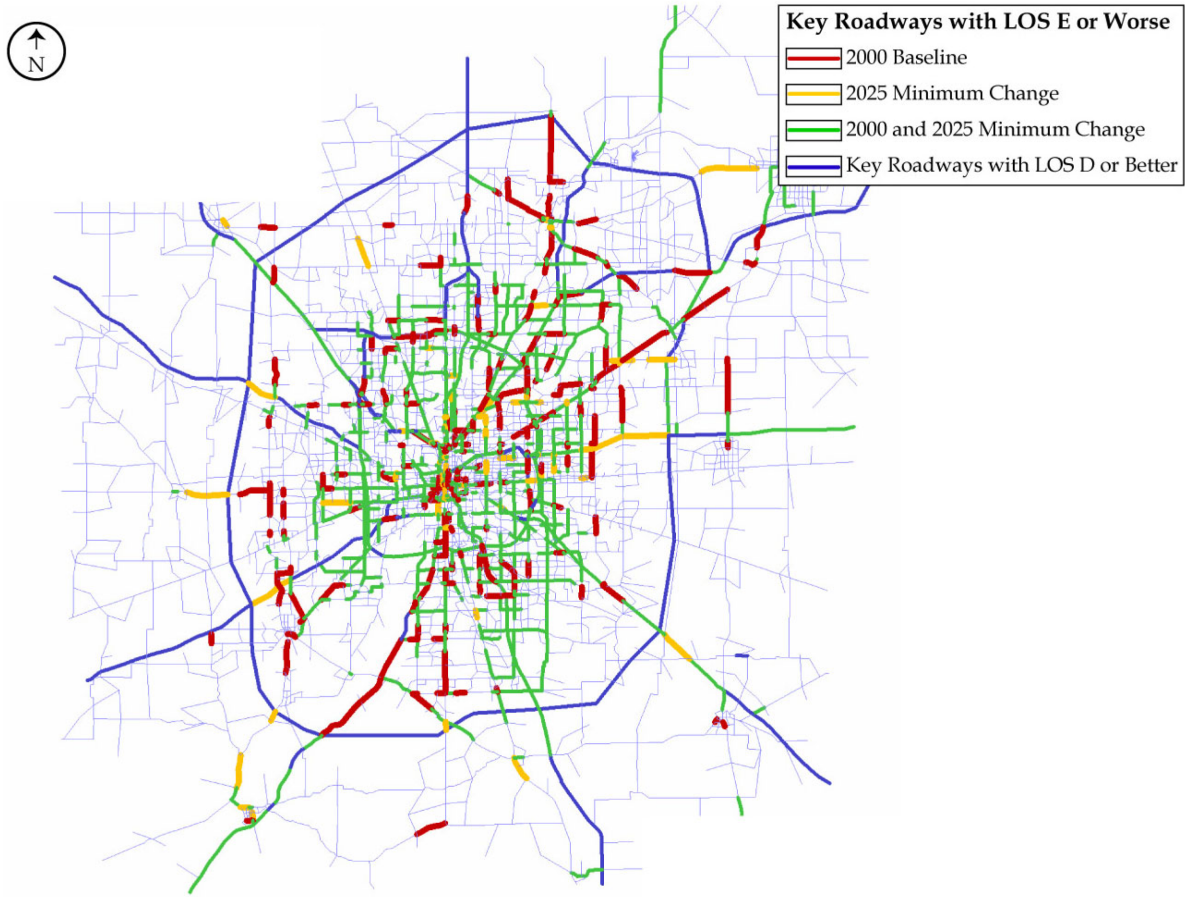
Table 3.14 Estimated Miles of Roadway at LOS E or Worse

2025 Minimum Change – 2025 Maximum Change

Facility Type	Minimum Change	Maximum Change	Percent Change
Freeways and Expressways	219	210	-4.1%
Other	657	537	-18.2
All Facilities	**876**	**746**	**-14.8%**

Figure 3.7 Roadways Experiencing LOS E Conditions or Worse

2025 Baseline and 2025 Maximum Change Alternatives



4.0 Land Use Impacts

4.0 Land Use Impacts

This section describes the adaptation of the LUCI model for the CISTMS study and presents the results of its application to the 2025 Minimum Change and 2025 Maximum Change alternatives.

4.1 Re-estimation of LUCI Model

The LUCI regional land use model was developed by the Center for Urban Policy and Environment at IUPUI to evaluate the effects of policy alternatives on a 44-county area covering much of Indiana, centered on Indianapolis. The model is calibrated based on historical patterns of land conversion to urban uses, and considers other factors such as availability of water and sewer and environmental constraints on developable land. The original model used straight-line distance as a proxy for travel time in evaluating transportation accessibility.

For the CISTMS project, the LUCI model was reduced from 44 counties to the nine-county study area and enhanced to incorporate transportation network-based accessibility measures. An initial step involved the development of alternative baseline land use forecasts for 2025 that would produce results that coincide with MPO forecasts. For the nine-county region, LUCI was re-estimated using network-based travel times as a measure of accessibility. After review and approval of the re-estimated model outputs, an interface between LUCI and the MPO travel demand model was developed. During this process, the capability to input employment forecasts, such as that resulting from the expert panel, was also built into the user interface. The resulting modified model is referred to as LUCI/T, reflecting its transportation enhancements. Appendix B includes more detailed documentation of the model development and validation process.

4.2. Baseline Model Validation

Alternative baseline forecasts were developed for the evaluation of the use of the LUCI/T model for the CISTMS project and were compared to land use forecasts that were developed by the MPO and INDOT. In total, seven baseline forecasts were developed, all of which were for a 2025 forecast year. These forecasts reflect the use of different final employment data and different assumptions regarding the density and dispersal of future urban development. They are intended to represent some of the range of possible forecasts that can be produced with the model and to provide a basis for the evaluation of the model's capabilities. The seven alternative sets of baseline assumptions include:

- **Baseline Forecast 1** assumes that employment by TAZ will remain unchanged from the initial 2000 values over the simulation period. It is intended to serve as a basis for comparison with the other forecasts that assume change in employment.

- **Baseline Forecast 2A** assumes that employment by TAZ in 2025 will be as forecast by the Indianapolis MPO. LUCI/T starts the simulation in 2000 using the initial 2000 employment data. For the succeeding simulation periods, the model uses employment interpolated between the initial 2000 employment data and the final 2025 employment data.

- **Baseline Forecast 2B** assumes an alternative 2025 employment forecast developed by taking the forecast change in employment from the initial 1996 data to the MPO forecast 2025 values and adding this to the updated 2000 employment levels. This provides a forecast in which the employment in each TAZ from 2000 to 2025 grows or declines by the amount originally forecast for 1996 to 2025. This eliminates the problem of declines in employment occurring in TAZs that were originally forecast to grow.

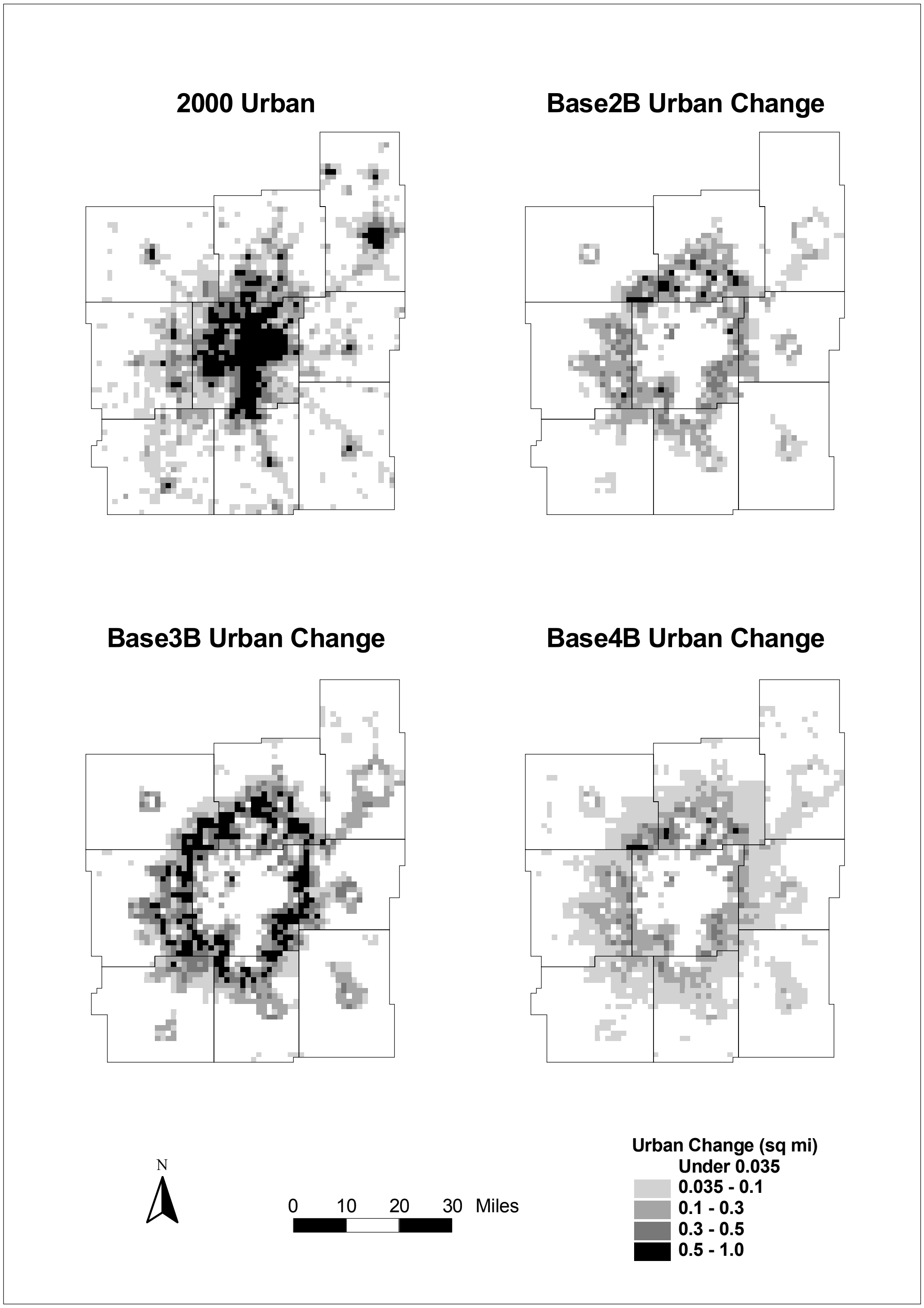
Likewise, the remaining baseline forecasts will also have A and B versions, with the A version using the MPO forecast of TAZ employment for 2025 and the B version using the MPO forecast of employment change from 1996 to 2025 added to the updated 2000 TAZ employment.

- **Baseline Forecasts 3A and 3B** assume that population densities will be 50 percent lower than those predicted within the model. These baseline forecasts are analogous to the lower density baseline forecast developed for the original LUCI model.

- **Baseline Forecasts 4A and 4B** assume greater dispersal of development than would otherwise have been predicted by the model. Dispersal refers to the tendency for development to cluster around previously developed areas. A dispersal setting of 25 was selected, where zero means no increase in dispersal and 50 is maximum dispersal of development, with all grid cells being given an equal probability. This has the effect of decreasing the amounts of new development in the inner, higher probability development portions of the study area and increasing the amounts of new development in the outlying areas.

The results of the baseline forecasts are illustrated in Figure 4.1. The map on the upper left shows the pattern of existing urban development in the region, expressed as the share of each one-square mile grid cell that is urbanized. The other three maps show the differences in the patterns of development that have been simulated for the 25-year period for Baseline Forecasts 2B, 3B, and 4B. (Baseline Forecasts 1, 2A, and 2B show similar patterns. Likewise, the A and B versions of Baseline Forecasts 2, 3, and 4 are very much the same. Therefore, only maps for Baseline Forecasts 2B, 3B, and 4B are shown for comparison.)

Figure 4.1 Comparison of 2025 Baseline Forecasts
Change in Urbanized Area



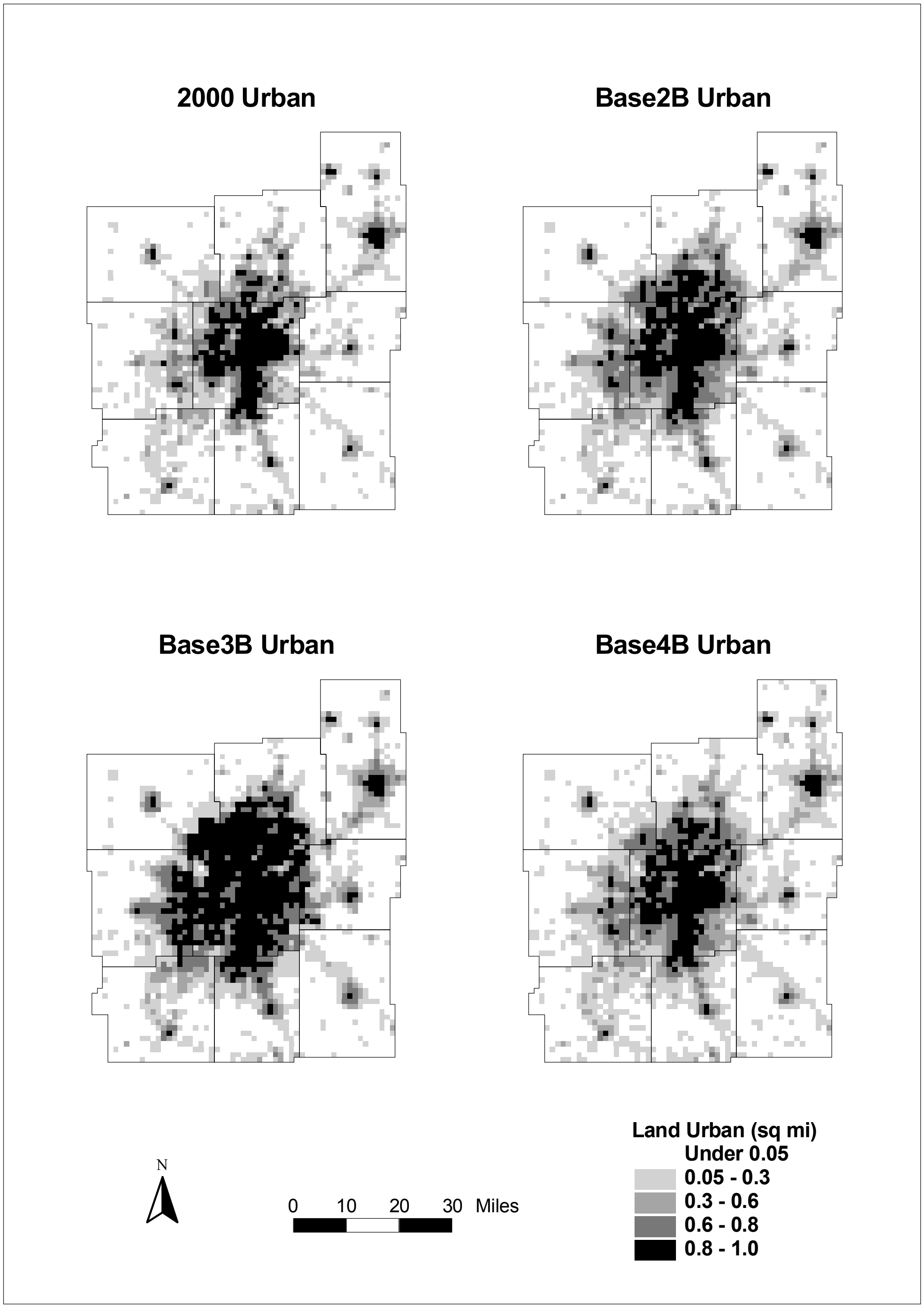
Source: IUPUI, 2003.

The map for Baseline Forecast 2B shows new urban development clustered around the existing urban areas. For Baseline Forecast 3B, with its much lower density of development, the area of urban development is much larger, and a higher proportion of the land in the areas of development is converted to urban use. The map for Baseline Forecast 4B illustrates the effect of increasing the dispersal of development, with lower proportions of the land in the developing areas being converted to urban use and with the areas of significant development extending farther out from the previously urbanized areas.

Figure 4.2 shows the final amount of urban development for 2025 for the three baseline forecasts. These maps reflect the sum of the development in 2000 and the change between 2000 and 2025 shown above. The map for Baseline Forecast 2B shows the expansion of the area of urban development in comparison to that in 2000. It retains the mixture of more- and less-developed grid cells in the outer parts of the urban area. Baseline Forecast 3B has a much higher proportion of land in urban use throughout more of the area, as the lower densities of development force the conversion of more of the land to accommodate the same population growth. For Baseline Forecast 4B with the increased dispersal of development, less of the land is urban closer in and there is more land with at least modest levels of urban development extending farther away from the centers.

These maps for the baseline forecasts demonstrate the extent to which the pattern of urban development simulated by the model can be adjusted to reflect alternative assumptions regarding how future urban development is likely to occur.

Figure 4.2 Comparison of 2025 Baseline Forecasts
Total Urbanized Area



Source: IUPUI, 2003.

4.2.1 Population Comparison with MPO and INDOT Forecasts

The population forecast for 2025 by counties and townships by the MPO, INDOT, the LUCI Baseline Forecast 2, and the seven LUCI/T baseline forecasts are summarized Table 4.1. These forecasts differ slightly from the Woods and Poole-derived forecasts that are discussed in Section 1.0 and that were used throughout the study for transportation and land use forecasting, but are considered to be sufficient for model validation.

Baseline Forecasts 1, 2A, and 2B render similar population forecast results. These results are also generally comparable to the original LUCI baseline forecast. For the outlying counties, the three LUCI/T forecasts are slightly higher than the LUCI forecast for Boone County, and Baseline Forecasts 1 and 2B are slightly higher for Hamilton County. The forecasts for the remaining counties are quite similar. Within Marion County, the LUCI/T forecasts are a bit lower for Decatur and Warren Townships.

Looking at Baseline Forecasts 3 and 4, the most significant effect is the decrease in the predicted population for Hamilton County in comparison to the previous forecasts. Forecast populations in Morgan and Shelby Counties increase for all of these forecasts. With reduced population densities in Baseline Forecast 3, Hancock, Hendricks, and Johnson Counties also see increases as more of the increased demand for land is accommodated there. The dispersal of development with Baseline Forecast 4 causes increases in the predicted populations for Boone and Madison Counties. By pushing development farther out, these forecasts produce lower predicted populations for Marion County as a whole, with smaller populations forecast for most of the townships.

4.2.2 Household Comparison with MPO and INDOT Forecasts

The forecast of households produced by the model is proportional to the population forecasts. However, the household forecast bears a different relationship to those conducted by the MPO and INDOT, as those forecasts reflect differences in household sizes in different areas. Treating the model as allocating households requires the use of the region's mean household size. A value of 2.50 persons per household for the nine-county region was selected based on the 2000 Census and is a middle value between MPO and Woods and Poole 2025 forecasts that reflect a continued decline in household size. The household forecast for 2025 by counties and townships by the MPO, INDOT, the LUCI Baseline Forecast 2, and the seven LUCI/T baseline forecasts are summarized in Table 4.2.

Considering Baseline Forecasts 1, 2A, and 2B, the forecasts for numbers of households are considerably closer to the MPO and INDOT forecasts than were the population forecasts. Among the outlying counties, these three LUCI/T forecasts give predicted numbers of households that fall between the MPO and INDOT forecasts for five of the counties and are very close for Morgan County, where the MPO and INDOT forecasts are nearly identical. The LUCI/T forecasts of households are somewhat higher for Boone County and somewhat lower for Johnson County in comparison to the MPO and INDOT forecasts. The overall forecasts of households for Marion County are likewise closer to those other predictions. Fewer households are forecast for Marion County and the townships than were forecast using the original LUCI model, bringing the township forecast values closer to those forecast by the MPO and INDOT. For households, the Baseline Forecasts 3 and 4 vary with respect to the Baseline Forecasts 1 and 2 in exactly the same way as did population.

Table 4.1 Comparison of Population Forecasts by County and Marion Township

2025

Area	MPO Forecast	INDOT Forecast	Baseline Forecasts							
			LUCI	LUCI/T						
			Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties										
Boone	67,100	64,114	67,649	73,504	71,623	72,673	70,726	71,845	77,845	78,863
Hamilton	344,200	279,198	269,957	273,952	268,964	273,380	259,054	261,520	261,268	264,660
Hancock	78,800	84,618	80,999	80,911	81,331	80,618	89,643	89,050	82,685	82,194
Hendricks	183,600	166,892	165,166	162,334	161,774	162,237	164,251	165,369	157,793	157,746
Johnson	174,700	168,330	144,836	140,934	143,572	141,964	148,927	147,426	143,608	142,369
Madison	124,000	145,968	142,269	141,906	141,028	140,956	144,549	144,555	149,768	149,772
Morgan	85,000	87,738	76,965	76,662	78,040	77,291	82,240	81,347	84,498	83,973
Shelby	47,400	52,638	49,835	49,119	49,222	49,303	51,383	51,522	59,188	59,237
Marion County Townships										
Center	151,330	160,716	167,158	166,956	166,921	166,925	166,834	166,839	166,754	166,758
Decatur	30,840	23,700	42,380	39,023	40,466	39,504	39,370	38,763	36,929	36,270
Franklin	47,990	24,353	53,313	51,396	53,880	52,348	52,116	50,947	48,940	47,701
Lawrence	114,750	88,273	119,447	120,403	119,979	120,139	116,782	116,886	117,114	117,253
Perry	92,670	94,168	106,578	103,977	104,815	104,251	102,941	102,645	102,359	101,866
Pike	68,970	53,705	85,907	85,881	85,285	85,611	83,215	83,421	83,317	83,597
Warren	95,570	92,218	114,460	111,664	112,459	111,818	110,280	109,994	108,775	108,275
Washington	126,740	180,570	139,006	138,753	138,176	138,484	135,937	136,082	136,850	137,129
Wayne	125,170	171,121	136,609	135,856	135,723	135,752	134,927	134,970	134,582	134,601
County Total	**854,030**	**888,824**	**964,858**	**953,908**	**957,704**	**954,833**	**942,401**	**940,546**	**935,620**	**933,450**
Region Total[a]	**1,958,830**	**1,938,320**	**1,962,533**	**1,953,231**	**1,953,259**	**1,953,256**	**1,953,173**	**1,953,180**	**1,952,273**	**1,952,266**

[a] The LUCI/T validation analysis was conducted early in the study using MPO forecasts which differ somewhat from the Woods and Poole-derived forecasts that were subsequently developed for CISTMS. As a result, the regional population totals do not correspond exactly with those presented in previous sections. The updated socioeconomic forecasts were used in the development of land use forecasts for the Minimum Change and Maximum Change alternatives and the sensitivity analyses described below.

