APPENDIX D

TRAFFIC MODELING TECHNICAL REPORT

I-69 Evansville to Indianapolis
Tier 2 Studies

I-69 Corridor Travel Demand Model: Technical Memorandum

Prepared for the
Indiana Department of Transportation

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I. INTRODUCTION

The I-69 Evansville to Indianapolis Study Tier 1 Environmental Impact Statement (EIS) focused on the choice of a preferred corridor that connects Evansville and Indianapolis by addressing broad planning issues. The Tier 1 Study revealed Alternative "3C" as the preferred corridor that satisfies transportation, economic development and national I-69 goals. For the preferred corridor, the Tier 2 EIS began to address detailed "foot print", impacts and mitigation associated with the corridor. The corridor was organized into six (6) Tier 2 sections each of which was assigned to the Environmental and Engineering Assessment Services Consultant (EEAC). Bernardin, Lochmueller & Associates, Inc (BLA) was selected as the Tier 2 Project Management Consultant (PMC) to manage the six EEACs.

The traffic analysis responsibility of the PMC is to provide centralized traffic modeling and forecasting services to the EEACs in support of their I-69 Tier 2 alternatives design. Although the preferred corridor is divided into six separate sections, traffic in one section can be influenced by design features of the alternative in other sections. Thus, it is essential to provide the EEACs with the forecasts that are consistent from one Tier 2 section to another. For the consistency, the PMC utilized the updated version (version 4) of the Indiana Statewide Travel Demand Model (ISTDM v4) as the backbone of traffic forecasting for the EEACs.

The ISTDM v4 was initially developed in year 2004 under the contract with the Indiana Department of Transportation (INDOT) to provide Specialized Planning Services for statewide projects. The prior version of ISTDM v4 (ISTDM v3), utilized as one of analytical tools developed for the Major Indiana Corridor Investment Benefit Analysis System (MCIBAS), was specifically designed for the I-69 Tier 1 EIS. This version of the statewide model expanded its geographical coverage to bordering states while detailing the network and traffic analysis zones (TAZs) in the southwestern Indiana I-69 Tier 1 study area. The model was built for the base year 1998 and its forecasting was aimed for the horizon year 2025.

The upgraded version ISTDM v4 significantly improved the prior version by increasing the zone and network details to the remainder of Indiana and by updating the base year from 1998 to 2000 using the newly available year 2000 Census data. For example, ISTDM v4 is represented by 4,720 TAZs, a huge increase in zone detail from 844 TAZs in ISTDM v3. After the initial production, model adjustments were made to ISTDM v4 for the I-69 Tier 2 EIS so that the model can produce forecasts consistent with those from ISTDM v3.

The scope of the I-69 Tier 2 EIS specifically called for development of a highly disaggregated I-69 corridor model based on ISTDM v4. The purpose of the I-69 corridor model is twofold: First, it is to serve as a basis for traffic forecasts for I-69 alternatives for each section prepared by the associated section EEAC. Second, it is used as an input to microsimulation models that are built for Sections 5 and 6. To serve this purpose, the corridor model needs to satisfy two basic requirements: On a macro scale, it should maintain the regional trip making patterns forecasted by the statewide model. At the same time, the model should be detail and sensitive enough to capture the difference in I-69 Tier 2 alternatives.

These requirements led to the development of a modeling package in which ISTDM v4 and the corridor model are interconnected in a hierarchical fashion. In the following chapters of this report, the hierarchical modeling process and the features of the I-69 corridor model are described in detail.

II. CORRIDOR MODEL DEVELOPMENT

1. MODEL STRUCTURE

The ISTDM v4 and the I-69 corridor model constitute a single hierarchical modeling package. In this hierarchical structure, statewide-level trip making patterns are first established by performing a sequential modeling process using ISTDM v4 network and TAZ systems. The process results in origin-destination trip interchanges between ISTDM TAZs as the end-product of the statewide model portion of the modeling package. This end product reflects regional trip making patterns forecasted in the I-69 Tier 1 EIS.

The I-69 corridor modeling stems from the end phase of the statewide modeling process. The corridor model uses the ISTDM-generated trips as an input and assigns them to a more detailed network within the I-69 corridor.

The overall steps taken in the hierarchical modeling structure are presented in **Figure 1**. The top-half of the flowchart in the figure illustrates the procedure taken in statewide modeling. The procedure follows the traditional sequential process, beginning with trip generation. In trip generation, trip productions and attractions are estimated by trip purpose for ISTDM TAZs. The trip distribution phase utilizes the Gravity Model to distribute trip productions and attractions between ISTDM TAZs on the statewide model network. The output of the Gravity Model, production-attraction person trip tables by trip purpose, is then divided to extract highway and transit trips by applying mode choice factors. The highway trips are converted to auto trips by applying auto occupancy factors by trip purpose.

In the next step, the production-attraction auto trip tables are converted to an origin-destination format so that those trips can be expressed as correct directional flows. Truck trips and auto external trips are then combined to the auto trips to produce a single origin-destination matrix as the final product of the statewide modeling procedure. In the corridor modeling stream, the matrix is not assigned to the statewide network since the assigned statewide network is not needed by the corridor model.

As the first step in the corridor modeling, the production-attraction auto trip tables by trip purpose are converted to origin-destination trip tables by time-of-day by applying appropriate time-of-day and directional factors. The corridor model retains the trip purposes used for the statewide model, which are home-base work, home-based other, non-home-based and long trips. Truck and auto external trip tables are also disaggregated into time-of-day tables.

The I-69 corridor area is defined from the whole ISTDM modeled area to prepare for the subarea analysis. This area is located in the southwestern Indiana covering entire or part of 28 counties. The auto and truck trip tables by time-of-day are used for the subarea analysis for the corridor modeling area. Trip tables representing the corridor area are extracted using the subarea trip table extraction procedure in TransCAD through the multi-modal multi-class assignment (MMA).

The TAZ system of the corridor model is more detailed and refined than that of ISTDM. All corridor model TAZs were created by disaggregating the associated ISTDM TAZs. Since the extracted subarea trip tables are still in the ISTDM TAZ system, they need to be disaggregated to the corridor model TAZ level. For matrix disaggregation, each ISTDM TAZ of the subarea trip tables is applied with factors indicating what proportion each disaggregated corridor TAZ is of the original ISTDM TAZ. Those factors are obtained through the trip generation process performed on corridor TAZs. In the final step, the disaggregated trip tables are assigned to the corridor model network.

Details of the corridor modeling are presented in Section 5 of this report.