Table 4.2 Comparison of Household Forecasts by County and Marion Township

2025

			Baseline Forecasts							
	MPO	INDOT	LUCI	LUCI/T						
Area	**Forecast**	**Forecast**	**Base 2**	**Base 1**	**Base 2A**	**Base 2B**	**Base 3A**	**Base 3B**	**Base 4A**	**Base 4B**
Outlying Counties										
Boone	26,320	24,723	27,853	29,401	28,649	29,069	28,290	28,738	31,138	31,545
Hamilton	132,390	103,165	111,151	109,581	107,586	109,352	103,622	104,608	104,507	105,864
Hancock	38,570	30,958	33,350	32,365	32,533	32,247	35,857	35,620	33,074	32,878
Hendricks	66,450	60,431	68,005	64,934	64,710	64,895	65,700	66,148	63,117	63,099
Johnson	67,190	63,054	59,634	56,374	57,429	56,786	59,571	58,970	57,443	56,948
Madison	51,700	57,613	58,577	56,762	56,411	56,383	57,820	57,822	59,907	59,909
Morgan	32,720	32,212	31,689	30,665	31,216	30,916	32,896	32,539	33,799	33,589
Shelby	19,100	20,214	20,519	19,648	19,689	19,721	20,553	20,609	23,675	23,695
Marion County Townships										
Center	66,180	66,251	68,825	66,782	66,768	66,770	66,734	66,736	66,701	66,703
Decatur	12,100	8,531	17,449	15,609	16,186	15,802	15,748	15,505	14,772	14,508
Franklin	19,190	8,676	21,951	20,558	21,552	20,939	20,846	20,379	19,576	19,080
Lawrence	46,840	33,942	49,181	48,161	47,991	48,056	46,713	46,754	46,845	46,901
Perry	39,600	39,313	43,882	41,591	41,926	41,700	41,176	41,058	40,944	40,746
Pike	31,490	24,809	35,371	34,352	34,114	34,244	33,286	33,368	33,327	33,439
Warren	41,190	37,691	47,127	44,666	44,984	44,727	44,112	43,998	43,510	43,310
Washington	60,350	81,830	57,234	55,501	55,271	55,394	54,375	54,433	54,740	54,852
Wayne	55,140	71,902	56,247	54,343	54,289	54,301	53,971	53,988	53,833	53,840
County Total	**372,080**	**372,945**	**397,266**	**381,563**	**383,081**	**381,933**	**376,961**	**376,219**	**374,248**	**373,380**
Region Total[a]	**806,520**	**765,315**	**808,045**	**781,292**	**781,304**	**781,302**	**781,269**	**781,272**	**780,909**	**780,906**

[a] The LUCI/T validation analysis was conducted early in the study using MPO forecasts which differ somewhat from the Woods and Poole-derived forecasts that were subsequently developed for CISTMS. As a result, the regional household totals do not correspond exactly with those presented in previous sections. The updated socioeconomic forecasts were used in the development of land use forecasts for the Minimum Change and Maximum Change alternatives and the sensitivity analyses described below.

4.2.3 Urban Land Area Comparison

Unlike population and households, comparison of the urbanized land forecasts between the MPO and the LUCI baselines is more complex. (The INDOT forecast does not include predictions of urban land area.) Difficulties arise from different ways in which urban land use is defined and measured and also from some issues associated with the MPO data. Keeping these caveats in mind, the 2025 urbanized land forecast for counties and townships by the MPO, the LUCI Baseline Forecast 2, and the seven LUCI/T baseline forecasts are summarized in the Table 4.3.

The Baseline Forecasts 1 and 2 of the amounts of urban land are very similar to the baseline forecast shown for the original LUCI model. For all areas, the amounts of urban land predicted by these forecasts are substantially less than the amounts forecasted by the MPO. The LUCI/T forecasts generally range from about one-half to three-quarters of the MPO forecast values. Exceptions exist in the more heavily urbanized townships of Marion County, where the values are closer, and for Boone and Shelby Counties, where the MPO forecasts are very high. The latter is attributable to differences in methodologies as earlier noted.

The *Baseline Forecast 3*, with the much lower density of development, predicts greater amounts of urban land than would be expected. These differences are most dramatic in the outlying counties. The dispersal of development specified in *Baseline Forecast 4* resulted in somewhat higher predictions of the amounts of urban land in the outlying counties both because of the displacement of some development from Marion County and because development farther from the centers will tend to be somewhat less dense. With the dispersal of urban development, the urbanized land forecasts for the townships in Marion County were somewhat lower than the amounts predicted by the first three baseline forecasts.

The percentage increases in urban land predicted by the MPO forecast and the baseline forecasts were also compared in Table 4.4. The first three baseline forecasts predict percentage increases in the amounts of urban land that are reasonably close to the MPO predictions for the townships in Marion County. For the outlying counties, the baseline forecast percentage increases are much less for the baseline forecasts than for the MPO forecast. Given that the *Baseline Forecast 3* predicts lower density development, the predicted increases in urban land for the outlying counties are, of course, far higher. These percentage increases are higher than the MPO forecasts for some counties and lower for others. So in this respect, the lower-density baseline forecasts appear to be more comparable to the MPO forecast.

Table 4.3 Comparison of Urbanized Land Area Forecasts by County and Marion Township

2025

		Baseline Forecasts							
	MPO	LUCI	LUCI/T						
Area	Forecast	Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties									
Boone	91,540	18,108	19,817	19,144	19,358	27,290	27,819	25,207	25,405
Hamilton	120,821	66,228	69,434	67,728	68,597	88,148	89,104	67,613	68,244
Hancock	37,540	21,853	22,047	21,867	21,660	35,717	35,404	24,579	24,455
Hendricks	88,249	50,228	50,609	49,960	49,994	70,235	70,706	51,443	51,391
Johnson	85,130	36,384	35,867	36,195	35,780	50,086	49,349	37,993	37,710
Madison	46,839	36,182	35,878	35,470	35,445	41,928	41,944	42,033	42,045
Morgan	45,637	24,341	24,173	24,377	24,177	32,121	31,664	29,947	29,841
Shelby	43,889	11,577	11,165	11,128	11,139	15,242	15,304	18,222	18,260
Marion County Townships									
Center	24,673	24,918	24,912	24,902	24,902	25,053	25,054	24,867	24,867
Decatur	18,917	11,059	10,723	10,894	10,689	14,507	14,272	10,012	9,877
Franklin	20,593	13,262	13,264	13,575	13,263	18,750	18,286	12,359	12,107
Lawrence	27,317	22,209	22,798	22,635	22,647	24,710	24,730	21,897	21,908
Perry	28,237	22,812	22,667	22,740	22,631	24,760	24,662	22,150	22,054
Pike	21,305	18,571	18,687	18,525	18,570	20,076	20,132	18,048	18,087
Warren	29,369	23,314	23,149	23,190	23,060	26,058	25,963	22,292	22,189
Washington	26,120	26,479	26,699	26,575	26,615	27,336	27,369	26,280	26,318
Wayne	30,184	26,284	26,298	26,245	26,245	27,134	27,143	25,980	25,979
County Total	**226,715**	**188,907**	**189,197**	**189,281**	**188,622**	**208,385**	**207,612**	**183,885**	**183,385**
Region Total	**786,360**	**453,808**	**458,187**	**455,150**	**454,772**	**569,152**	**568,907**	**480,923**	**480,736**
Total	**60.4%**	**29.2%**	**30.6%**	**29.8%**	**29.6%**	**62.3%**	**62.2%**	**37.1%**	**37.0%**

Table 4.4 Comparison of Change in Urbanized Land Area by County and Marion Township
2000-2025

		Baseline Forecasts							
		LUCI	LUCI/T						
Area	**MPO Forecast**	**Base 2**	**Base 1**	**Base 2A**	**Base 2B**	**Base 3A**	**Base 3B**	**Base 4A**	**Base 4B**
Outlying Counties									
Boone	116.4%	59.3%	74.3%	68.4%	70.3%	140.1%	144.7%	121.7%	123.5%
Hamilton	126.3%	52.3%	59.8%	55.9%	57.9%	102.8%	105.0%	55.6%	57.0%
Hancock	95.5%	59.6%	61.0%	59.7%	58.2%	160.8%	158.5%	79.5%	78.6%
Hendricks	144.2%	56.1%	57.4%	55.4%	55.5%	118.5%	120.0%	60.0%	59.9%
Johnson	92.0%	37.1%	36.4%	37.7%	36.1%	90.5%	87.7%	44.5%	43.5%
Madison	2.3%	13.6%	12.7%	11.4%	11.3%	31.7%	31.8%	32.0%	32.1%
Morgan	68.8%	22.7%	22.0%	23.1%	22.0%	62.1%	59.8%	51.2%	50.6%
Shelby	90.5%	29.7%	26.0%	25.6%	25.7%	72.0%	72.7%	105.7%	106.1%
Marion County Townships									
Center	0.1%	0.8%	0.8%	0.8%	0.8%	1.4%	1.4%	0.6%	0.6%
Decatur	54.1%	60.9%	56.1%	58.5%	55.6%	111.1%	107.7%	45.7%	43.7%
Franklin	75.6%	70.8%	70.8%	74.8%	70.8%	141.5%	135.5%	59.1%	55.9%
Lawrence	15.0%	17.2%	20.3%	19.5%	19.5%	30.4%	30.5%	15.6%	15.6%
Perry	12.0%	14.7%	14.0%	14.3%	13.8%	24.5%	24.0%	11.4%	10.9%
Pike	3.0%	16.0%	16.8%	15.8%	16.0%	25.5%	25.8%	12.8%	13.0%
Warren	17.3%	20.6%	19.7%	19.9%	19.3%	34.8%	34.3%	15.3%	14.7%
Washington	1.2%	6.7%	7.6%	7.1%	7.2%	10.1%	10.3%	5.9%	6.0%
Wayne	1.3%	5.2%	5.3%	5.0%	5.0%	8.6%	8.6%	4.0%	4.0%
County Total	**14.0%**	**15.7%**	**15.8%**	**15.9%**	**15.5%**	**27.6%**	**27.1%**	**12.6%**	**12.3%**

4.2.4 Comparisons at the Township and TAZ Level

A brief statistical comparison was conducted for the LUCI/T baseline forecasts and the MPO forecasts at more detailed levels of geography – townships and MPO TAZs. The LUCI/T baseline forecast results for these spatial units were estimated by apportioning the areas of the grid cells according to township or TAZ boundaries. For the TAZs, which are much smaller, this estimation procedure at times resulted in significant error. The results of these statistical comparisons are exhibited in Tables 4.5 and 4.6.

The correlations of the LUCI/T baseline forecast populations with the MPO forecast population and households are very high, all being above 0.98. The correlations of the household forecasts are even slightly higher, with most being 0.99 or above. While these forecast totals are the relevant values for the travel demand model, comparison of the forecast changes provide a more stringent test, as these do not include the starting population or household numbers. The correlations of the changes in population forecast by the LUCI/T baseline forecasts and the changes from the MPO forecast are still quite high, all being above 0.70. These correlations are higher than the correlation of the original LUCI baseline forecast of population change with the MPO forecast. The correlations involving the predictions of household change are even higher, with most greater than 0.80. This further supports the possibility raised above of interpreting the LUCI forecasts as forecasts of households rather than population. The correlations between the baseline forecasts of percentage urban change with the MPO forecasts are all near 0.90 or above.

As would be expected, with the much greater number of smaller TAZs, the correlations between forecasts are lower. However, the correlations between population and households as predicted by the LUCI/T baseline forecasts and the MPO forecast are still quite good. All correlations exceed 0.80. The correlations involving population and household changes are substantially lower, ranging from 0.44 to 0.51 for the correlations between the LUCI/T baseline forecasts and the MPO forecasts of population and household change. The correlations for the LUCI/T baseline forecasts were all somewhat higher than the corresponding correlations for the original LUCI model baseline forecast provided for comparison. Contrary to what was observed with the correlations across townships, for all but one of the baseline forecasts, the correlations involving population change exceeded the correlations involving household change. So this makes the question of which might be the better prediction more ambiguous. The correlations between the baseline forecasts of percentage urban change with the MPO forecasts were all high, exceeding 0.80.

Table 4.5 Correlation across Townships of MPO Forecast Values with LUCI/T Forecast Values

	Baseline Forecasts							
	LUCI	LUCI/T						
Area	Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
MPO Forecast Population with LUCI/T Forecast Population	0.984	0.985	0.985	0.985	0.982	0.982	0.982	0.983
MPO Forecast Households with LUCI/T Forecast Households	0.990	0.991	0.991	0.991	0.989	0.989	0.990	0.991
MPO Forecast Population Change with LUCI/T Forecast Population Change	0.702	0.735	0.725	0.737	0.705	0.711	0.747	0.756
MPO Forecast Household Change with LUCI/T Forecast Household Change	0.793	0.820	0.811	0.822	0.780	0.786	0.825	0.834
MPO Forecast Percent Urban with LUCI/T Forecast Percent Urban	0.909	0.926	0.928	0.927	0.896	0.896	0.933	0.932

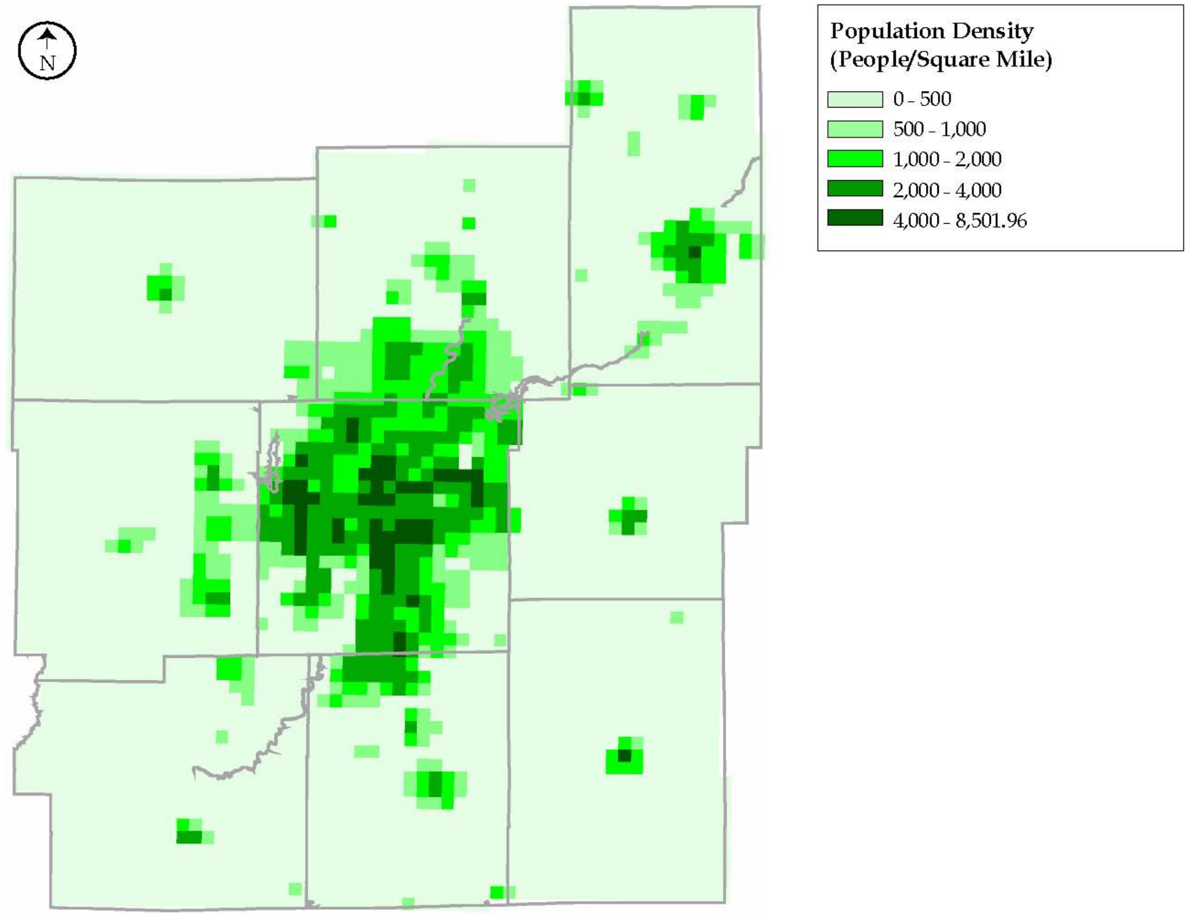
Table 4.6 Correlation across TAZs of MPO Forecast Values with LUCI/T Forecast Values

	Baseline Forecasts							
	LUCI	LUCI/T						
Area	Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
MPO Forecast Population with LUCI/T Forecast Population	0.805	0.810	0.809	0.811	0.815	0.816	0.817	0.818
MPO Forecast Households with LUCI/T Forecast Households	0.805	0.809	0.808	0.809	0.815	0.816	0.817	0.818
MPO Forecast Population Change with LUCI/T Forecast Population Change	0.489	0.515	0.506	0.516	0.491	0.495	0.478	0.486
MPO Forecast Household Change with LUCI/T Forecast Household Change	0.426	0.447	0.440	0.490	0.479	0.449	0.492	0.484
MPO Forecast Percent Urban with LUCI/T Forecast Percent Urban	0.871	0.861	0.864	0.863	0.801	0.802	0.873	0.872

■ 4.3 Minimum Change Forecast

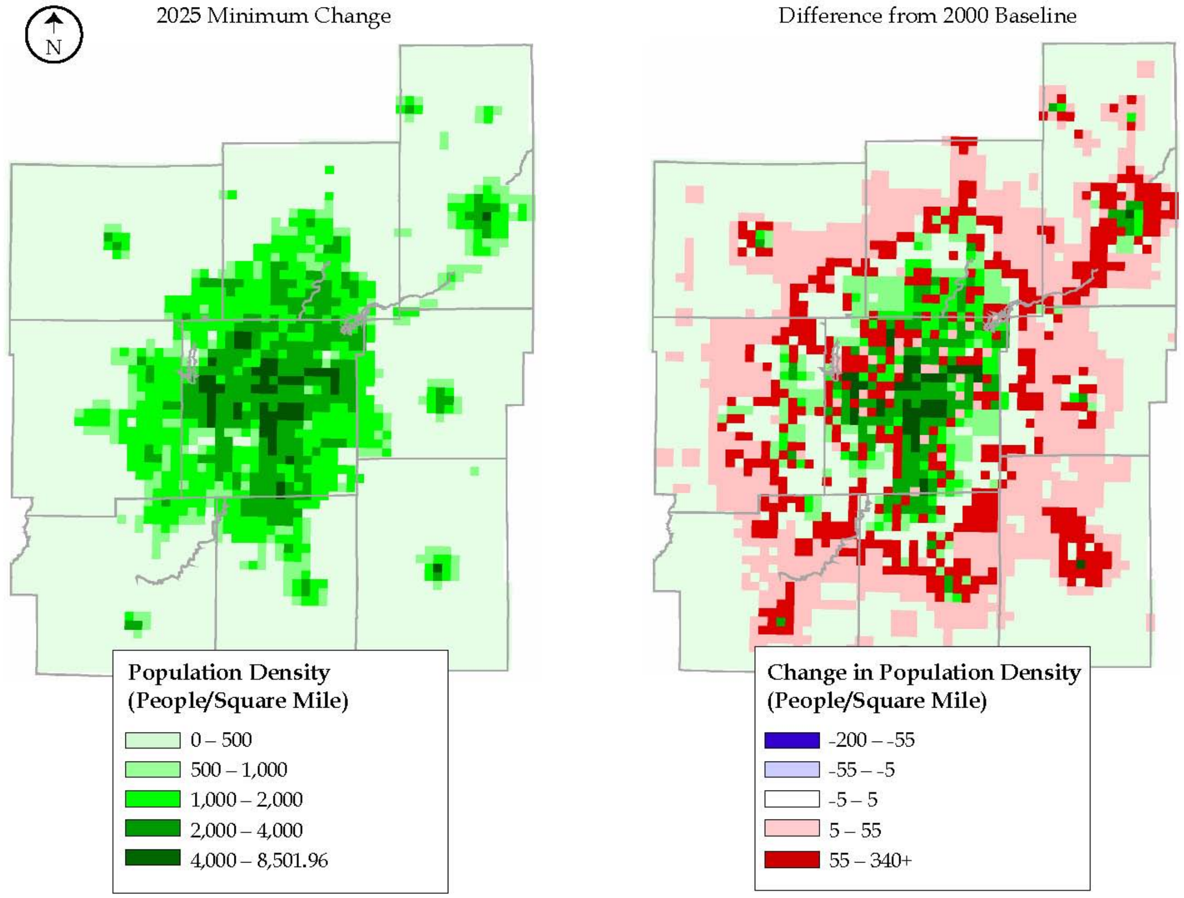
In 2000, the nine-county Indianapolis region included approximately 550 square miles of urbanized land, as estimated from satellite imagery upon which the LUCI/T model is based. Of this total, nearly half (255 square miles) was in Marion County. In the eight outlying counties, urbanized land ranged from a high of 69 square miles in Hamilton County to a low of 14 square miles in Shelby County. Figure 4.3 shows the existing population density in the region, which serves as the baseline condition for LUCI/T forecasts.

Figure 4.3 2000 Baseline Population Density



The 2025 Minimum Change forecasts, depicted in Figure 4.4, project an increase in urbanized land area of 299 square miles or 54 percent, bringing the total urbanized land area in the region to 849 square miles. Marion and Hamilton Counties are forecast to experience the largest magnitude of urbanization, with each developing between 60 and 65 square miles of land or just more than 20 percent of regional new land urbanized. Other counties, in descending order of projected square miles of new land urbanized, are Hendricks (51), Johnson (33), Hancock (28), Boone (23), Morgan (15), Madison (14), and Shelby (nine).

Figure 4.4 2025 Minimum Change Land Use Forecast



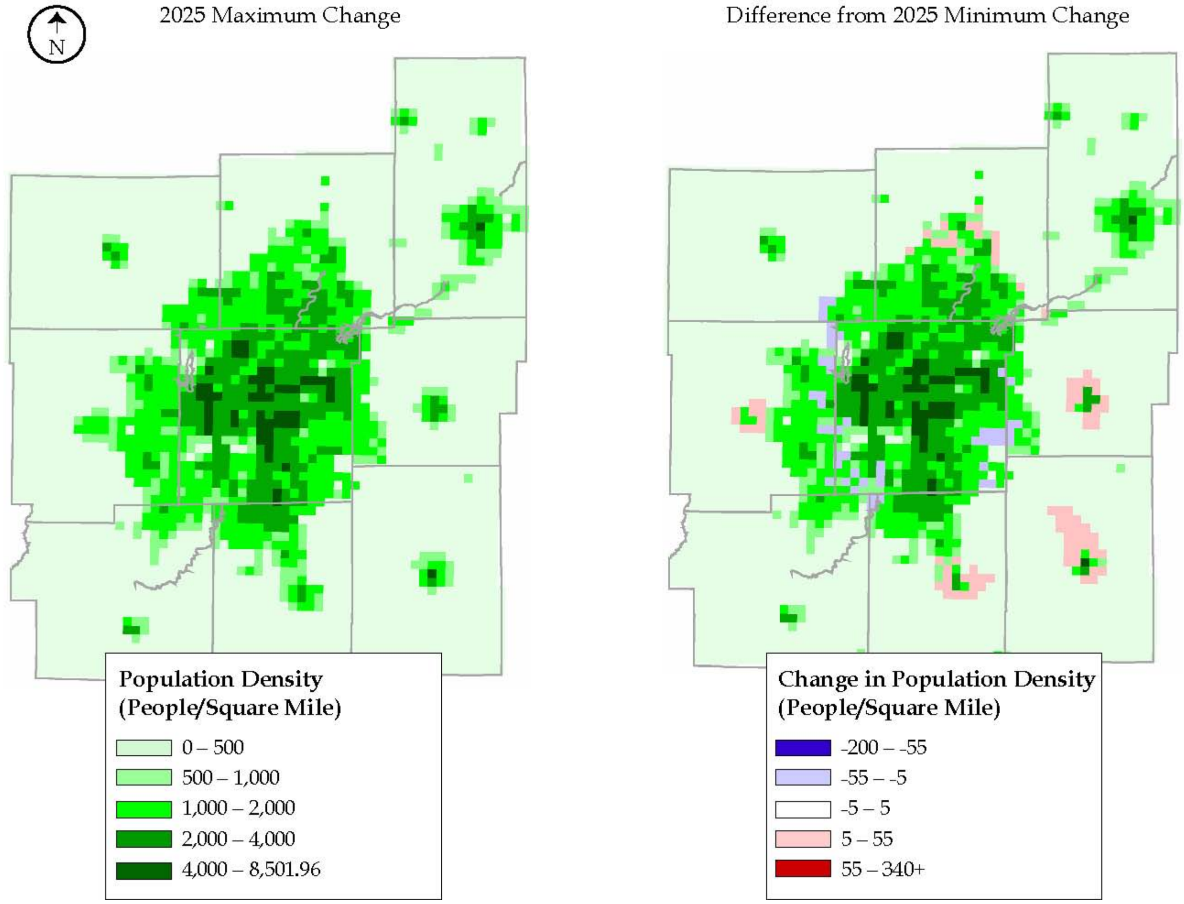
LUCI/T was initially run using uncongested travel times as the transportation accessibility measure for projecting land urbanization in 2025 under the Minimum Change alternative. Because the results showed negligible differences between alternatives, congested travel times were substituted in the development of final forecasts. The model validation process described above was conducted using free-flow travel times. While the relative importance of peak versus off-peak travel conditions in affecting the locational decisions of people and businesses is not known, it is likely that peak-period conditions do have a significant impact, especially for commuters and commuter-reliant businesses.

■ 4.4 Effects of Maximum Change Alternative

In comparison to the 2025 Minimum Change alternative, the 2025 Maximum Change alternative, depicted in Figure 4.5, is based on the 2025 Maximum Change road network along with the corresponding employment reallocations as projected by the expert panel. Evaluated at a county level, the land use modeling for the Maximum Change alternative shows negligible changes in total urbanized land area in comparison to the Minimum

Change alternative. The differences are less than 0.1 square mile per county. When mapped and viewed at the level of the one-mile grid cell, only very minor differences can be observed in the locations of urbanized land on the urban fringes of the region.

Figure 4.5 2025 Maximum Change Land Use Forecast



The very small differences in land use patterns that appear under the Maximum Change alternative were considered to have negligible impacts on regional transportation performance measures. For this reason, it was decided that the feedback analysis depicted in Figure 1.8 would not be warranted. If significant land use changes were found to result from the circumferential highway, this analysis would be useful in estimating the combined effects of transportation and land use changes on travel patterns and traffic volumes. As it turned out, the effects are believed to be below the sensitivity threshold of the travel demand model for producing reliable insights.

5.0 Sensitivity Tests

5.0 Sensitivity Tests

The findings described in Section 4.0 suggest that the CISTMS alternatives will have minor impacts on land use patterns when viewed from a regional perspective. To further test this finding, a number of sensitivity tests were run to determine the impact of the Maximum Change alternative under different assumptions. These sensitivity tests included:

- More significant reallocation of employment under the Maximum Change alternative, in comparison to that predicted by the expert panel;
- Examination of impacts over a longer time horizon, through 2040 as well as 2025;
- Changes in the average density of new development; and
- Changes in policies regarding the provision of water and sewer as well as assumptions regarding the sensitivity of development to the availability of utilities.

Testing in the previous section found that the use of congested travel times when predicting development trends led to somewhat more pronounced effects than the use of uncongested travel times. For consistency with the forecasts and because impacts using free flow travel times were frequently so small as to be virtually impossible to observe, congested travel times were used for all of these sensitivity analyses.

■ 5.1 Reallocation of Employment

The expert panel forecast a reallocation of approximately 45,000 jobs in 2025 under the Maximum Change alternative in comparison to the Minimum Change alternative, or 3.0 percent of regional employment. Two alternative, and more aggressive, reallocation scenarios were also tested in case the expert panel's forecast of impacts is conservative. The various employment scenarios tested include:

- "Base" = Expert panel-derived allocation under the Minimum Change scenario, based on the MPO forecast;
- "Max" = Expert panel-derived reallocation under the Maximum Change scenario (Figure 5.1);
- "NewMax1" = Maximum Change Scenario 1 = "Max" with additional employment at the interchange between I-69 and the corridor in the northeast (Figure 5.2); and
- "NewMax2" = Maximum Change Scenario 2 = Triple the NewMax1 employment shift to the corridor (Figure 5.2).

The NewMax1 scenario allocates about 20,000 additional jobs to the area near the intersection of I-69 and the corridor in the northeast, assuming that this area will become a significant employment center. The NewMax2 scenario triples the expert panel-forecast increase in employment in each TAZ in the corridor, as well as the additional increase in the northeast assumed under the NewMax1 scenario. The additional corridor employment is reallocated from other TAZs in the nine-county region in proportion to their baseline levels of total employment. The total reallocation of jobs under this scenario is about 231,000 jobs or 15 percent of total regional employment.

Figure 5.1 Expert Panel-Derived Employment Shift under Maximum Change Scenario

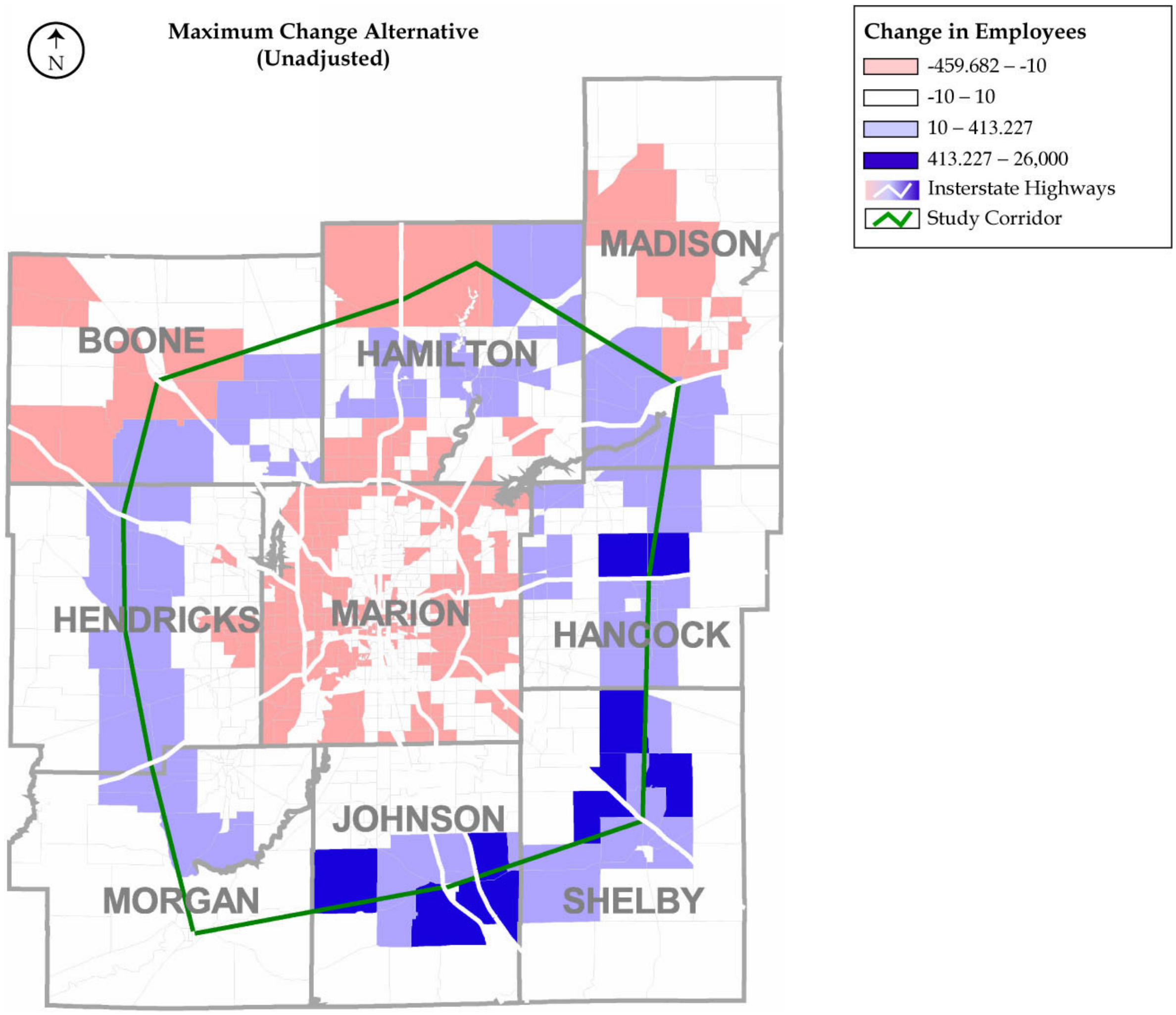
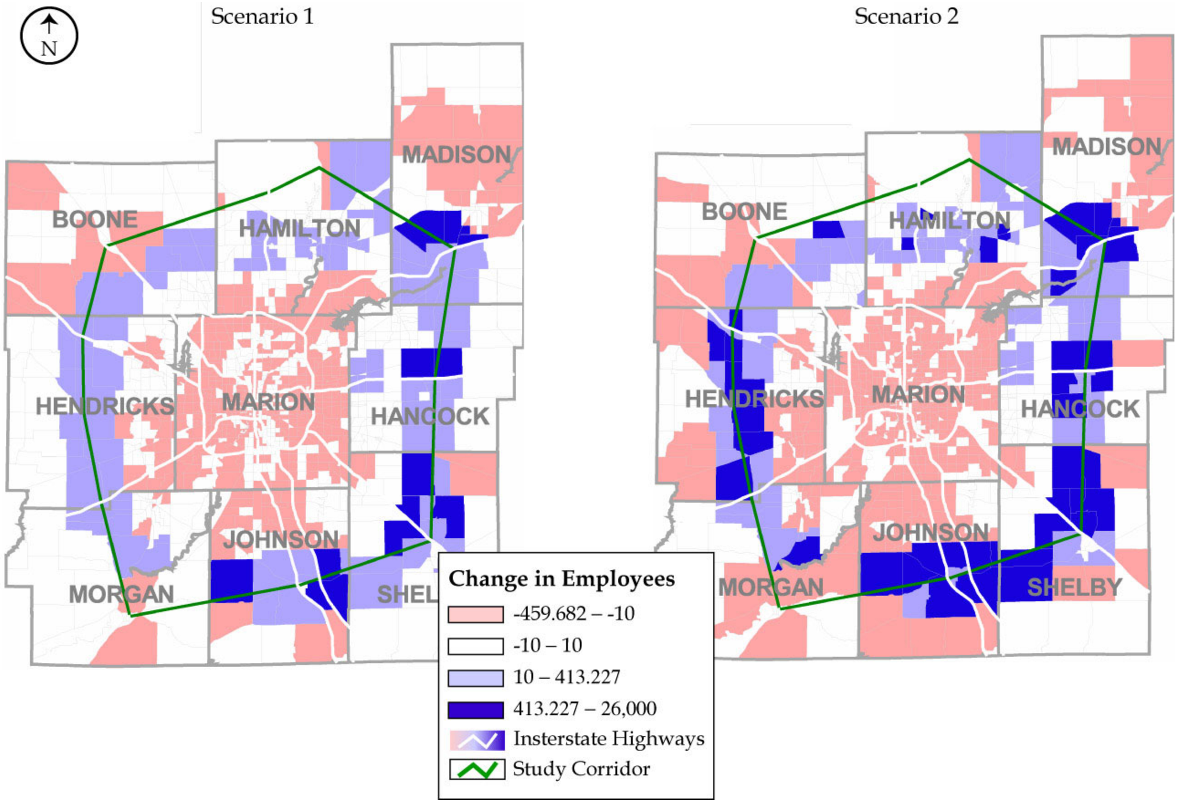


Figure 5.2 Alternative "Maximum Change" Employment Allocations



Note: Graphical employment ranges shown are same as in Figure 5.1.

The findings show that the more aggressive employment reallocation scenarios do lead to a slightly more measurable effect on land use patterns, but nonetheless an effect that is still negligible by regional standards. For example, the Maximum Change scenario shows a change of less than 0.1 square mile in urbanized land area per county, in comparison to the Minimum Change scenario. The NewMax1 scenario shows a slight increase in land urbanized in Madison County (about one square mile), while the NewMax2 scenario shows a larger increase (about three square miles) along with a corresponding decrease of no more than one square mile per county in other counties. As expected, the additional employment in Madison County draws more residents to this County. However, the additional change is relatively small in comparison to the existing 50 square miles of land urbanized in 2000 and to the projected urbanization of an additional 14 square miles of land by 2025.

Figure 5.3 Difference in Urbanization for NewMax1 versus Max Employment Allocation Scenario, *2025*

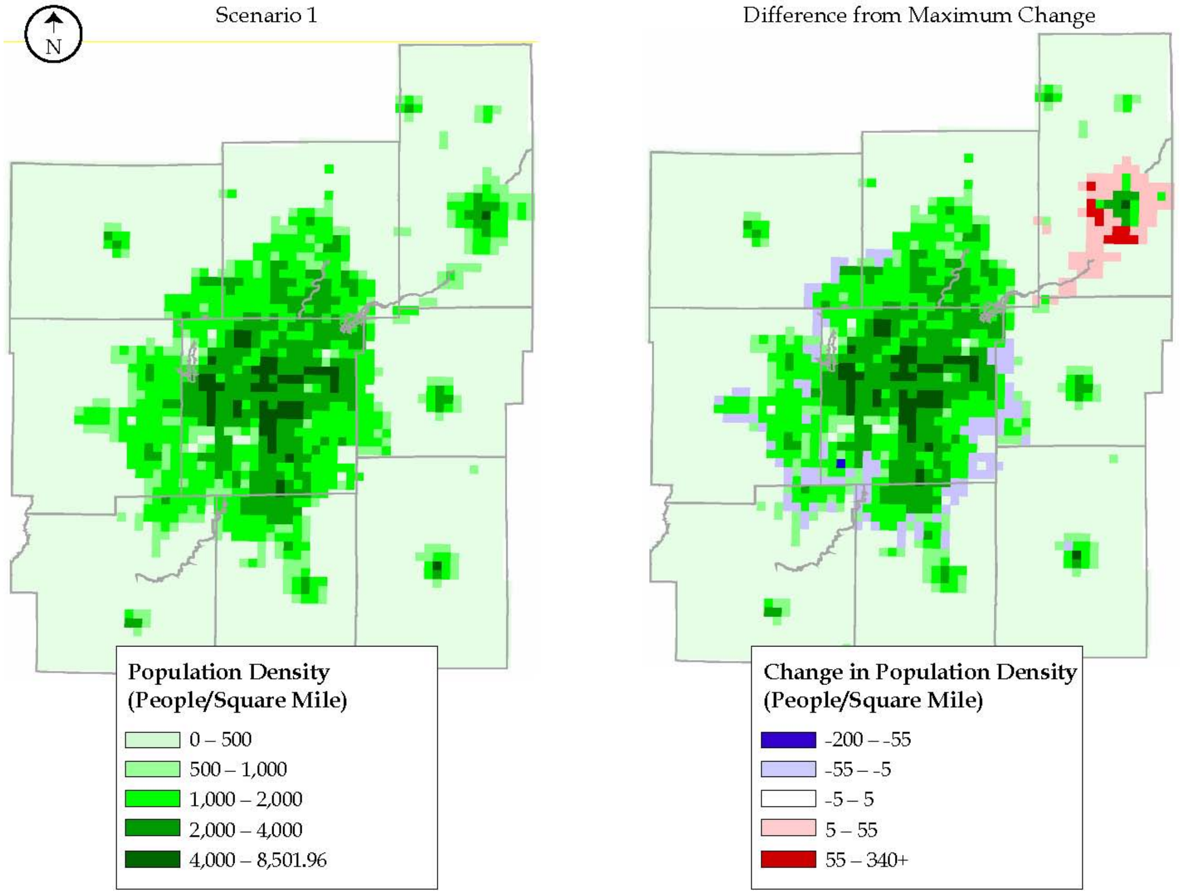
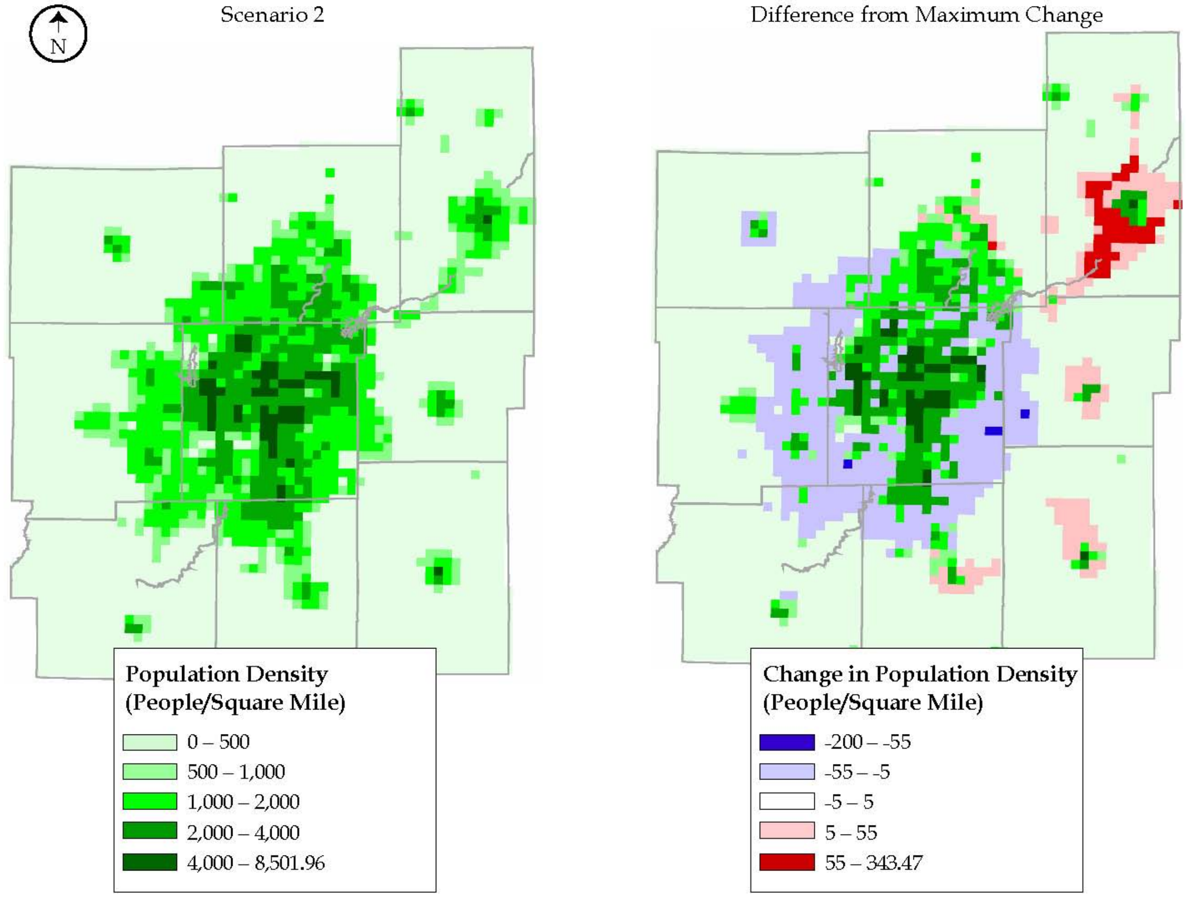


Figure 5.4 Difference in Urbanization for NewMax2 versus Max Employment Allocation Scenario, *2025*



■ 5.2 Timeframe of Impacts

An examination of impacts in 2040 provides a perspective on the potential longer term impacts of the CISTMS project. While making development projections for 2040 is, of course, even more speculative than doing so for 2025, it is not so much the accuracy of the absolute numbers projected that is of interest, but rather the *differences* in patterns that emerge as a result of differences in transportation systems (and other factors) over this time horizon. Whereas the 2025 scenarios were run using congested travel times from the 2000 network, the 2040 scenarios were run using congested travel times from the 2025 network, beginning in 2025. Therefore, not only do the 2040 employment projections affect accessibility by TAZ and therefore attractiveness for development, but beginning in 2025, travel times that reflect the CISTMS project (under the Maximum Change scenario) affect accessibility and therefore begin to affect development patterns as well. In other words, the modeled 2040 urbanization results reflect not only the employment shifts resulting from the CISTMS project, but also the direct effect of the CISTMS transportation improvements on residential location patterns.

To estimate land use impacts in 2040, employment by TAZ was first projected, assuming that the same annual growth rate projected for the 2000-2025 period will be observed between 2025 and 2040. Because of projected declines in employment in certain TAZs (in part because of the need to reallocate employment under the Maximum Change scenario), or because of small baseline levels in some TAZs, the original 2040 projection resulted in negative employment levels in some TAZs. To prevent this from happening, employment in each TAZ was set at a minimum of zero, and the difference taken from other TAZs with positive employment, in proportion to each TAZ's total employment.

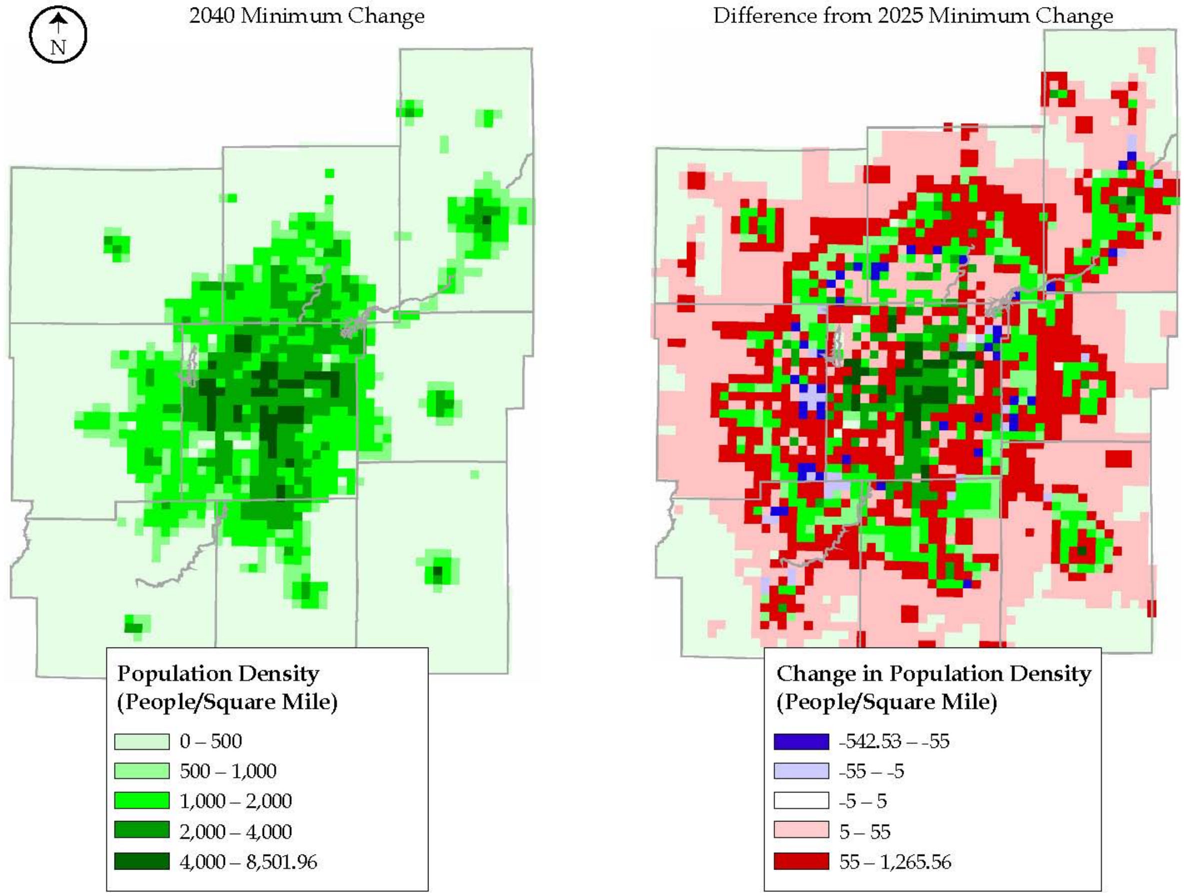
Figure 5.5 shows 2040 population density under the Minimum Change alternative. Figure 5.6 compares 2040 Minimum Change with 2040 Maximum Change forecasts. Examining patterns of urbanization under the Maximum Change versus Minimum Change alternatives in 2040 continues to show small impacts. Under the Maximum Change alternative, the model actually predicts a slight *decrease* in regional new urbanized land (542 versus 548 square miles newly urbanized between 2000 and 2040). There are slight decreases (about one square mile each) in Boone, Madison, Hancock, and Hendricks Counties. Morgan County shows a slight increase. The magnitude of these changes, however, cannot be considered significant in comparison to either existing or forecast levels of total urbanization in these counties.

Table 5.1 Change in Urbanized Land, 2000-2040 (Square Miles)

County	Minimum Change Scenario	Maximum Change Scenario	Max2 Scenario	Maximum versus Minimum	Max2 versus Minimum
Boone	42.6	41.7	41.1	-0.9	-1.5
Hamilton	100.8	100.5	99.4	-0.3	-1.4
Hancock	61.2	60.0	59.5	-1.2	-1.7
Hendricks	92.5	91.6	90.5	-0.9	-2.0
Johnson	68.4	68.1	67.2	-0.3	-1.2
Madison	35.4	34.3	39.2	-1.1	3.8
Marion	83.0	82.3	81.8	-0.7	-1.2
Morgan	37.3	37.7	36.8	0.4	-0.5
Shelby	26.7	26.4	26.7	-0.3	0.0
Total	**547.9**	**542.6**	**542.2**	**-5.3**	**-5.7**

The sensitivity impacts of alternative employment allocation scenarios (Max1 and Max2) show results similar to 2025 and only slightly larger in magnitude. These scenarios result in an increase in urbanization of three to four square miles in Madison County, and a slight decrease in most other counties, in comparison to the Minimum Change scenario.

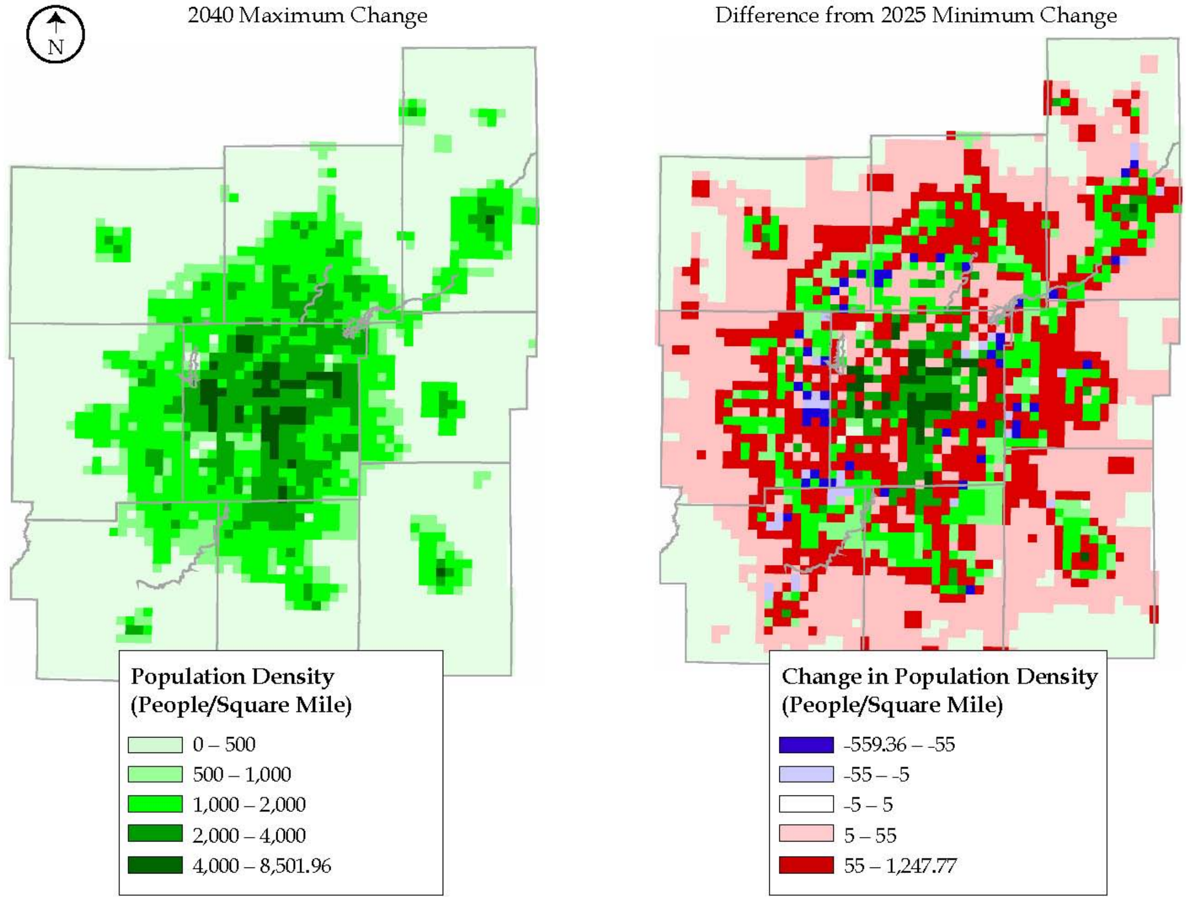
Figure 5.5 2040 Minimum Change Land Use Forecast



2040 Minimum Change

Difference from 2025 Minimum Change

Figure 5.6 Difference in Urbanization for Maximum Change versus Minimum Change Scenarios, *2040*



■ 5.3 Density of New Development

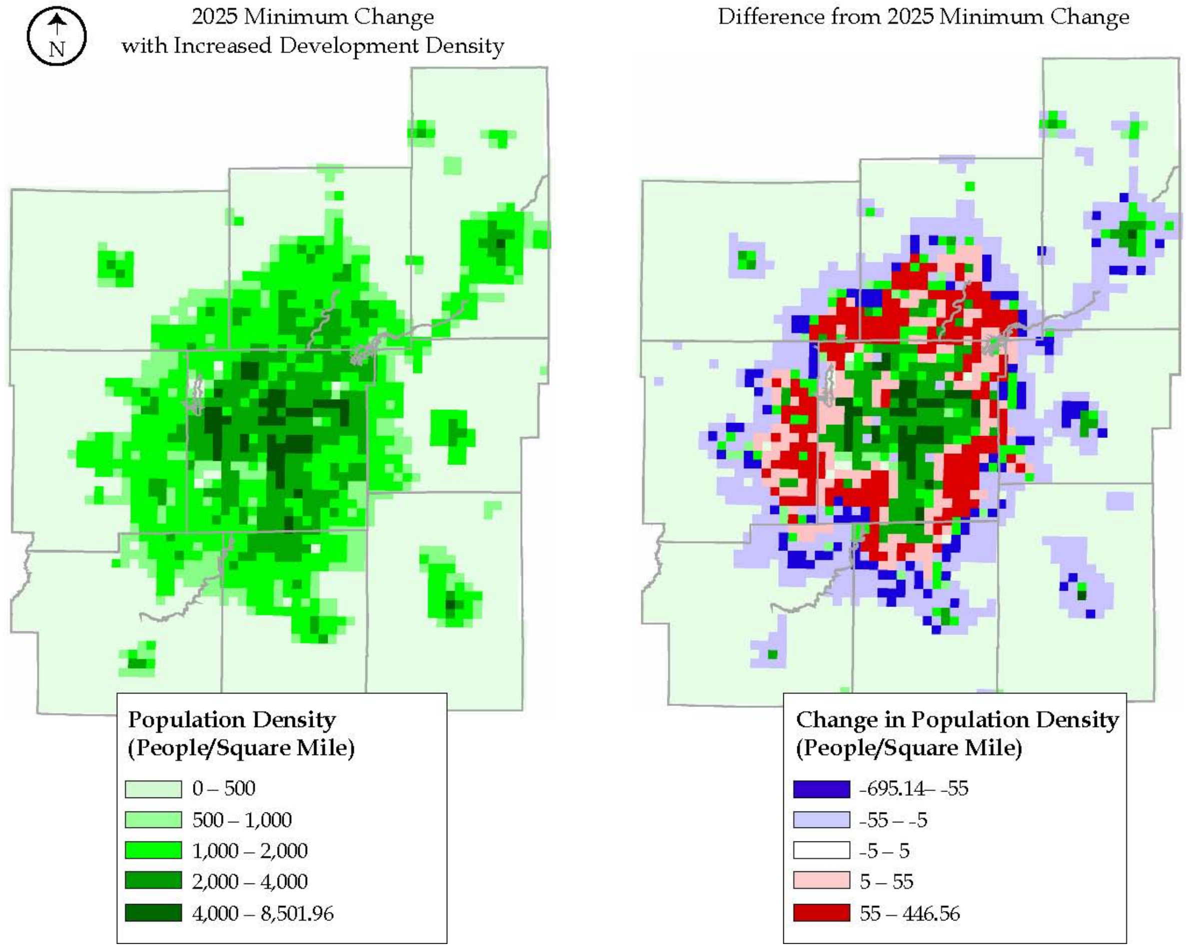
The LUCI/T model assumes that new development will be built at the same average densities as recent new development in the Indianapolis region, but allows for this assumption to be changed. Two alternative assumptions were tested: a 30 percent increase in the average density of new residential development, and a 30 percent decrease. Of these two assumptions, the first (increasing density) is believed to be more likely. National trends in most parts of the country show average residential densities increasing, in part because of smaller single-family lot sizes and in part because of a shift towards more multifamily units. However, trends in the Indianapolis region will depend upon both demographics and land values. Density increases are likely to be less than in many parts of the country because of the relative lack of constraints on the availability of land for development.

The density assumption has significant (and expected) impacts on the total amount of land urbanized. For comparison, the 2000 total urbanized land area is 550 square miles. Table 5.2 shows that the projected increase in urbanized land area ranges from 226 to 443 square miles in 2025 (41 to 81 percent), and from 408 to 840 square miles in 2040 (74 to 150 percent), in comparison to 2000 levels. The density assumption, though, has very little impact on the *relative* impact of the transportation improvements on development patterns. The overall impacts of the Maximum Change scenario in comparison to the Minimum Change scenario are generally proportional (in terms of new urbanized land area) to the density of new development. For example, the incremental impact of the Maximum Change scenarios in comparison to the Minimum Change scenario in 2040 ranges from 2.4 to 3.3 square miles urbanized land on a regionwide basis under the increased density assumption, versus a 5.3 to 6.2 square mile difference under the base density assumption. There are some minor variations in the effects by county, as shown in Figure 5.7.

Table 5.2 Additional Square Miles of Urbanized Land Area in Comparison to 2000

Year	Base Density	Density + 30 Percent	Density – 30 Percent
2025	299	226	443
2040	548	408	840

Figure 5.7 Effect of 30 Percent Increase in Density on Urbanization in 2025



■ 5.4 Utility Policies

The LUCI/T model considers utilities in the following ways. First, grid cells are assumed to be provided with utilities once their levels of urbanization reaches 20 percent. Second, the density of development increases if utilities are present. The utility assumptions, therefore, are relatively permissive – they assume that a certain amount of development can take place even without utilities, and that if enough development occurs in an area, utilities will be provided.

A number of sensitivity tests on the utility parameters (specifically, provision of water and sewer) were conducted:

- Requirements – Water and sewer were both made requirements for development (similar to establishing an urban growth boundary).
- Expansion policies – Moderate to aggressive expansion policies were tested that assume that utilities continue to be expanded regardless of whether development has

reached the 20 percent threshold. A "moderate expansion" scenario assumed that water and sewer would be expanded by 0.5 miles ever five years near major centers, and 0.2 miles every five years elsewhere. An "aggressive expansion" scenario assumed that water and sewer would be expanded by 0.8 miles ever five years near major centers, and 0.5 miles every five years elsewhere.

- Expansion thresholds – These scenarios assumed that utilities would be provided to grid cells at different levels of urbanization than the default 20 percent. A 10 percent threshold represents a less restrictive expansion policy, while a 40 percent threshold represents a more restrictive policy.

As might be expected, more stringent expansion requirements tend to limit the spread of "partial urbanization" at the metropolitan fringe, and increase the urbanization level of more centrally located areas. They also tend to shift development towards existing centers, including centers in outlying counties as well as the central Indianapolis area in Marion County. The level of urbanization by county shifts, but not consistently, and the specific effects appear to depend upon the specific parameters.

Perhaps somewhat counter-intuitively, though, less stringent requirements (such as more aggressive expansion) tend to *increase* overall population density and reduce the overall urbanized land area. This effect occurs for a couple of reasons. First, as noted above, the utilities affect the predicted residential density, with higher densities predicted in areas served by utilities. Therefore, as utilities are provided to more areas, overall density will increase. Second, the more widespread provision of utilities permits urbanization to occur in areas of greatest accessibility instead of being constrained to existing centers (i.e., people can locate closer to employment options). Because the model uses accessibility as a predictor of density, the average density of development will therefore increase. (Accessibility itself would not be expected to affect density, but it can be thought of as a proxy for land values, which are not directly reflected in the model because of lack of available data.)

The scenario requiring water and sewer utilities for development, without any provisions for expansion, essentially operates as an urban growth boundary. While its effects were significant, this scenario is considered unrealistic for the Indianapolis region. The most significant effect of the various other utility scenarios is under the "aggressive expansion" scenario. Impacts are fairly small in 2025 but, in 2040, this scenario shows a somewhat larger decrease in new urbanized land area (531 versus 548 square miles). By county, the biggest decreases in urbanized land in comparison to the base utilities assumption are in Johnson, Madison, and Marion Counties (about eight fewer square miles urbanized in each), while Boone, Hamilton, and Hancock Counties show increases of four to 10 square miles each. These shifts suggest how the region might grow differently if utilities were not a factor in determining the location of new development.[1]

---

[1] This scenario is provided simply to test the effects of allowing relatively unrestricted development. It does not assess the fiscal wisdom of pursuing such a policy.

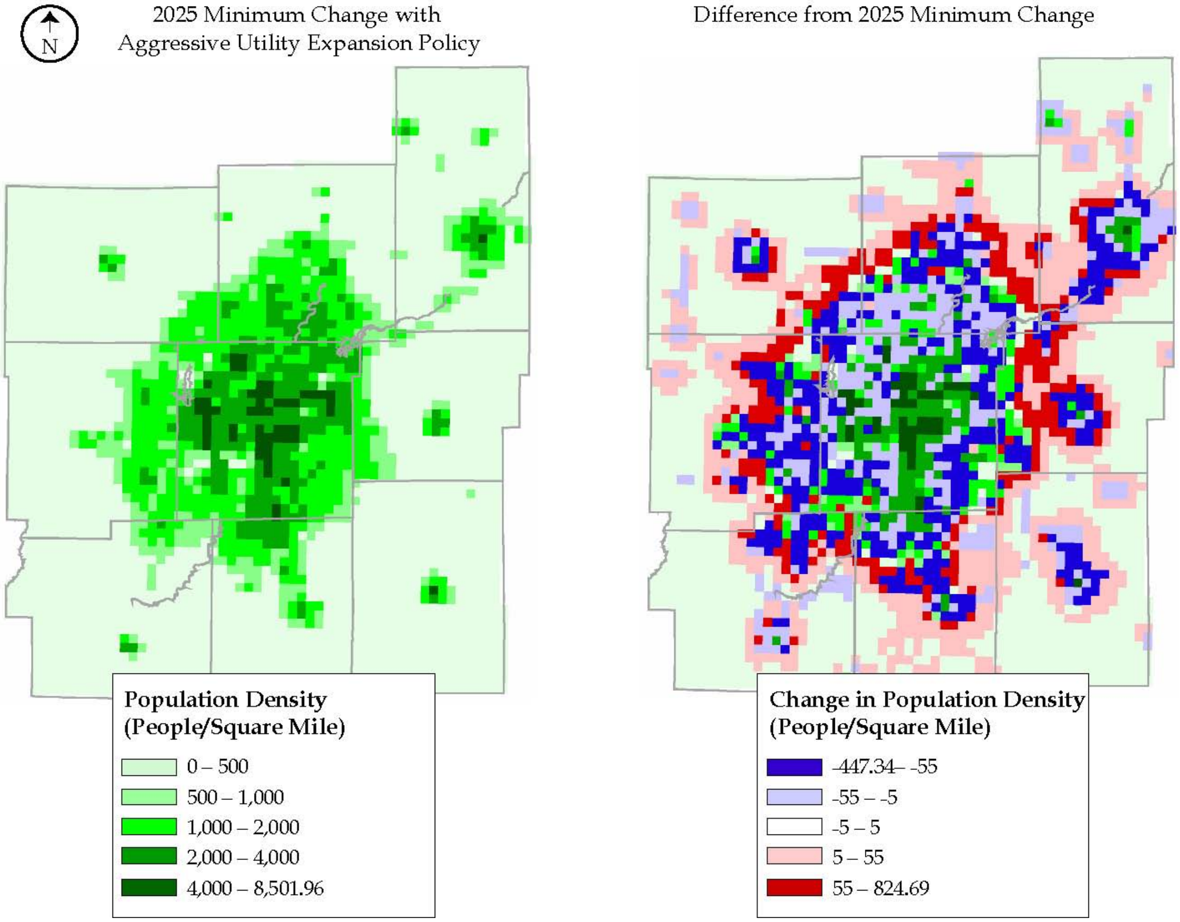
Table 5.3 Land Urbanized 2000-2040 under Alternative Utility Scenarios (Square Miles)

County	Base Utility Assumptions	Aggressive Expansion	10 Percent Expansion Threshold	Aggressive versus Base	10 Percent Expansion versus Base
Boone	42.6	46.7	43.7	4.1	1.1
Hamilton	100.8	110.2	98.8	9.4	-2.0
Hancock	61.2	65.6	60.5	4.4	-0.7
Hendricks	92.5	89.5	92.7	-3.0	0.2
Johnson	68.4	60.6	65.4	-7.8	-3.0
Madison	35.4	27.0	32.5	-8.4	-2.9
Marion	83.0	75.0	80.4	-8.0	-2.6
Morgan	37.3	32.9	39.3	-4.4	2.0
Shelby	26.7	23.7	24.2	-3.0	-2.5
Total	**547.9**	**531.2**	**537.5**	**-16.7**	**-10.4**

Figure 5.8 shows the forecast effects of the aggressive expansion scenario on land use in 2025. Figure 5.9 shows the forecast effects of the 10 percent expansion threshold on land use in 2025.

While the overall regional impacts are significant, the impacts of utility assumptions on the CISTMS transportation findings are, again, very small. Comparing the NewMax2 and Minimum Change scenarios in 2040 under the aggressive utility expansion policy described above, there is an increase of three square miles of urbanized land area in Madison County and a decrease of one to three square miles in Hancock, Hendricks, and Marion Counties. Again, this change can be compared with a total of 548 square miles of new urbanized land area in the region.

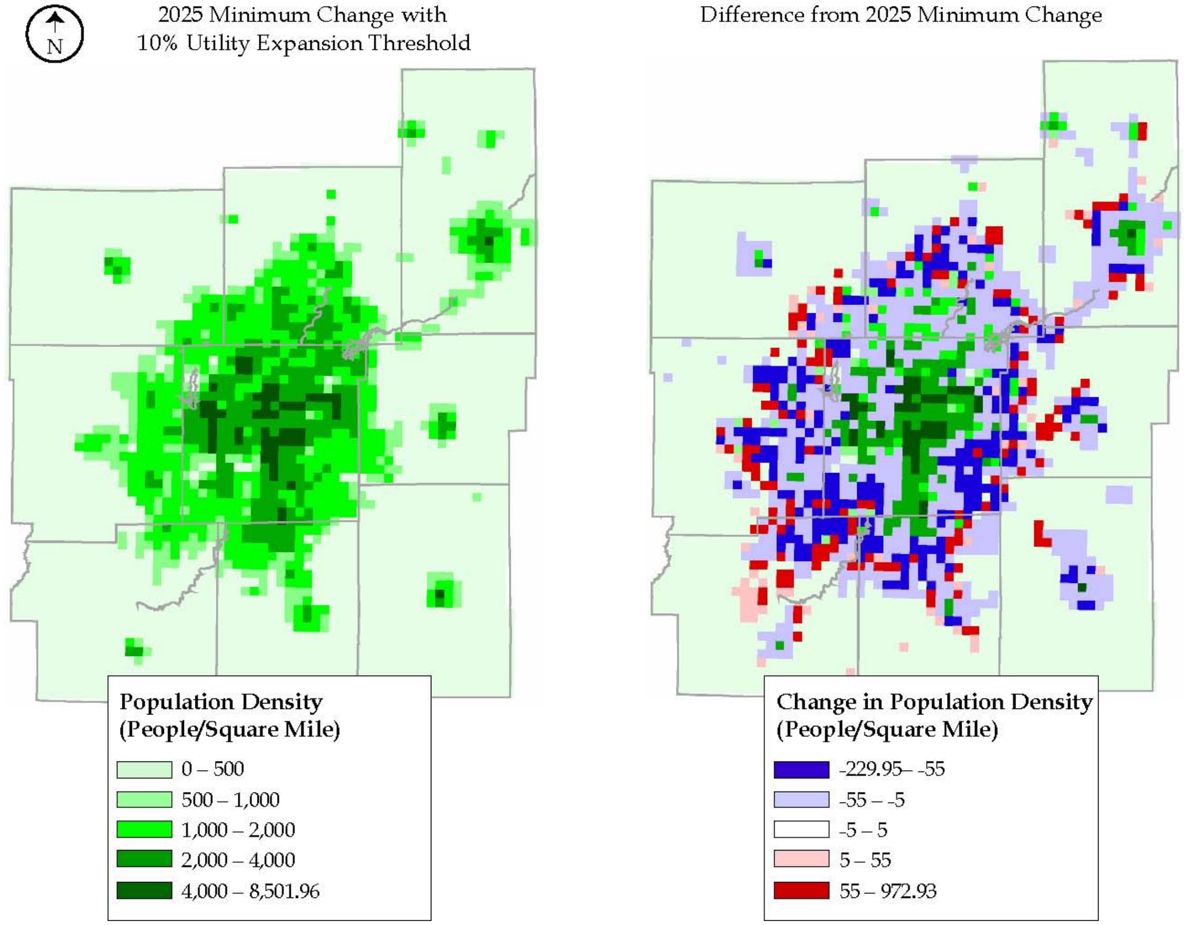
Figure 5.8 Effect of Aggressive Utility Expansion Policy Scenario on Urbanization in 2025



2025 Minimum Change with Aggressive Utility Expansion Policy

Difference from 2025 Minimum Change

Figure 5.9 Effect of 10 Percent Utility Expansion Threshold on Urbanization in 2025



6.0 Conclusions

6.0 Conclusions

The Maximum Change alternative appears to have a significant effect on regional travel patterns. The circumferential freeway diverts more than 15,000 vehicles per day from segments of I-69 near Indianapolis and I-465. The new terrain highway also diverts existing traffic from existing state highways in the four corridors under study. By providing a major new facility and less congested existing facilities, the Maximum Change alternative results in a 15 percent reduction in the miles of roadways that operate under congested conditions (LOS E or worse). The majority of this improvement is experienced on arterial streets and other non-limited access highways. However, some highways that feed the new facility experience increased traffic volumes and congestion, including I-70 and I-74.

The new travel options provided by the circumferential freeway contribute to a two percent increase in overall VMT in the region. This increase corresponds to longer average trip lengths as trip origins and destinations in the region spread out. Reflecting the continued patterns of decentralization, the greatest increases in VMT are expected in Hancock, Hendricks, and Shelby Counties while Marion County VMT declines by five percent.

Despite increases in spatial trip lengths, actual travel time per trip is expected to decline as a result of higher travel speeds on the new circumferential freeway and less congested existing facilities.

Despite these significant changes in travel patterns, the Maximum Change alternative appears to have a generally negligible impact on regional development patterns. This finding holds true even in the long term (2040) after the alternative has been in operation for more than 15 years. More aggressive employment reallocation assumptions, especially to the northeast sector, suggest some potential shift in urbanization to Madison County (up to three to four additional square miles urbanized). This shift occurs primarily from Hendricks, Hamilton, and Johnson Counties. Various assumptions about the density of future development as well as the restrictiveness of utility provision have little effect on the relative impacts of the Maximum Change in comparison to the Minimum Change scenarios, although they do have significant impacts on the baseline projected patterns of growth.

This lack of predicted impact may be surprising to some, given experience in other cities (and even Indianapolis itself, with I-465) where beltways have helped spur considerable development. However, there are some reasons that the impacts may indeed be relatively small. In particular, the corridor is quite far out from the center of the Indianapolis region and therefore remains well beyond the edge of the urbanized area even in 2040. With one or two possible exceptions, it provides little accessibility benefit to existing employment centers, such as downtown Indianapolis, the airport, and Hamilton County near I-465, U.S. 31, and SR 431. There is a significant amount of land available for development closer in than the study corridors that will continue to have a higher accessibility to employment, even with the proposed transportation improvements.

That is not to say that a circumferential freeway as envisioned under the Maximum Change alternative will not affect land use patterns. Development is likely to occur around major interchanges, especially highway-oriented retail establishments such as restaurants and gas stations, as well as warehousing and distribution centers. Some smaller office parks may also locate near major interchanges such as I-69 and the corridor on the northeast. In the long term, as the region continues to grow and development begins to reach the corridor, urbanization pressures will increase and the corridor will become a more attractive location for residential development. However, as we have seen, even if new development continues to occur at low densities and population increases at relatively optimistic rates, it will take decades before a significant amount of regional development reaches the CISTMS corridor. If population densities increase or population growth is less than projected, it will take even longer.

These results should not diminish the importance of sound local planning in advance of any highway or other transportation investment. Land use planning can help ensure that future development – when it does occur – will be located for optimum transportation access and designed to create minimum demands on the transportation system. It can also ensure fiscal prudence through the timing of development capacity with the provision of appropriate utilities.

Appendix A

Expert Panel Employment Forecasts

Appendix A

Expert Panel Employment Forecasts

Table A.1 Employment Projections by Township

	Baseline			Minimum Change Alternative			Maximum Change Alternative	
County Township	**Adjusted 2000 Employment**	**Adjusted 2025 Employment**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**
Boone County								
Center	12,598	17,028	0	17,028	0%	-215	16,813	-1%
Clinton	285	356	0	356	0%	0	356	0%
Eagle	6,474	7,687	215	7,901	3%	358	8,045	5%
Harrison	326	231	0	231	0%	143	374	62%
Jackson	485	721	-143	578	-20%	-430	291	-60%
Jefferson	340	82	0	82	0%	0	82	0%
Marion	415	298	0	298	0%	0	298	0%
Perry	42	52	358	410	688%	358	410	688%
Sugar Creek	787	2,869	-287	2,582	-10%	-573	2,296	-20%
Union	76	954	0	954	0%	573	1,528	60%
Washington	711	273	0	273	0%	0	273	0%
Worth	971	1,093	143	1,237	13%	358	1,451	33%
County Total	**23,510**	**31,645**	**287**	**31,932**	**1%**	**573**	**32,219**	**2%**
Hamilton County								
Adams	7,698	5,872	-72	5,800	-1%	-358	5,514	-6%
Clay	39,638	47,709	-358	47,351	-1%	-1,827	45,883	-4%
Delaware	14,344	16,883	0	16,883	0%	-36	16,847	0%
Fall Creek	7,934	18,045	0	18,045	0%	-72	17,973	0%
Jackson	1,763	3,862	0	3,862	0%	-72	3,791	-2%
Noblesville	18,735	24,054	-215	23,839	-1%	860	24,914	4%
Washington	14,720	25,407	0	25,407	0%	1,361	26,768	5%
Wayne	1,909	3,645	215	3,860	6%	716	4,362	20%
White River	360	196	72	268	36%	215	411	109%
County Total	**107,100**	**145,674**	**-358**	**145,316**	**0%**	**788**	**146,462**	**1%**

Table A.1 Employment Projections by Township (continued)

	Baseline			Minimum Change Alternative			Maximum Change Alternative	
County Township	**Adjusted 2000 Employment**	**Adjusted 2025 Employment**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**
Hancock County								
Blue River	192	156	0	156	0%	0	156	0%
Brandywine	61	116	0	116	0%	72	188	62%
Brown	68	161	0	161	0%	0	161	0%
Buck Creek	3,892	8,049	1,433	9,213	14%	2,149	9,929	23%
Center	15,155	28,512	0	28,512	0%	2,865	31,377	10%
Green	180	116	0	116	0%	72	188	62%
Jackson	191	560	0	560	0%	0	560	0%
Sugar Creek	909	1,164	-1,433	0	-100%	-1,433	0	-100%
Vernon	3,493	6,238	0	6,238	0%	143	6,381	2%
County Total	**24,141**	**45,071**	**0**	**45,071**	**0%**	**3,868**	**48,939**	**9%**
Hendricks County								
Brown	2,429	5,121	0	5,121	0%	0	5,121	0%
Center	9,077	16,746	-2,149	14,597	-13%	-1,361	15,385	-8%
Clay	711	1,029	0	1,029	0%	0	1,029	0%
Eel River	458	1,629	0	1,629	0%	0	1,629	0%
Franklin	364	1,073	0	1,073	0%	0	1,073	0%
Guilford	17,660	27,908	0	27,908	0%	0	27,908	0%
Liberty	1,449	2,372	0	2,372	0%	788	3,160	33%
Lincoln	5,378	6,023	0	6,023	0%	-72	5,951	-1%
Marion	1,656	22	0	22	0%	0	22	0%
Middle	1,119	1,643	0	1,643	0%	72	1,715	4%
Union	395	528	0	528	0%	860	1,388	163%
Washington	5,251	7,046	4,298	11,344	61%	4,155	11,200	59%
County Total	**45,947**	**71,140**	**2,149**	**73,289**	**3%**	**4,441**	**75,582**	**6%**

Table A.1 Employment Projections by Township (continued)

County Township	Baseline		Predicted Change from Baseline	Minimum Change Alternative		Predicted Change from Baseline	Maximum Change Alternative	
	Adjusted 2000 Employment	Adjusted 2025 Employment		Forecast 2025 Employment	Percent Change from Baseline		Forecast 2025 Employment	Percent Change from Baseline
Johnson County								
Blue River	1,502	4,343	0	4,343	0%	0	4,343	0%
Clark	1,843	3,584	0	3,584	0%	0	3,584	0%
Franklin	13,967	22,244	-1,433	20,811	-6%	0	22,244	0%
Hensley	668	1,403	0	1,403	0%	0	1,403	0%
Needham	3,385	958	2,436	3,393	254%	5,301	6,259	554%
Nineveh	90	666	0	666	0%	0	666	0%
Pleasant	22,522	31,421	716	32,137	2%	716	32,137	2%
Union	377	232	0	232	0%	716	948	309%
White River	11,075	18,674	-1,075	17,599	-6%	-1,075	17,599	-6%
County Total	**55,428**	**83,524**	**645**	**84,169**	**1%**	**5,659**	**89,183**	**7%**
Madison County								
Adams	1,244	387	0	387	0%	0	387	0%
Anderson	41,729	54,342	0	54,342	0%	-1,003	53,339	-2%
Boone	408	47	0	47	0%	0	47	0%
Duck Creek	1,072	3	0	3	0%	0	3	0%
Fall Creek	1,364	1,786	287	2,073	16%	573	2,359	32%
Green	544	1,459	0	1,459	0%	430	1,889	29%
Jackson	230	34	0	34	0%	0	34	0%
Lafayette	2,055	2,924	0	2,924	0%	-287	2,638	-10%
Monroe	1,542	3,351	0	3,351	0%	0	3,351	0%
Pipe Creek	4,017	6,068	-287	5,782	-5%	-573	5,495	-9%
Richland	2,021	1,399	287	1,686	20%	287	1,686	20%
Stony Creek	244	1,310	0	1,310	0%	143	1,453	11%
Union	3,092	1,602	573	2,175	36%	573	2,175	36%
Van Buren	458	333	0	333	0%	0	333	0%
County Total	**60,020**	**75,046**	**860**	**75,905**	**1%**	**143**	**75,189**	**0%**

Table A.1 Employment Projections by Township (continued)

	Baseline			Minimum Change Alternative			Maximum Change Alternative	
County Township	**Adjusted 2000 Employment**	**Adjusted 2025 Employment**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**	**Predicted Change from Baseline**	**Forecast 2025 Employment**	**Percent Change from Baseline**
Marion County								
Center	213,242	264,984	-1,282	263,702	0%	-5,896	259,089	-2%
Decatur	36,750	66,410	788	67,198	1%	-14	66,396	0%
Franklin	39,687	77,102	-1,282	75,820	-2%	-1,663	75,439	-2%
Lawrence	59,075	78,485	788	79,273	1%	-509	77,976	-1%
Perry	56,924	89,902	-1,282	88,619	-1%	-1,663	88,238	-2%
Pike	69,257	95,764	824	96,588	1%	-767	94,997	-1%
Warren	77,206	105,676	-2,328	103,348	-2%	-6,198	99,478	-6%
Washington	80,233	94,476	-234	94,243	0%	-756	93,720	-1%
Wayne	92,370	119,642	-2,797	116,846	-2%	-7,105	112,538	-6%
County Total	**724,743**	**992,442**	**-6,805**	**985,637**	**-1%**	**-24,571**	**967,871**	**-2%**
Morgan County								
Adams	90	233	0	233	0%	0	233	0%
Ashland	104	35	0	35	0%	0	35	0%
Brown	5,940	7,326	573	7,900	8%	573	7,900	8%
Clay	560	894	0	894	0%	287	1,180	32%
Green	947	380	0	380	0%	0	380	0%
Gregg	365	103	0	103	0%	0	103	0%
Harrison	389	1,108	0	1,108	0%	0	1,108	0%
Jackson	536	26	72	98	275%	72	98	275%
Jefferson	1,782	522	0	522	0%	0	522	0%
Madison	358	488	0	488	0%	0	488	0%
Monroe	613	1,385	0	1,385	0%	573	1,958	41%
Ray	277	507	0	507	0%	0	507	0%
Washington	9,076	18,054	0	18,054	0%	0	18,054	0%
County Total	**21,037**	**31,061**	**645**	**31,706**	**2%**	**1,504**	**32,565**	**5%**

Table A.1 Employment Projections by Township (continued)

County Township	Baseline		Predicted Change from Baseline	Minimum Change Alternative		Predicted Change from Baseline	Maximum Change Alternative	
	Adjusted 2000 Employment	Adjusted 2025 Employment		Forecast 2025 Employment	Percent Change from Baseline		Forecast 2025 Employment	Percent Change from Baseline
Shelby County								
Addison	9,104	23,943	0	23,943	0%	479	24,421	2%
Brandywine	512	1,010	0	1,010	0%	1,910	2,920	189%
Hanover	1,469	3,219	0	3,219	0%	0	3,219	0%
Hendricks	143	189	0	189	0%	477	666	253%
Jackson	46	92	0	92	0%	0	92	0%
Liberty	313	590	-143	447	-24%	-143	447	-24%
Marion	3,486	397	2,149	2,546	541%	3,582	3,979	902%
Moral	2,377	3,175	716	3,891	23%	716	3,891	23%
Noble	54	55	0	55	0%	0	55	0%
Shelby	364	550	0	550	0%	0	550	0%
Sugar Creek	908	344	-143	201	-42%	-143	201	-42%
Union	3,053	86	0	86	0%	0	86	0%
Van Buren	1,115	938	0	938	0%	716	1,655	76%
Washington	36	157	0	157	0%	0	157	0%
County Total	**22,981**	**34,744**	**2,579**	**37,323**	**7%**	**7,593**	**42,338**	**22%**
Regional Total	**1,084,907**	**1,510,347**	**0**	**1,510,347**	**0%**	**0**	**1,510,347**	**0%**

Appendix B

LUCI/T Documentation

Appendix B

LUCI/T Documentation

- **Model Estimation**
- **Baseline Forecasts**
- **LUCI/T Documentation**

Model Estimation

LUCI/T Model Estimation Report for the Central Indiana Suburban Transportation & Mobility Study

John R. Ottensmann
Center for Urban Policy and the Environment

November 19, 2003

This report presents the results of the re-estimation of the models to predict the probability of development and the density of development for the LUCI/T adaptation of the LUCI model for the Central Indiana Suburban Transportation & Mobility Study. It documents the development of the estimates, comparing those to the original estimates obtained for the LUCI 1.0 model. For the model to predict the probability of development, the predicted development is compared with the actual development for the period used to estimate the model.

Model to Predict the Probability of Development

The model to predict the probability of development is an aggregate logit model that is estimated using the proportion of the available land in 1993 that was converted to urban use between 1993 and 2000. The model is estimated using weighted least squares.

Estimations Using LUCI 1.0 Data

The model to predict the probability of development in LUCI 1.0 was estimated using accessibility to employment calculated using employment by ZIP code and distances from the grid cells to the ZIP code centers. These are the SPSS regression results for the model as originally estimated for the 44-county LUCI study area:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.688[a]	.473	.473	4.93790491

a. Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSTIN4L, LGDEV89, DSEWER, LACCNE15, LMN3

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	376024.0	9	41780.449	1713.514	.000[a]
	Residual	418898.3	17180	24.383		
	Total	794922.3	17189			

[a] Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSTIN4L, LGDEV89, DSEWER, LACCNE15, LMN3

[b] Dependent Variable: LGDEV90

[c] Weighted Least Squares Regression - Weighted by WGHT90

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-15.854	.601		-26.377	.000
	LACCNE15	.493	.015	.304	32.857	.000
	LDSTINST	-.016	.003	-.030	-4.836	.000
	DSTIN4L	-1.65E-05	.000	-.050	-7.294	.000
	DWATER	.315	.031	.074	10.179	.000
	DSEWER	.395	.031	.098	12.908	.000
	LISTEP	2.071	.157	.085	13.168	.000
	LGDEV89	.096	.005	.140	18.854	.000
	LMN3	6.856	.302	.524	22.695	.000
	SQLMN3	-10.719	.486	-.431	-22.066	.000

[a] Dependent Variable: LGDEV90

[b] Weighted Least Squares Regression - Weighted by WGHT90

The predictors included in the model are as follows:

- LACCNE15 – log of accessibility to employment using distance with accessibility coefficient of 0.00015
- LDSTINST – log of distance to nearest interstate
- DSTUN4L – distance to nearest interstate or 4-lane highway
- DWATER – dummy variable indicating presence of water utility service
- DSEWER – dummy variable indicating presences of sewer utility service
- LISTEP – log of ISTEP score for school district
- LGDEV89 – logit of proportion of available land in 1985 converted to urban use between 1985 and 1993 (persistence term)
- LMN3 – log of proportion of land urban in 3x3 neighborhood surrounding grid cell
- SQLMN3 – square of log of proportion of land urban in 3x3 neighborhood surrounding grid cell

The first step in the re-estimation process is the estimation of the model using the same data for the 3,562 grid cells in the 9-county CISTMS study area. These are the SPSS regression results:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.590[a]	.348	.346	7.33554334

a. Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSEWER, LGDEV89, DSTIN4L, LACCNE15, LMN3

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101381.9	9	11264.653	209.340	.000[a]
	Residual	190165.2	3534	53.810		
	Total	291547.1	3543			

a. Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSEWER, LGDEV89, DSTIN4L, LACCNE15, LMN3

b. Dependent Variable: LGDEV90

c. Weighted Least Squares Regression - Weighted by WGHT90

Coefficients[a,b]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-15.463	1.041		-14.858	.000
	LACCNE15	.410	.035	.237	11.761	.000
	LDSTINST	.011	.007	.026	1.583	.113
	DSTIN4L	-4.63E-05	.000	-.075	-4.453	.000
	DWATER	.291	.067	.071	4.363	.000
	DSEWER	.584	.059	.156	9.932	.000
	LISTEP	2.152	.275	.122	7.838	.000
	LGDEV89	.075	.010	.135	7.648	.000
	LMN3	5.301	.586	.508	9.048	.000
	SQLMN3	-8.008	.901	-.443	-8.887	.000

a. Dependent Variable: LGDEV90

b. Weighted Least Squares Regression - Weighted by WGHT90

The fit of the model is not as good for the 9-county area, with the R Square value dropping from 0.473 to 0.348. However, the regression coefficients are quite comparable to those estimated for the original model. (The major exception is that the regression coefficient for log of distance to the nearest interstate is no longer statistically significant and has the wrong sign.) The following table compares the regression coefficients for these two models:

Ind Var	**Regr Coeffs**	
	44-Cnty	**9-Cnty**
(Constant)	-15.854	-15.463
LACCNE15	0.493	0.41
LDSTINST	-0.016	0.011
DSTIN4L	-1.65E-05	-4.63E-05
DWATER	0.315	0.291
DSEWER	0.395	0.584
LISTEP	2.071	2.152
LGDEV89	0.096	0.075
LMN3	6.856	5.301
SQLMN3	-10.719	-8.008

Estimation of LUCI/T Model

The next step is the estimation of the model substituting accessibility to employment calculated using 2000 employment by TAZ from the file *9CTY_TAZ2000_INDOTSOCEC.DBF*, and travel times from the file *CIST_2000_Valid_Skim_1285.txt*. An accessibility coefficient value of 0.15 was used for this estimation, which is the value to the nearest 0.05 yielding the best fit of the model. (Note that the accessibility coefficients for travel time and distance are not comparable because they depend upon the units in which separation is measured.) These are the SPSS regression results for this model:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.589[a]	.347	.345	7.34029797

a. Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSEWER, LGDEV89, DSTIN4L, LACC15, LMN3

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101135.3	9	11237.254	208.561	.000[a]
	Residual	190411.8	3534	53.880		
	Total	291547.1	3543			

a. Predictors: (Constant), SQLMN3, LISTEP, LDSTINST, DWATER, DSEWER, LGDEV89, DSTIN4L, LACC15, LMN3

b. Dependent Variable: LGDEV90

c. Weighted Least Squares Regression - Weighted by WGHT90

Coefficients[a,b]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-17.005	1.027		-16.551	.000
	LACC15	.356	.031	.219	11.557	.000
	LDSTINST	.014	.007	.034	2.117	.034
	DSTIN4L	-3.82E-05	.000	-.062	-3.644	.000
	DWATER	.309	.067	.076	4.645	.000
	DSEWER	.587	.059	.157	9.986	.000
	LISTEP	2.626	.260	.149	10.101	.000
	LGDEV89	.071	.010	.128	7.282	.000
	LMN3	5.341	.586	.512	9.116	.000
	SQLMN3	-7.535	.900	-.417	-8.370	.000

a. Dependent Variable: LGDEV90

b. Weighted Least Squares Regression - Weighted by WGHT90

The fit is virtually identical to the previous model using the old accessibility based on distance. Once again, the regression coefficients are quite comparable. (Note that the regression coefficients on accessibility cannot be directly compared because these are different measures. The general magnitudes are similar because the logs of each are being used.) The following table compares the regression coefficients for the three models:

Ind Var	Regr Coeffs		
	44-Cnty	9-Cnty	
		Old Access	New Access
(Constant)	-15.854	-15.463	-17.005
Log Access	0.493	0.41	0.356
LDSTINST	-0.016	0.011	0.014
DSTIN4L	-1.65E-05	-4.63E-05	-3.82E-05
DWATER	0.315	0.291	0.309
DSEWER	0.395	0.584	0.587
LISTEP	2.071	2.152	2.626
LGDEV89	0.096	0.075	0.071
LMN3	6.856	5.301	5.341
SQLMN3	-10.719	-8.008	-7.535

The original LUCI model included the two predictors involving distances to highways in order to incorporate the effects of transportation infrastructure on development. The LUCI/T adaptation will be using travel times in the calculation of accessibility to employment, so it will be incorporating the effects of the transportation infrastructure in that way. Therefore, it does not appear to be reasonable or necessary to include the two distance to highway variables in the model to predict the probability of development for LUCI/T. (Also, the log distance to interstate variable has the wrong sign in this model.)

The final model to predict the probability of development is then estimated, excluding these variables. The final accessibility coefficient used in producing the accessibility to employment measure is 0.17, which is the value to two significant digits that results in the best fit of the model. These are the SPSS regression results for the final model:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.587[a]	.344	.343	7.35222085

a. Predictors: (Constant), SQLMN3, LISTEP, DWATER, DSEWER, LGDEV89, LACC17, LMN3

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	100408.1	7	14344.014	265.359	.000[a]
	Residual	191139.0	3536	54.055		
	Total	291547.1	3543			

a. Predictors: (Constant), SQLMN3, LISTEP, DWATER, DSEWER, LGDEV89, LACC17, LMN3

b. Dependent Variable: LGDEV90

c. Weighted Least Squares Regression - Weighted by WGHT90

Coefficients[a,b]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-17.229	1.026		-16.785	.000
	LACC17	.352	.028	.231	12.565	.000
	DWATER	.265	.065	.065	4.065	.000
	DSEWER	.603	.058	.161	10.417	.000
	LISTEP	2.717	.256	.155	10.607	.000
	LGDEV89	.069	.010	.124	7.073	.000
	LMN3	5.707	.574	.547	9.936	.000
	SQLMN3	-8.083	.884	-.447	-9.147	.000

a. Dependent Variable: LGDEV90

b. Weighted Least Squares Regression - Weighted by WGHT90

The goodness-of-fit of the model is not reduced significantly by eliminating the two distance to highway predictors, with R Square only dropping from 0.347 to 0.344. The regression coefficients for the remaining predictors are not significantly changed. This will be the model to predict the probability of development that will be used in LUCI/T.

Comparisons of Predicted and Actual Development

Comparisons are now made of the amount of development that would be predicted by this model for 1993 to 2000 with the known, actual amount of development that was used to estimate the model. The prediction of the amount of development for the period is produced in the same way as it will be done in the simulations in the LUCI/T model: The predicted logit from the regression is restandardized. This adjusted logit is converted to the probability of development, which is multiplied by the amount of available land in 1993 to produce an initial prediction. Finally, this initial prediction is adjusted to equal the total amount of development that occurred from 1993 to 2000.

The correlation across the grid cells of the predicted development with the actual development is 0.606. This compares with a correlation of 0.634 for the original LUCI model. That it would be slightly less is not surprising, given that the fit of the model predicting the probability of development is lower for the 9-county area than for the 44 counties.

The prediction of the amount of urban land in 2000 is made by adding the predicted development to the amount of urban land in 1993. The correlation of this prediction of urban land in 2000 with the actual amount of urban land in 2000 is 0.974. This compares with a correlation of 0.984 for the original LUCI model.

The amount of urban development predicted by the model for 1993 to 2000 is summarized by county. This is compared with the actual amount of urban development and with the comparable predictions for the original LUCI model in the following table:

County	Actual Development	Predicted Development	
		LUCI	LUCI/T
Boone	4.71	5.91	6.16
Hamilton	21.27	23.11	25.19
Hancock	3.82	4.27	3.69
Hendricks	13.48	11.46	10.21
Johnson	8.39	7.40	7.42
Madison	3.66	3.38	2.25
Marion	25.19	27.32	27.10
Morgan	3.87	2.50	2.19
Shelby	1.09	1.66	1.27

The predictions for the two models are quite similar. In some cases the predictions made for the original LUCI model were closer to the actual values and in some cases the predictions made for the LUCI/T model were closer. This suggests that using this model to predict the probability of development in the LUCI/T model will produce results that are similar to those obtained with the original LUCI model.

One final comparison is made between the total amount of urban land predicted by the model for 2000 with the actual amount, summarized by county:

County	Actual Urban	Predicted Urban
Boone	18.82	20.41
Hamilton	69.48	73.55
Hancock	21.40	21.41
Hendricks	49.23	46.32
Johnson	40.30	39.64
Madison	49.88	48.75
Marion	255.25	257.46
Morgan	30.82	29.67
Shelby	14.37	14.63

All of the predicted values are within ten percent of the actual values. Most are much closer than that.

Model to Predict Population Density

The second model to be estimated predicts the density of population. The dependent variable is the log of population density in 2000. Given the varying amounts of urban land in the grid cells, the regression is weighted by the amount of urban land in 2000.

Estimations Using LUCI 1.0 Data

The model to predict population density is far simpler, using only accessibility to employment and the presence of water and sewer utilities as predictors. Following are the SPSS regression results for the model as estimated for LUCI for the 44-county area using accessibility to employment calculated using distance:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.607[a]	.369	.368	.35069221

a. Predictors: (Constant), DSEWER, LACCNE15, DWATER

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	319.358	3	106.453	865.574	.000[a]
	Residual	546.668	4445	.123		
	Total	866.026	4448			

a. Predictors: (Constant), DSEWER, LACCNE15, DWATER

b. Dependent Variable: LPDEN

c. Weighted Least Squares Regression - Weighted by URB00

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.835	.081		47.161	.000
	LACCNE15	.323	.009	.476	35.236	.000
	DWATER	.202	.036	.089	5.680	.000
	DSEWER	.321	.034	.149	9.504	.000

a. Dependent Variable: LPDEN

b. Weighted Least Squares Regression - Weighted by URB00

Once again, the same model is estimated using only the grid cells within the 9-county CISTMS study area. These are the SPSS regression results:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.474[a]	.225	.223	.38739563

a. Predictors: (Constant), DSEWER, LACCNE15, DWATER

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	69.213	3	23.071	153.730	.000[a]
	Residual	238.920	1592	.150		
	Total	308.133	1595			

a. Predictors: (Constant), DSEWER, LACCNE15, DWATER

b. Dependent Variable: LPDEN00

c. Weighted Least Squares Regression - Weighted by URB00

Coefficients[a,b]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.305	.175		24.618	.000
	LACCNE15	.287	.018	.393	15.622	.000
	DWATER	.215	.065	.090	3.280	.001
	DSEWER	.145	.058	.066	2.482	.013

a. Dependent Variable: LPDEN00

b. Weighted Least Squares Regression - Weighted by URB00

As was the case for the model to predict the probability of development, the fit of the model is not nearly as good when estimated for the 9-county areas as for the 44-county area. R Square declines from 0.369 to 0.225. This should not be surprising given that the 9-county area has far more variation in population density than the remainder of the larger area.

The regression coefficient for the presence of sewer utilities is considerably lower for the model estimated for the 9-county area. The other regression coefficients are comparable for the two models.

Estimation of LUCI/T Model

The model to predict population density for LUCI/T is now estimated. Accessibility to employment calculated using travel times and TAZ employment is now used as a predictor, using the same accessibility coefficient as used in the model to predict the probability of development. These are the SPSS regression results:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.464[a]	.215	.213	.38982224

a. Predictors: (Constant), DSEWER, LACC17, DWATER

ANOVA[b,c]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	66.211	3	22.070	145.236	.000[a]
	Residual	241.923	1592	.152		
	Total	308.133	1595			

a. Predictors: (Constant), DSEWER, LACC17, DWATER

b. Dependent Variable: LPDEN00

c. Weighted Least Squares Regression - Weighted by URB00

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.868	.147		33.073	.000
	LACC17	.237	.016	.375	14.875	.000
	DWATER	.230	.066	.096	3.493	.000
	DSEWER	.160	.059	.073	2.727	.006

a. Dependent Variable: LPDEN00

b. Weighted Least Squares Regression - Weighted by URB00

These are the results that will be used in the LUCI/T model.

Baseline Forecasts

LUCI/T Model as Modified for the Central Indiana Suburban Transportation & Mobility Study: Baseline Forecasts and Forecast Comparisons

John R. Ottensmann
Center for Urban Policy and the Environment

November 26, 2003

Introduction

LUCI, the Land Use in Central Indiana Model, has been modified for use in the Central Indiana Transportation & Mobility Study (CISTMS). This new version of the model is being called LUCI/T. The new model is restricted to the 9-county CISTMS study area. The model uses travel times and employment by traffic analysis zone (TAZ). The equations to predict the probability of development and population density have been estimated using these data. Details of this estimation have been provided in the document *LUCI/T Model Estimation Report for the Central Indiana Suburban Transportation & Mobility Study*.

This report presents information on the baseline forecasts that have been developed for the evaluation of the use of the LUCI/T model for the Central Indiana Suburban Transportation & Mobility Study. Comparisons are made of those forecasts with the forecasts that have been developed by the Indianapolis Metropolitan Planning Organization (MPO) and the Indiana Department of Transportation (INDOT).

Baseline Forecasts

Seven baseline forecasts of urban development for the CISTMS study area have been developed using the LUCI/T model. These forecasts reflect the use of different final employment data and different assumptions regarding the density and dispersal of future urban development. They are intended to represent some of the range of possible forecasts that can be produced with the model and to provide a basis for the evaluation of the model's capabilities.

All of the forecasts are for urban development in 2025, the CISTMS target year. The forecasts assume that the population in the study area will grow as forecast in the document *Indianapolis 2025: Addendum: Projections of Population and Employment to 2025, Indianapolis Metropolitan Area*, provided by the MPO. The travel times used for the entire simulation period are the revised 2000 travel times provided by Cambridge Systematics in the file *CIST_2000_Valid_Skim_1285.txt*. Initial year 2000 employment data by TAZ are the updated values provided in the file *9CTY_TAZ2000_INDOTSOCEC.DBF*.

Except when specified for individual forecasts, the parameters used are the default parameters in the model intended to reflect the continuation of current trends that have been estimated or identified for the recent past. These assume no changes in public policies affecting development and no changes in assumed behavior. With respect to the provision of water and sewer utilities, the assumption is that utilities will not be required for development to occur and that utilities are extended to adjacent grid cells when the levels of urbanization in those grid cells exceed 20 percent.

Baseline Forecast 1

The first baseline forecast assumes that employment by TAZ will remain unchanged from the initial year 2000 values over the simulation period. It is intended to serve as a basis for comparison with the other forecasts that assume change in employment.

Baseline Forecast 2A

The second forecast assumes that employment by TAZ in the year 2025 will be as forecast by the Indianapolis MPO, as provided in the file *2025TAZ.DBF*. LUCI/T starts the simulation in 2000 using the initial year 2000 employment data. For the succeeding simulation periods, the model uses employment interpolated from the initial 2000 employment data and the final year 2025 employment data.

Baseline Forecast 2B

Comparison of the MPO forecast 2025 employment with the updated 2000 employment by TAZ showed inconsistencies. The 2025 forecast was developed using the prior 1996 estimates of employment by TAZ and does not reflect the update of the employment data to 2000 using the INDOT data. As a result, there are TAZs in which the forecast 2025 employment is less than the revised 2000 employment even though the MPO forecast predicts growth in employment from 1996 to 2025 in those TAZs.

An alternative forecast of TAZ employment for 2025 was developed by taking the forecast change in employment from the initial 1996 data to the MPO forecast 2025 values and adding this to the updated 2000 employment levels. This provides a forecast in which the employment in each TAZ from 2000 to 2025 grows or declines by the amount originally forecast for 1996 to 2025. This eliminates the problem of declines in employment occurring in TAZs that were originally forecast to grow. Of course, such a simple adjustment can introduce other inconsistencies, but this was what was possible with the data available.

Baseline Forecast 2B then uses this revised forecast of employment for 2025 in place of the original MPO forecast. Likewise, the remaining baseline forecasts will also have *A* and *B* versions, with the *A* version using the MPO forecast of TAZ employment for 2025 and the *B* version using the MPO forecast of employment change from 1996 to 2025 added to the updated 2000 TAZ employment.

Baseline Forecast 3A
Baseline Forecast 3B

The LUCI/T model predicts the population density of new development based on estimations using existing population densities in the region in 2000. The MPO forecast of new development assumes lower population densities and greater land consumption for new development. These baseline forecasts assume that population densities will be 50 percent lower than those predicted within the model. These baseline forecasts are analogous to the lower density baseline forecast developed for the original LUCI model.

Baseline Forecast 4A
Baseline Forecast 4B

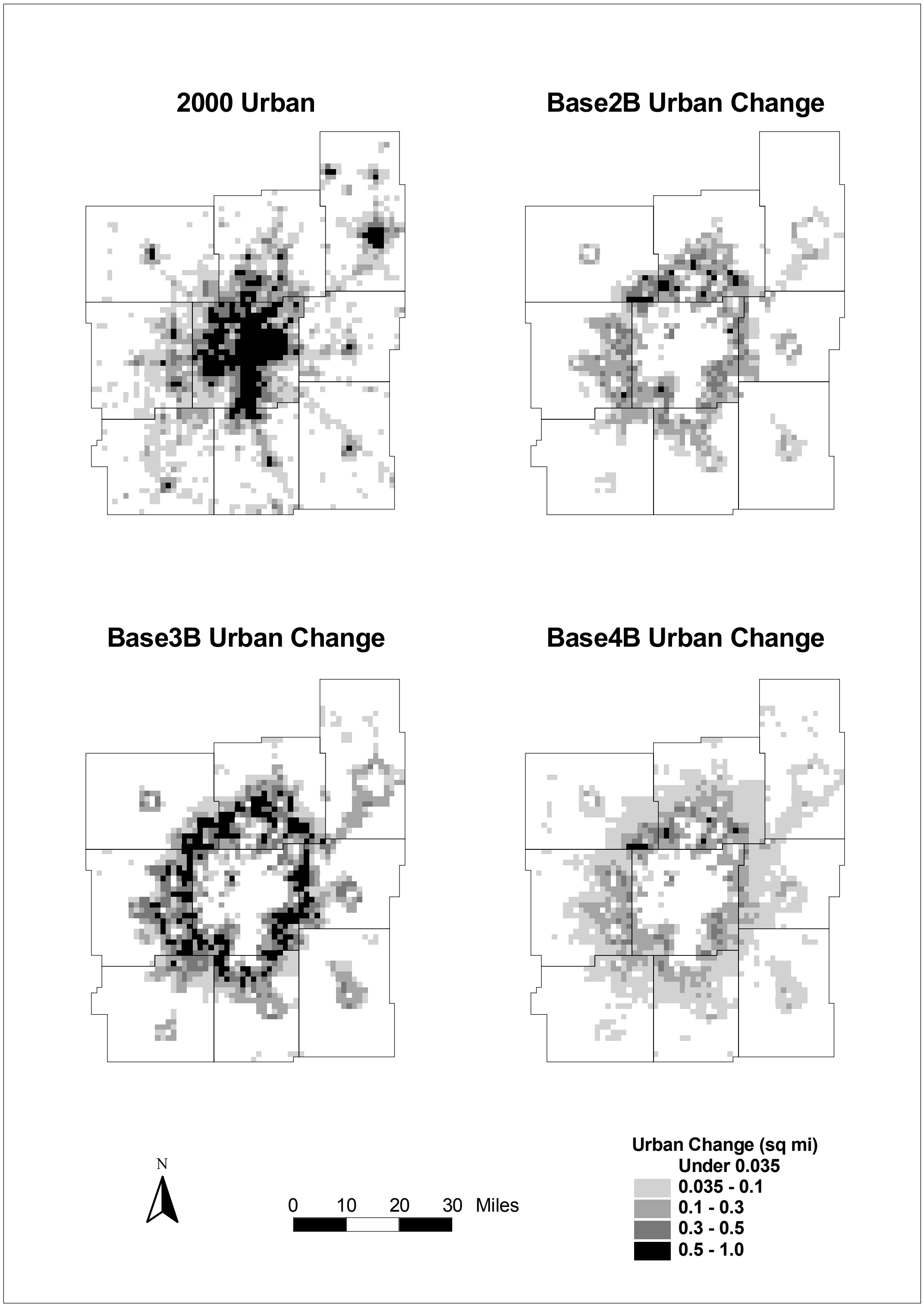
The LUCI and LUCI/T models predict the amount of new urban development in each grid cell using the predicted probability of development to determine the proportion of available land that will be developed. The dispersion of new development is thus determined by these predicted probabilities. The models include the option of increasing or decreasing the dispersal of development. These baseline forecasts assume greater dispersal of development than would otherwise have been predicted by the model. A dispersal setting of 25 was selected, where 0 means no increase in dispersal and 50 is maximum dispersal of development, with all grid cells being given an equal probability. This has the effect of decreasing the amounts of new development in the inner, higher probability development portions of the study area and increasing the amounts of new development in the outlying areas.

This option was considered for the original LUCI baseline forecasts but was not used. In the context of the original 44-county LUCI area, such dispersal had the effect of moving development away from the CISTMS study area while having minimal effect within the area.

Forecast Maps

Maps of the baseline forecasts show the differences in the patterns of development that have been simulated. *Baseline Forecast 1*, *2A*, and *2B* show similar patterns. Likewise, the *A* and *B* versions of *Baseline Forecasts 2*, *3*, and *4* are very much the same. Therefore selected maps for *Baseline Forecasts 2B*, *3B*, and *4B* will be displayed for comparison. (Shapefiles including the data for all seven of the baseline forecasts will accompany this report, so additional maps can be produced if desired.)

The first set of maps, on the following page, show the new urban development simulated for the 25-year period for these three baseline forecasts. The initial amount of land urban in 2000 is also shown for reference. The map for *Baseline Forecast 2B* shows new urban development clustered around the existing urban areas. For *Baseline Forecast 3B*, with the much lower density of development, the area of urban development is much larger, and a higher proportion of the land in the areas of development is converted to urban use.


2000 Urban
Base2B Urban Change
Base3B Urban Change
Base4B Urban Change
N
0 10 20 30 Miles
Urban Change (sq mi)
Under 0.035
0.035 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1.0

The map for *Baseline Forecast 4B* shows the effect of increasing the dispersal of development, with lower proportions of the land in the developing areas being converted to urban use and with the areas of significant development extending farther out from the previously-urbanized areas.

The second set of maps, on the next page, displays the final amount of urban development for 2025 for the three baseline forecasts. The map for *Baseline Forecast 2B* shows the expansion of the area of urban development compared with that in 2000. It retains the mixture of more- and less-developed grid cells in the outer parts of the urban area. *Baseline Forecast 3B* has a much higher proportion of land in urban use throughout more of the area, as the lower densities of development force the conversion of more of the land to accommodate the same population growth. For *Baseline Forecast 4B* with the increased dispersal of development, less of the land is urban closer in and there is more land with at least modest levels of urban development extending farther away from the centers.

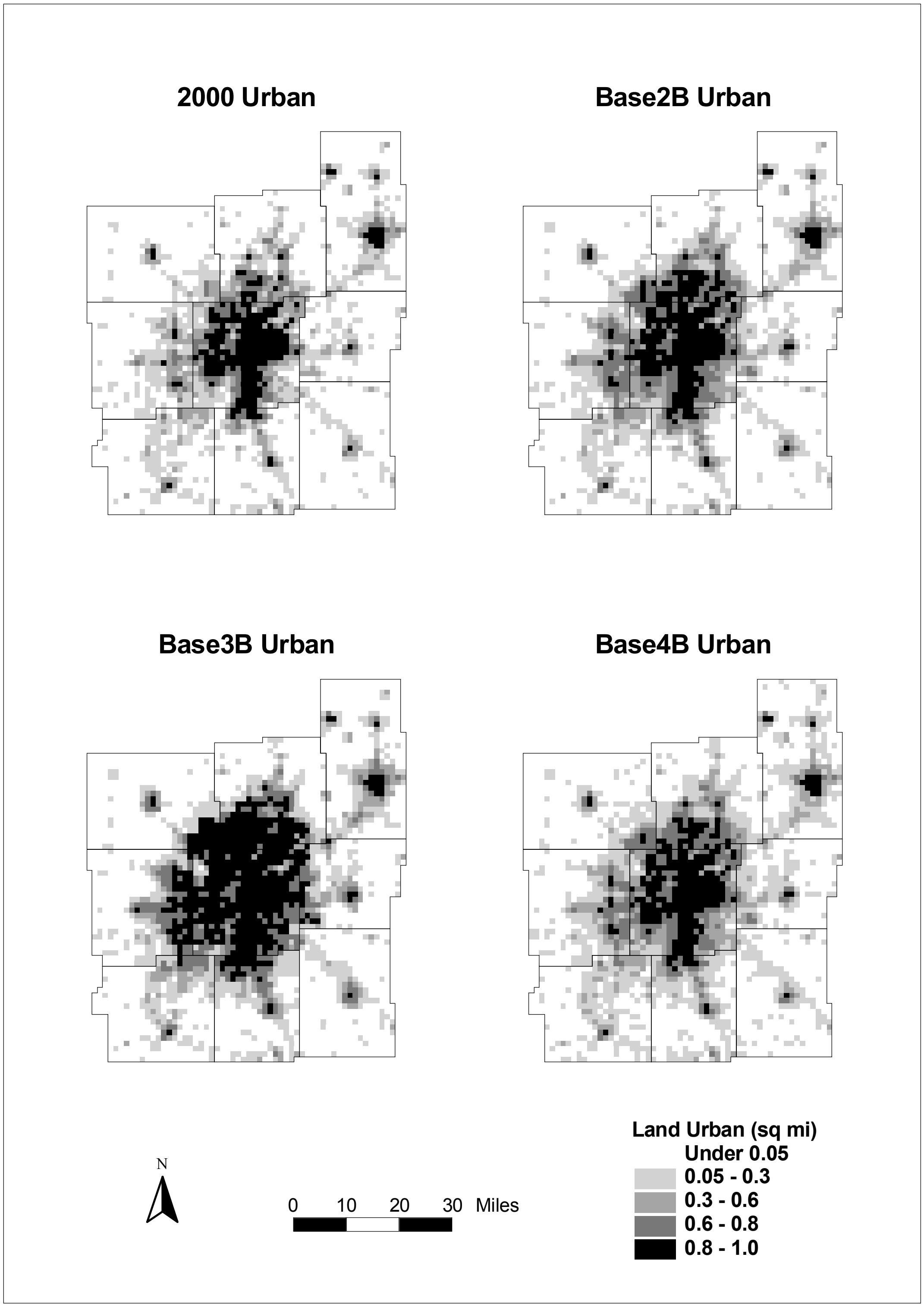
These maps for the baseline forecasts demonstrate the extent to which the pattern of urban development simulated by the model can be adjusted to reflect alternative assumptions regarding how future urban development is likely to occur.

Initial Comparisons with MPO and INDOT Forecasts

The initial set of comparisons focus on the results aggregated by county for the outlying counties in the area and by township for the individual townships within Marion County. This is the level of geographic detail provided in the document *Indianapolis 2025: Addendum: Projections of Population and Employment to 2025, Indianapolis Metropolitan Area*. Comparison at this level allows ready examination of the values for individual areas. Statistical comparisons at more detailed levels of geographic detail are provided in the following section.

The forecast population, households, and urbanized land for the seven baseline forecasts are compared with the 2025 forecasts developed by the MPO and by INDOT. The MPO forecasts are from the document *Indianapolis 2025: Addendum: Projections of Population and Employment to 2025, Indianapolis Metropolitan Area*, including the re-allocations. The INDOT forecasts are from the 9-county TAZ files for 2000 Base and 2025 No Build provided by INDOT. These data are from the files *9-CO_TAZ2000BASE.DBF* and 9-*CO_TAZ2025NB.DBF*.

The MPO forecast provides forecast values by county for the outlying counties in the area and by township for the individual townships within Marion County by five-year intervals from 2000 to 2025. The population and household values were obtained directly from the report. The report includes forecasts of acres of land in various uses. The total amount of land in all of the categories except for *Agriculture* and *Rec* is taken to be the total amount of urbanized land forecast for the year 2025.



2000 Urban

Base2B Urban

Base3B Urban

Base4B Urban

The INDOT forecast is for the state TAZs. These TAZs are subareas of the outlying counties and subareas of the Marion County townships. The INDOT forecast values have been aggregated to the counties and townships used for the MPO forecast. Since limited documentation was provided with the INDOT files, assumptions were required regarding the data contained in the attribute tables for those files. The *HOUSEHOLD* field apparently contains the number of households for each TAZ for the forecast year. Each of the files contained two household size variables, *AV_HH_SIZ* and AVHHS. The former contains the same values for both 2000 and 2025. The latter contains different values for the two years. It is being assumed that the latter represents the intended final household size as it is distinct for the two years. Therefore, *AVHHS* was multiplied by *HOUSEHOLDS* to obtain the estimate of the forecast population for each year. The INDOT files did not appear to have information on urbanized land area.

For the seven baseline forecasts, the populations and urbanized areas are output by the model for the mile-square grid cells. Totals for the outlying counties and for the townships in Marion County were estimated from these data, with values for grid cells split by the county or township boundaries being apportioned according to the area of the grid cells in each county or township.

To allow comparison of the LUCI/T baseline forecasts with the original LUCI model, the results from the *LUCI Baseline Forecast 2*, *Three Percent Region Growth*, are also included. This is the forecast that provided for population growth in the CISTMS study area at approximately the rate being forecast by the MPO. It involved no other changes in density or other parameters.

Population Comparison

The populations forecast for 2025 by counties and townships by the MPO, INDOT, the *LUCI Baseline 2 Forecast*, and the seven LUCI/T baseline forecasts are summarized in the table on the following page.

Baseline Forecasts 1, *2A*, and *2B* give very similar results for populations. These results are also generally comparable to the original LUCI baseline forecast that has been included. For the outlying counties, the three LUCI/T forecasts are slightly higher than the LUCI forecast for Boone County, and *Baseline Forecasts 1* and *2B* are slightly higher for Hamilton County. The forecasts for the remaining counties are quite similar. Within Marion County, the LUCI/T forecasts are a bit lower for Decatur and Warren Townships.

Looking *at Baseline Forecasts 3* and *4*, the most significant effect is the decrease in the predicted populations for Hamilton County when compared with the previous forecasts. Forecast populations in Morgan and Shelby Counties increase for all of these forecasts. With *Baseline Forecasts 3*, with reduced population densities, Hancock, Hendricks, and Johnson also see increases as more of the increased demand for land is accommodated there. The dispersal of development with *Baseline Forecasts 4* causes increases in the predicted populations for Boone and Madison Counties. By pushing development farther

Table 1

Forecast 2025 Population

Area	MPO Forecast	INDOT Forecast	Baseline Forecasts							
			LUCI	LUCI/T						
			Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties										
Boone	67,100	64,114	67,649	73,504	71,623	72,673	70,726	71,845	77,845	78,863
Hamilton	344,200	279,198	269,957	273,952	268,964	273,380	259,054	261,520	261,268	264,660
Hancock	78,800	84,618	80,999	80,911	81,331	80,618	89,643	89,050	82,685	82,194
Hendricks	183,600	166,892	165,166	162,334	161,774	162,237	164,251	165,369	157,793	157,746
Johnson	174,700	168,330	144,836	140,934	143,572	141,964	148,927	147,426	143,608	142,369
Madison	124,000	145,968	142,269	141,906	141,028	140,956	144,549	144,555	149,768	149,772
Morgan	85,000	87,738	76,965	76,662	78,040	77,291	82,240	81,347	84,498	83,973
Shelby	47,400	52,638	49,835	49,119	49,222	49,303	51,383	51,522	59,188	59,237
Marion County Townships										
Center	151,330	160,716	167,158	166,956	166,921	166,925	166,834	166,839	166,754	166,758
Decatur	30,840	23,700	42,380	39,023	40,466	39,504	39,370	38,763	36,929	36,270
Franklin	47,990	24,353	53,313	51,396	53,880	52,348	52,116	50,947	48,940	47,701
Lawrence	114,750	88,273	119,447	120,403	119,979	120,139	116,782	116,886	117,114	117,253
Perry	92,670	94,168	106,578	103,977	104,815	104,251	102,941	102,645	102,359	101,866
Pike	68,970	53,705	85,907	85,881	85,285	85,611	83,215	83,421	83,317	83,597
Warren	95,570	92,218	114,460	111,664	112,459	111,818	110,280	109,994	108,775	108,275
Washington	126,740	180,570	139,006	138,753	138,176	138,484	135,937	136,082	136,850	137,129
Wayne	125,170	171,121	136,609	135,856	135,723	135,752	134,927	134,970	134,582	134,601
County Total	854,030	888,824	964,858	953,908	957,704	954,833	942,401	940,546	935,620	933,450
Total	1,958,830	1,938,320	1,962,533	1,953,231	1,953,259	1,953,256	1,953,173	1,953,180	1,952,273	1,952,266

out, these forecasts produce lower predicted populations for Marion County as a whole, with smaller populations forecast for most of the townships.

Household Comparison

As explained in the report on the original LUCI baseline forecasts, the model can alternatively be conceptualized as allocating households rather than population. The forecasts of households produced by the model will be proportional to the population forecasts. However, they will bear a different relationship to the forecasts of households developed by the MPO and by INDOT, as those forecasts reflect differences in household sizes in different areas. Treating the model as allocating households requires the use of the mean household size for the region. The value of 2.50 persons per household is used. This is the mean household size for the 9-county CISTMS study areas as reported by the Census for 2000.

The numbers of households forecast for 2025 by counties and townships by the MPO, INDOT, the *LUCI Baseline 2 Forecast*, and the seven LUCI/T baseline forecasts are summarized in the table on the following page.

Starting again looking at the first three LUCI/T baseline forecasts, the forecasts for numbers of households are considerably closer to the MPO and INDOT forecasts than were the population forecasts. Among the outlying counties, these first three LUCI/T forecasts give predicted numbers of households than fall between the MPO and INDOT forecasts for five of the counties and are very close for Morgan County, where the MPO and INDOT forecasts are nearly identical. The LUCI/T forecasts of households are somewhat higher for Boone County and somewhat lower for Johnson County when compared with the MPO and INDOT forecasts. The overall forecasts of households for Marion County are likewise closer to those other predictions. Fewer households are forecast for Marion County and the townships than were forecast using the original LUCI model, bringing the township forecast values closer to those forecast by the MPO and INDOT.

For households, the *Baseline Forecasts 3* and *4* vary with respect to the *Baseline 1* and *2* forecasts in exactly the same way as did population, so there is nothing to add here.

Urban Land Area Comparison

As noted in the report on the original LUCI baseline forecasts, comparison of the forecasts of land area urban between the MPO forecast and the LUCI baseline forecasts is far more complex. (The INDOT forecast does not include predictions of urban land area.) The difficulties arise from different ways in which urban land use is defined and measured and from some issues associated with the MPO data.

Urban land use is normally determined based on ownership parcels, with the entire area of each parcel being assigned the predominant use made of that parcel. The urbanized area data used in the LUCI model were derived from classified LANDSAT satellite

Table 2

Forecast 2025 Households

Area	MPO Forecast	INDOT Forecast	Baseline Forecasts							
			LUCI	LUCI/T						
			Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties										
Boone	26,320	24,723	27,853	29,401	28,649	29,069	28,290	28,738	31,138	31,545
Hamilton	132,390	103,165	111,151	109,581	107,586	109,352	103,622	104,608	104,507	105,864
Hancock	38,570	30,958	33,350	32,365	32,533	32,247	35,857	35,620	33,074	32,878
Hendricks	66,450	60,431	68,005	64,934	64,710	64,895	65,700	66,148	63,117	63,099
Johnson	67,190	63,054	59,634	56,374	57,429	56,786	59,571	58,970	57,443	56,948
Madison	51,700	57,613	58,577	56,762	56,411	56,383	57,820	57,822	59,907	59,909
Morgan	32,720	32,212	31,689	30,665	31,216	30,916	32,896	32,539	33,799	33,589
Shelby	19,100	20,214	20,519	19,648	19,689	19,721	20,553	20,609	23,675	23,695
Marion County Townships										
Center	66,180	66,251	68,825	66,782	66,768	66,770	66,734	66,736	66,701	66,703
Decatur	12,100	8,531	17,449	15,609	16,186	15,802	15,748	15,505	14,772	14,508
Franklin	19,190	8,676	21,951	20,558	21,552	20,939	20,846	20,379	19,576	19,080
Lawrence	46,840	33,942	49,181	48,161	47,991	48,056	46,713	46,754	46,845	46,901
Perry	39,600	39,313	43,882	41,591	41,926	41,700	41,176	41,058	40,944	40,746
Pike	31,490	24,809	35,371	34,352	34,114	34,244	33,286	33,368	33,327	33,439
Warren	41,190	37,691	47,127	44,666	44,984	44,727	44,112	43,998	43,510	43,310
Washington	60,350	81,830	57,234	55,501	55,271	55,394	54,375	54,433	54,740	54,852
Wayne	55,140	71,902	56,247	54,343	54,289	54,301	53,971	53,988	53,833	53,840
County Total	372,080	372,945	397,266	381,563	383,081	381,933	376,961	376,219	374,248	373,380
Total	806,520	765,315	808,045	781,292	781,304	781,302	781,269	781,272	780,909	780,906

imagery. This provides data for 30-meter-square pixels on *land cover*, the observed characteristics of the surface of the earth, rather than *land use*, as traditionally defined. This means that especially within residential areas, significant numbers of pixels will be classified as herbaceous or forest rather than developed, reflecting the presence of grass and trees in those areas. This means that the classified satellite image will designate significantly smaller areas of land as being developed than are normally considered to be in urban use.

To more closely approximate the traditional notion of urban *land use* for the development of LUCI, the area of land cover classified as developed in the satellite imagery was expanded, using the rule that a pixel would be considered to be urban land use if any one pixel in the surrounding 3 x 3 neighborhood were classified as developed land cover. This provides a measure of the amount of land in urban use that is much closer to the normal designation of urban land use. However, it can still result in significant underestimates in very low-density suburban areas with homes on multiple-acre lots.

Comparison of the MPO and baseline urban land use forecasts is further complicated by some anomalies that appear in the MPO land use data. As described above, urban land use is taken to be the sum of land designated as industrial, retail, office, institutional, and the three residential categories. Agricultural and recreational land is not included here in calculating the amount of urban land.

The report on the original LUCI baseline forecasts included a comparison of the amounts of land currently identified as urban by the MPO and in the LUCI data. As expected, the analysis showed the LUCI data having generally consistently lower estimates of the amounts of land in urban use than the MPO across the outlying counties and the townships within Marion County. However, two anomalies were identified in the MPO estimates of the amounts of urban land for Boone and, to a lesser extent, Shelby Counties. The net population densities obtained by dividing total populations by the amounts of urban land estimated by the MPO showed unreasonably low densities for these two counties. This suggests that the MPO may have substantially overestimated the amounts of urban land in these two counties. This should be kept in mind in comparing the LUCI/T forecasts of urban land with the MPO forecast.

With these caveats in mind, the amounts of urban land forecast for 2025 by counties and townships by the MPO, the *LUCI Baseline 2 Forecast*, and the seven LUCI/T baseline forecasts are summarized in the table on the following page. Because of the lower estimates of urban land in the LUCI/T model, a second table follows comparing the forecast percentage changes in the amounts of vacant land, which provides another perspective

The *Baseline Forecasts 1* and *2* of the amounts of urban land are very similar to the baseline forecast shown for the original LUCI model. For all areas, the amounts of urban land predicted by these forecasts are substantially less than the amounts forecast by the MPO. The LUCI/T forecasts generally range from about a half to three-quarters of the MPO forecast values. The exceptions are for the more heavily urbanized townships of Marion County, in which the values are closer, and for Boone and Shelby Counties,

Table 3

Forecast 2025 Urban Land Area

Area	MPO Forecast	Baseline Forecasts							
		LUCI	LUCI/T						
		Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties									
Boone	91,540	18,108	19,817	19,144	19,358	27,290	27,819	25,207	25,405
Hamilton	120,821	66,228	69,434	67,728	68,597	88,148	89,104	67,613	68,244
Hancock	37,540	21,853	22,047	21,867	21,660	35,717	35,404	24,579	24,455
Hendricks	88,249	50,228	50,609	49,960	49,994	70,235	70,706	51,443	51,391
Johnson	85,130	36,384	35,867	36,195	35,780	50,086	49,349	37,993	37,710
Madison	46,839	36,182	35,878	35,470	35,445	41,928	41,944	42,033	42,045
Morgan	45,637	24,341	24,173	24,377	24,177	32,121	31,664	29,947	29,841
Shelby	43,889	11,577	11,165	11,128	11,139	15,242	15,304	18,222	18,260
Marion County Townships									
Center	24,673	24,918	24,912	24,902	24,902	25,053	25,054	24,867	24,867
Decatur	18,917	11,059	10,723	10,894	10,689	14,507	14,272	10,012	9,877
Franklin	20,593	13,262	13,264	13,575	13,263	18,750	18,286	12,359	12,107
Lawrence	27,317	22,209	22,798	22,635	22,647	24,710	24,730	21,897	21,908
Perry	28,237	22,812	22,667	22,740	22,631	24,760	24,662	22,150	22,054
Pike	21,305	18,571	18,687	18,525	18,570	20,076	20,132	18,048	18,087
Warren	29,369	23,314	23,149	23,190	23,060	26,058	25,963	22,292	22,189
Washington	26,120	26,479	26,699	26,575	26,615	27,336	27,369	26,280	26,318
Wayne	30,184	26,284	26,298	26,245	26,245	27,134	27,143	25,980	25,979
County Total	226,715	188,907	189,197	189,281	188,622	208,385	207,612	183,885	183,385
Total	786,360	453,808	458,187	455,150	454,772	569,152	568,907	480,923	480,736

Table 4

Percentage Change in Urban Land Area, 2000-2025

Area	MPO Forecast	Baseline Forecasts							
		LUCI	LUCI/T						
		Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
Outlying Counties									
Boone	116.4%	59.3%	74.3%	68.4%	70.3%	140.1%	144.7%	121.7%	123.5%
Hamilton	126.3%	52.3%	59.8%	55.9%	57.9%	102.8%	105.0%	55.6%	57.0%
Hancock	95.5%	59.6%	61.0%	59.7%	58.2%	160.8%	158.5%	79.5%	78.6%
Hendricks	144.2%	56.1%	57.4%	55.4%	55.5%	118.5%	120.0%	60.0%	59.9%
Johnson	92.0%	37.1%	36.4%	37.7%	36.1%	90.5%	87.7%	44.5%	43.5%
Madison	2.3%	13.6%	12.7%	11.4%	11.3%	31.7%	31.8%	32.0%	32.1%
Morgan	68.8%	22.7%	22.0%	23.1%	22.0%	62.1%	59.8%	51.2%	50.6%
Shelby	90.5%	29.7%	26.0%	25.6%	25.7%	72.0%	72.7%	105.7%	106.1%
Marion County Townships									
Center	0.1%	0.8%	0.8%	0.8%	0.8%	1.4%	1.4%	0.6%	0.6%
Decatur	54.1%	60.9%	56.1%	58.5%	55.6%	111.1%	107.7%	45.7%	43.7%
Franklin	75.6%	70.8%	70.8%	74.8%	70.8%	141.5%	135.5%	59.1%	55.9%
Lawrence	15.0%	17.2%	20.3%	19.5%	19.5%	30.4%	30.5%	15.6%	15.6%
Perry	12.0%	14.7%	14.0%	14.3%	13.8%	24.5%	24.0%	11.4%	10.9%
Pike	3.0%	16.0%	16.8%	15.8%	16.0%	25.5%	25.8%	12.8%	13.0%
Warren	17.3%	20.6%	19.7%	19.9%	19.3%	34.8%	34.3%	15.3%	14.7%
Washington	1.2%	6.7%	7.6%	7.1%	7.2%	10.1%	10.3%	5.9%	6.0%
Wayne	1.3%	5.2%	5.3%	5.0%	5.0%	8.6%	8.6%	4.0%	4.0%
County Total	14.0%	15.7%	15.8%	15.9%	15.5%	27.6%	27.1%	12.6%	12.3%
Total	60.4%	29.2%	30.6%	29.8%	29.6%	62.3%	62.2%	37.1%	37.0%

where the MPO forecasts are very high. The latter were expected given the anomalies described above.

The *Baseline Forecasts 3*, with the much lower density of development, predict much higher amounts of urban land as would be expected. These differences are most dramatic in the outlying counties. The dispersal of development specified in *Baseline Forecasts 4* resulted in somewhat higher predictions of the amounts of urban land in the outlying counties both because of the displacement of some development from Marion County and because development farther from the centers will tend to be somewhat less dense. With the dispersal of urban development, the forecast amounts of urban land for the townships in Marion County were somewhat lower than the amounts predicted by the first three baseline forecasts.

As mentioned above, comparison of the percentage increases in urban land predicted by the MPO forecast and the baseline forecasts provides another perspective. The table with this information is on the preceding page.

The first three baseline forecasts predict percentage increases in the amounts of urban land that are fairly close to the MPO predictions for the townships in Marion County. For the outlying counties, the baseline forecast percentage increases are much less for the baseline forecasts than for the MPO forecast. Looking at the *Baseline Forecasts 3* predicting lower density development, the predicted increases in urban land for the outlying counties is, of course, far higher. These percentage increases are higher than the MPO forecasts for some counties and lower for others. So in this respect, the lower-density baseline forecasts appear to be more comparable to the MPO forecast.

Comparisons at the Township and TAZ Level

This section presents a brief statistical comparison of the LUCI/T baseline forecasts with the MPO forecasts at more detailed levels of geography, townships for the entire study area and the MPO TAZs. The forecast results for the LUCI/T baseline forecasts have been estimated for these spatial units. Values for grid cells split by the township or TAZ boundaries are apportioned according to the areas of the grid cells in each township or TAZ. For the TAZs, which are much smaller, this estimation procedure will result in some significant error.

For the townships, the baseline forecasts are compared with the MPO forecast values reported in the spreadsheet *9-county township forecasts.xls*. Correlation coefficients between the MPO forecast values for 2025 and the LUCI/T baseline forecasts are reported in the table on the following page.

The correlations of the LUCI/T baseline forecast populations with the MPO forecast population and households are very high, all above 0.98. The correlations of the household forecasts are even slightly higher, with most 0.99 or above. While these forecast totals are the relevant values for the travel demand model, comparison of the

Table 5

Correlations Across Townships of MPO Forecast Values with LUCI/T Baseline Forecast Values Estimated for Townships

Area	Baseline Forecasts							
	LUCI	LUCI/T						
	Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
MPO Forecast Population with LUCI/T Forecast Population	0.984	0.985	0.985	0.985	0.982	0.982	0.982	0.983
MPO Forecast Households with LUCI/T Forecast Households	0.990	0.991	0.991	0.991	0.989	0.989	0.990	0.991
MPO Forecast Population Change with LUCI/T Forecast Population Change	0.702	0.735	0.725	0.737	0.705	0.711	0.747	0.756
MPO Forecast Household Change with LUCI/T Forecast Household Change	0.793	0.820	0.811	0.822	0.780	0.786	0.825	0.834
MPO Forecast Percent Urban with LUCI/T Forecast Percent Urban	0.909	0.926	0.928	0.927	0.896	0.896	0.933	0.932

forecast changes provide a more stringent test, as these do not include the starting populations or numbers of households. The correlations of the changes in population forecast by the LUCI/T baseline forecasts and the changes from the MPO forecast are still quite high, all above 0.70. These correlations are higher than the correlation of the original LUCI baseline forecast of population change with the MPO forecast. The correlations involving the predictions of household change are even higher, with most greater than 0.80. This further supports the possibility raised above of interpreting the LUCI forecasts as forecasts of households rather than population. The correlations between the baseline forecasts of percentage urban change with the MPO forecasts are all near 0.90 or above.

For the TAZs, the baseline forecasts are compared with the MPO forecasts reported in the file *2025TAZ.dbf*. The estimated 2000 households from the file *TAZ96.DBF* were used in computing forecast household change. Correlation coefficients between the MPO forecast values for 2025 and the LUCI/T baseline forecasts are reported in the table on the following page.

With the much greater number of smaller TAZs, one would expect the correlations between forecasts to be lower and they are. However, the correlations between population and households as predicted by the LUCI/T baseline forecasts and the MPO forecast are still quite good. All correlations exceed 0.80. The correlations involving population and household changes are substantially lower, ranging from 0.44 to 0.51 for the correlations between the LUCI/T baseline forecasts and the MPO forecasts of population and household change. The correlations for the LUCI/T baseline forecasts were all somewhat higher than the corresponding correlations for the original LUCI model baseline forecast provided for comparison. Contrary to what was observed with the correlations across townships, for all but one of the baseline forecasts, the correlations involving population change exceeded the correlations involving household change. So this makes the question of which might be the better prediction more ambiguous. The correlations between the baseline forecasts of percentage urban change with the MPO forecasts were all high, exceeding 0.80.

Conclusions

Measured by its ability to match the MPO and INDOT forecasts, the LUCI/T model does as well or slightly better than the original LUCI model. The patterns of the forecasts produced by LUCI and LUCI/T observed by examining the individual county and township predicted values are very similar.

The set of baseline forecasts that have been produced demonstrate the range of LUCI/T for producing alternative forecasts representing different assumptions regarding future development. Changing the forecast density and the degree of dispersal of new urban development can yield quite different forecasts of future patterns.

Table 6

Correlations Across TAZs of MPO Forecast Values with LUCI/T Baseline Forecast Values Estimated for TAZs

Area	Baseline Forecasts							
	LUCI	LUCI/T						
	Base 2	Base 1	Base 2A	Base 2B	Base 3A	Base 3B	Base 4A	Base 4B
MPO Forecast Population with LUCI/T Forecast Population	0.805	0.810	0.809	0.811	0.815	0.816	0.817	0.818
MPO Forecast Households with LUCI/T Forecast Households	0.805	0.809	0.808	0.809	0.815	0.816	0.817	0.818
MPO Forecast Population Change with LUCI/T Forecast Population Change	0.489	0.515	0.506	0.516	0.491	0.495	0.478	0.486
MPO Forecast Household Change with LUCI/T Forecast Household Change	0.426	0.447	0.440	0.490	0.479	0.449	0.492	0.484
MPO Forecast Percent Urban with LUCI/T Forecast Percent Urban	0.871	0.861	0.864	0.863	0.801	0.802	0.873	0.872

LUCI/T Documentation

LUCI/T Model for the Central Indiana Suburban Transportation & Mobility Study

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The *LUCI/T* model is an adaptation of the *LUCI, Land Use in Central Indiana* model that has been developed for the Central Indiana Suburban Transportation & Mobility Study (CISTMS). This report describes the changes made in developing the *LUCI/T* model, provides basic instruction on the use of the model, documents the user files and file formats used with the model, and gives some suggestions on the use of the model in the CISTMS. Complete documentation of the original *LUCI* model can be found at *http://luci.urbancenter.iupui.edu.*

Changes Made in *LUCI/T*

The development of *LUCI/T* involved making numbers of changes to the original *LUCI* model to adapt that model for use in the CISTMS. The primary modifications were as follows:

- The *LUCI/T* model is restricted to the 9-county CISTMS study area, while the original *LUCI* model simulated urban development for a larger 44-county region of central Indiana.

- The *LUCI/T* model provides the option for using and uses as the default the forecast of population for the 9-county CISTMS study area developed by the Indianapolis Metropolitan Planning Organization (MPO) as reported in *Indianapolis 2025: Addendum: Projections of Population and Employment to 2025, Indianapolis Metropolitan Area*.

- The original *LUCI* model calculated accessibility to employment—a major predictor of the location of new development—using distances from the grid cells to employment zones. The *LUCI/T* model uses travel times derived from the CISTMS travel demand models, beginning with the base year 2000 travel times provided in the file *CIST_2000_Valid_Skim_1285.txt*.

- The original *LUCI* model used employment by ZIP code. The *LUCI/T* model uses employment by traffic analysis zone (TAZ), starting with the CISTMS base year 2000 estimates of TAZ employment provided in the file *9CTY_TAZ2000_INDOTSOCEC.DBF*.

- The parameters for the models to predict the probability of development and the density of development have been re-estimated for the *LUCI/T* model to reflect the new study area, the new employment zones and data, and the use of the travel times. The results of this estimation are provided in *LUCI/T Model Estimation Report for the Central Indiana Suburban Transportation & Mobility Study*.

- The original *LUCI* model forecast employment growth using simple shift-share models. The *LUCI/T* model provides the option of specifying a forecast of target year employment by TAZ. This is then used with the base year employment to estimate employment for intermediate simulation years using interpolation.

- The *LUCI/T* model provides for the use of a forecast second travel time matrix to be used in the simulation beginning at a year specified by the user in creating a scenario.

- The *LUCI/T* model automatically outputs somewhat more extensive simulation results to a model results file each time a new scenario is created.

Instructions for Use

The *LUCI/T* program is installed like any Windows program. Running the file *setup.exe* runs the installation program, installs the program, and creates a *LUCIT* folder and, within that, a *LUCIT* program entry in the Start menu. (There are no slashes here because of the restrictions on file and folder naming in Windows.) If the defaults are accepted on installation, the *LUCIT* program folder will be installed in the *C:\Program Files* folder. A different location for installing the program can be selected during the setup. The location of the *LUCIT* program folder is important, because input and output files are stored in subfolders under the *LUCIT* program folder. (The files of concern to the user of the model are described in the following section.)

Like the original *LUCI* model, the *LUCI/T* model is very easy to use. One simply clicks on buttons to carry out all of the operations in *LUCI/T*. *LUCI/T* also contains an extensive, context-sensitive help system that can be accessed at any time when working with the program. Perhaps the easiest way to become familiar with using the model is to go through the short *New User Tutorial* that can be accessed in the help window when the program is first run.

A key element in the *LUCI/T* model is the *scenario*, a specific simulation of future urban development created by specifying a set of parameters for that simulation. The model always displays the results for two scenarios, the *Active Scenario* and a *Comparison Scenario*. When a new simulation is run and a new scenario is created, it becomes the *Active Scenario*. If desired, the *Comparison Scenario* can be changed by using tools that can be accessed using the *Manage Scenarios* button on the *Main Menu*.

When *LUCI/T* is first run, it displays as both the *Active* and *Comparison Scenarios* a scenario named the *Current Trends* scenario. The *Current Trends* scenario is a simulation of urban development to the year 2025. It assumes that population growth for the entire area will be as forecast by the Indianapolis MPO for the 9-county area. Employment by TAZ is assumed to be unchanged from the initial base year 2000 employment. Travel times over the period of the simulation are assumed to be unchanged from the base year 2000 travel times. Water and sewer utilities are not required for development and are assumed to be extended to grid cells adjacent to those already served when the level of urbanization in a grid cell exceeds 20 percent. (This is approximately the level of urbanization at which half of the grid cells have utility service.) Density and dispersal of development are as predicted by the model based upon the estimation of the equations using the 1993-2000 data.

At any time one is working with the model, one can view the simulation results for the two scenarios. The *View Summary Results* button provides access to tables that provide the specifications used in creating the scenarios, extensive results for the region as a whole, and limited results on urbanization by county. The *View Mapped Results* button displays maps showing simulated changes in urbanization, final total urbanization, and comparisons with year 2000 and final total urbanization.

The *Create Scenario* button is (obviously) used to run a simulation and create a new scenario, which will become the *Active Scenario*. The additional buttons open dialog boxes that allow changing of the scenario specifications from those used in creating the current *Active Scenario*. Two of these specifications are unique to *LUCI/T*. *Employment* allows the specification of a forecast of TAZ employment for the target year to be used in the simulation. Check the box and use the *Browse* button to select the file with the forecast employment. (The format required for this file is described in the following section.) If an employment forecast is used, levels of TAZ employment for simulation years after 2000 are obtained by interpolation from the base year 2000 employment and the forecast target year employment.

Travel Times is used to specify that a second travel time matrix be used in the simulation, beginning in the simulation year selected by the user in the dialog box. The user selects the file with the second travel time matrix in the same manner that is used to select the file for an employment forecast. (The format required for this file is also described in the following section.) If a second travel time matrix is used, the base year 2000 travel times are used in the simulation until the year specified by the user. For that simulation period and subsequent simulation periods, the second travel time matrix will be used.

The remaining scenario specification options are the same as in the original LUCI model. *Year and Growth* can be used to specify a different target year and a different rate of population growth for the study area. *Density* can be used to specify minimum or maximum densities or densities that are higher or lower than those otherwise predicted by the model. *Land Restrictions* can limit development on certain types of lands. *Water and Sewer* can be used to require that utilities be available for development to occur and to specify a fixed rate of expansion of utilities around the major urban centers. *Dispersal* can be used to specify more or less dispersal of new urban development than would otherwise be predicted by the model. *Maximum Development* sets the maximum amount of land in a grid cell that can be converted to urban use. Because the estimates of urban land in suburban areas are likely underestimates and because the past data show it to be highly unlikely that suburban grid cells will become completely urbanized, setting a maximum percentage less than 100 will likely result in better forecasts. The default value of 85 percent is used in the *Current Trends* scenario as this was the approximate value that resulted in the best predictions when fitting the model to the data for the period from 1993 to 2000.

After the specifications have been set for a new scenario, the *Run Simulation* button is used to start the process. A dialog box opens for the entry of the name to be given to the new scenario, with the results being saved in a scenario file with a *.luc* extension. (Note that the *LUCI/T* scenario files are not compatible with the scenario files from the original *LUCI* model.) Simulation results for each five-year simulation period are displayed on the screen as the simulation progresses. When a second travel time matrix is used or has been used, there can be significant delays caused by the need to load the very large travel time files and calculate the values to be used in determining employment accessibility. At the conclusion, the new scenario now becomes the *Active Scenario*.

In the *LUCI/T* model, beginning and ending urban land, population, and numbers of households by grid cell are automatically saved to a model results file with the same name that was given to the scenario and with the extension *.txt*. This file is saved in the *ModelResults* folder under the *LUCIT* program folder. The file format and use of these model results files are described in the following section as well.

User Files and File Formats

Users of *LUCI/T* will work with three types of files—employment forecast files, second travel time matrix files, and model results files. The first two file types are used to provide data for new scenarios and are provided by the user. The model results files are generated by the model. This section describes the three types of files and the file formats.

Employment Forecast Files

Employment forecast files provide forecast employment by TAZ for the target year. If an employment forecast is used in the simulation, employment by TAZ for the intermediate years in the simulation are obtained by interpolation between the base year 2000 TAZ employment and the forecast target year TAZ employment.

The employment forecast files are simple comma-delimited (comma-separated-variable, CSV) text files with the extension *.txt*. The files have one line for each TAZ and two entries on each line, separated by a comma. The first entry is the TAZ number and the second is the forecast employment for that TAZ. The file **must** be in numerical order by

TAZ. The employment forecast file has the same format as the base year employment file, *TAZEmp2000.txt*.

Since the *Target Year Employment Forecast File* option allows one to browse to any available folder, the employment forecast files can be at any location. The browsing begins, however, in the *Employment* folder under the *LUCIT* program folder (which will generally be installed under *C:\Program Files*). It will therefore probably be most convenient to copy employment forecast files to that folder to make them readily available when simulations are being run.

The *LUCI/T* program does not do any error checking when reading in the employment forecast files. The user is responsible for having the data in the proper format. Errors in the file format will either cause errors in the simulation or, more likely, the crashing of the program.

Second Travel Time Matrix Files

Second travel time matrix files provide forecast travel times by traffic analysis zone for some year following the starting year. If used in the simulation, a second travel time matrix file will be used in the simulation in calculating accessibility to employment beginning in the *Start Year* specified by the user.

The second travel time matrix files are simple comma-delimited (comma-separated-variable, CSV) text files with the extension *.txt*. The files have one line for each TAZ-to-TAZ travel time and four entries on each line, separated by commas. The first entry is the origin TAZ number, the second is the destination TAZ number, the third is the travel time, and the fourth is the distance. This is the format in which the base year travel times (skim tree) were provided by Cambridge Systematics for the development of the *LUCI/T* model. Note that the file must have the travel times only for the 1285 TAZs within the study area; records must not be included for the external stations.

Since the *Second Travel Time Matrix File* option allows one to browse to any available folder, the second travel time matrix files can be at any location. The browsing begins, however, in the *TravelTime* folder under the *LUCIT* program folder (which will generally be installed under *C:\Program Files*). It will therefore probably be most convenient to copy second travel time matrix files to that folder to make them readily available when simulations are being run.

The *LUCI/T* program does not do any error checking when reading in the second travel time matrix files. The user is responsible for having the data in the proper format. Errors in the file format will either cause errors in the simulation or, more likely, the crashing of the program.

Model Results Files

Each time a simulation is run in *LUCI/T*, the model automatically produces a model results file that is saved in the *ModelResults* folder under the *LUCIT* program folder, which will normally be installed under the *C:\Program Files* folder.

The model results file will have the same filename that was given to the scenario at the time the scenario was created, with the extension *.txt*. This means that each simulation created will produce a new model results file, unless the user provides for the new scenario the name of an existing scenario and overwrites that scenario file. In that case, the model results file will be overwritten with the results for the new scenario as well.

The model results files are simple, comma-delimited (comma-separated-variable, CSV) text files. The files have a header line with the variable names, enclosed in double quotes and separated by commas. The file has one line of data for each of the mile-square grid cells, with the data values separated by commas. The variables included in the model results files are as follows:

- *CellID* – the unique ID for the grid cell, which is used for joining the model results file data to the *gridcell.shp* file for use in a geographic information system
- *Urb2000* – the amount of urban land in the grid cell at the start of the simulation in 2000 in square miles (since these are 1-mile-square grid cells, this is, of course, also the proportion of the land urban)
- *UrbYYYY* – the amount of urban land in the grid cell forecast for the target year of the simulation, where *YYYY* is the target year (for most uses in CISTMS, this will generally be 2025)
- *Pop2000* – the population in the grid cell at the start of the simulation in 2000
- *PopYYYY* – the population in the grid cell forecast for the target year of the simulation, where *YYYY* is the target year
- *HHld2000* – the number of households in the grid cell at the start of the simulation in 2000
- *HHldYYYY* – the number of households in the grid cell forecast for the target year of the simulation, where *YYYY* is the target year

The *CellID* refers to the grid cell ID used in the shapefile *gridcell.shp*, which contains the polygons for the grid cells in the CISTMS study area. A model results file can be joined to the attribute table of the *gridcell* shapefile using the variables *CellID* in both files for mapping and analysis of the model results in a geographic information system.

The files for the *gridcell* shapefile are included in the *ModelResults* folder. Also included is the shapefile *county.shp* with county boundaries that have been adjusted to be aligned with the grid cell boundaries, including in each county those grid cells that have the majority of their areas in that county. This is for reference purposes in displaying the grid cell data.

The shapefiles are NAD 1927, UTM Zone 16. Projection files are included for using the files in ArcGIS.

Use of *LUCI/T* in CISTMS

This section offers some ideas on the use of *LUCI/T* in the CISTMS planning process. These are not intended to be definitive directions, but rather possibilities to be considered. Others will have different and possibly better ideas. The first part addresses the details of using the output from the model as input to the trip generation model. The second discusses the broader issues in the use of *LUCI/T* with the travel demand models. Some comments on generating alternative scenarios are in the final part. The suggestions become more speculative as one proceeds through this section.

Using the LUCI/T Output for the Trip Generation Model

Running a *LUCI/T* simulation produces output for the mile-square grid cells for urban land, population, and numbers of households. This provides some of the basic input for the trip generation model.

The first issue will be the estimation of the simulated results for the TAZs. Assuming that the values are uniformly distributed within the grid cells and then allocating the grid cell values to TAZs based upon the proportion of the area of each grid cell falling into each TAZ would seem to be a reasonable approach. Of course, determining these areas for the allocation need only be done one time, and once the appropriate conversion has been set up, it can be applied very quickly to the output of each simulation. Given the relatively small size of the grid cells compared with the TAZs in the suburban areas, which are the areas of greatest concern for this study, the error introduced by such an estimation process should be minimal compared with the error inherent in this (or any such) simulation.

Then there is the issue of which output values are to be used as input to the trip generation model. The *LUCI/T* output in the model results files includes both population and households. As explained in the first report, *LUCI Baseline Forecasts and Forecast Comparisons for the Central Indiana Suburban Transportation & Mobility Study*, it is possible to view the model as allocating either population or households when simulating urban development. (The model does not consider variations in household size within the study area, providing the household numbers by using the Census 2000 household size for the entire area.) Therefore, using simulated population and converting to households by using household sizes that vary by TAZ will give different estimates of the number of households by TAZ than using simulated numbers of households. The *Baseline Forecasts* report provides some evidence that the household forecasts from the original *LUCI* model were slightly closer to the numbers of households forecast by the MPO and by INDOT than were the population forecasts. (Of course, this is a valid basis for choice only by making the assumption that the MPO and INDOT forecasts themselves are closer to the correct future values.) My feeling is that using the households might be better, but I cannot provide conclusive evidence. There is clearly a judgment call that must be made here.

Another issue involving the selection of output to use is the choice between using the simulated final numbers of persons or households or the simulated changes in the numbers from 2000 to the target year. For several reasons, I believe it would be better to use the simulated change. The *LUCI/T* model begins with the populations estimated for the grid cells from 2000 census data. It does not incorporate actual numbers of households from the census; the numbers reported are simply estimates using the single uniform household size from the census for the entire study area. *LUCI/T* is simulating new urbanization and additions to the numbers of persons and households over time. So if households are to be used, it would be best to calculate the increases in the number of households from 2000 to the target year from the model results and add these increases to the numbers of households for the TAZs in 2000. Even if population were to be used rather than households, using the simulated change would be preferable as it would avoid introducing certain types of estimation errors. The grid cell populations were estimated from the census, and the process of doing that estimation will have introduced some error. Then converting the simulation results for the grid cells to the TAZs introduces additional error. Finally, the estimation of the populations for the TAZs from the census data may have introduced some error if the TAZ boundaries overlapped with the census geography. As a result, when the 2000 populations for the grid cells are converted to the TAZs, those values will not be exactly the same as the TAZ 2000 populations. Using simulated changes in population rather than the final simulated values avoids the introduction of inconsistencies arising from these errors.

Using LUCI/T with the Travel Demand Models

With the locations of population and households being a key determinant of travel demand, obviously the simulated forecasts of these are an important input into the travel demand models. However, since accessibility to employment and travel times can have a significant effect on the location of new urban development, which *LUCI/T* attempts to capture, the relationship works in the other direction as well. Travel times, as forecast by the travel demand models, are an important input to *LUCI/T*. This part presents some initial thoughts on how to capture this two-way relationship.

For any given alternative under consideration, one might begin by using the forecast of 2025 employment by TAZ to generate a scenario in *LUCI/T*, initially using the base year 2000 travel times. Use the change in simulated population or households to 2025 as input to the trip generation model. Proceed through the travel demand models to produce the forecast 2025 travel times. Of course, those will be different from the base year 2000 travel times. For some origin-destination pairs, the times will be longer, reflecting increased congestion resulting from increased demand. And for alternatives involving the development of new facilities, travel times between other origin-destination pairs will be lower, reflecting the greater accessibility provided by those facilities.

The changes in travel times will not, of course, suddenly occur in 2025. Changes due to increased congestion arising from population growth might be expected to occur incrementally throughout the period. Changes due to the development of new facilities would depend upon when those facilities were projected to be developed. But the effects of new facilities on urban development might even precede the opening of those facilities as locators anticipated the benefits of improved accessibility that those new facilities would be providing.

To capture these effects of travel time changes, run a second simulation in *LUCI/T* using the new, forecast 2025 travel times starting in some intermediate year, say 2010 or 2015. Then take the new model results as inputs to the trip generation models and run the travel demand models again, producing new travel times that should reflect the effect of the changes in travel times on the pattern of urban development.

Of course this would result in further changes to the travel times. However, given the various uncertainties and assumptions involved, I would seriously doubt whether repeating the process more than once would be worth the effort.

Admittedly, this is an imperfect procedure for capturing the dual effects of urban development on travel times and of travel times on urban development. One could easily imagine all sorts of elaborations that might be undertaken to refine the process. However, I believe this represents a reasonable approximation that allows the effects of travel times on urban development to be considered along with the effects of urban development on trip generation and travel times.

Generating Alternative Scenarios

The original *LUCI* model was premised on the assumption that the choices and uncertainties associated with future urban development made the generation of a single forecast of future urban patterns inappropriate. Therefore, the model provides the opportunity to generate and compare multiple scenarios reflecting differing policy choices and differing assumptions regarding how future urban development might occur. *LUCI/T* retains these capabilities.

The *LUCI/T* model, the model parameters, and the default scenario specifications (as incorporated in the *Current Trends* scenario), represent my best estimates using the data available from 1993 to 2000 as to how future development is likely to occur if it proceeds as it has in the recent past. But others might make different but equally reasonable assumptions. For example, as noted in the *Baseline Forecasts* report, the original *LUCI* model (and, for that matter, the *LUCI/T* model) forecasts higher densities of development and lower amounts of land converted to urban use than the MPO forecast. As the maps generated for the simulations show, the models simulate the continuing spreading out of urban development. But the extent of this dispersal of development may increase, causing even more spreading out than the default specifications would suggest. (The opposite is also, of course, possible, though recent trends might suggest this is less likely without some major changes affecting the nature and location of new urban development.)

It may be worthwhile to test the implications of alternative assumptions by running several different scenarios and inputting the results into the travel demand models. Doing so would not answer the question as to which scenario might be a more accurate forecast of future urban patterns. But it would give some idea as to the sensitivity of travel times and the performance of transportation alternatives with possible variations in future development patterns.

It seems to me that the more worthwhile alternatives to consider would be lower densities of development and increased dispersal of development. Scenarios reflecting such alternative assumptions have been generated using *LUCI/T* and are described in the report *LUCI/T Model as Modified for the Central Indiana Suburban Transportation & Mobility Study: Baseline Forecasts and Forecast Comparisons*.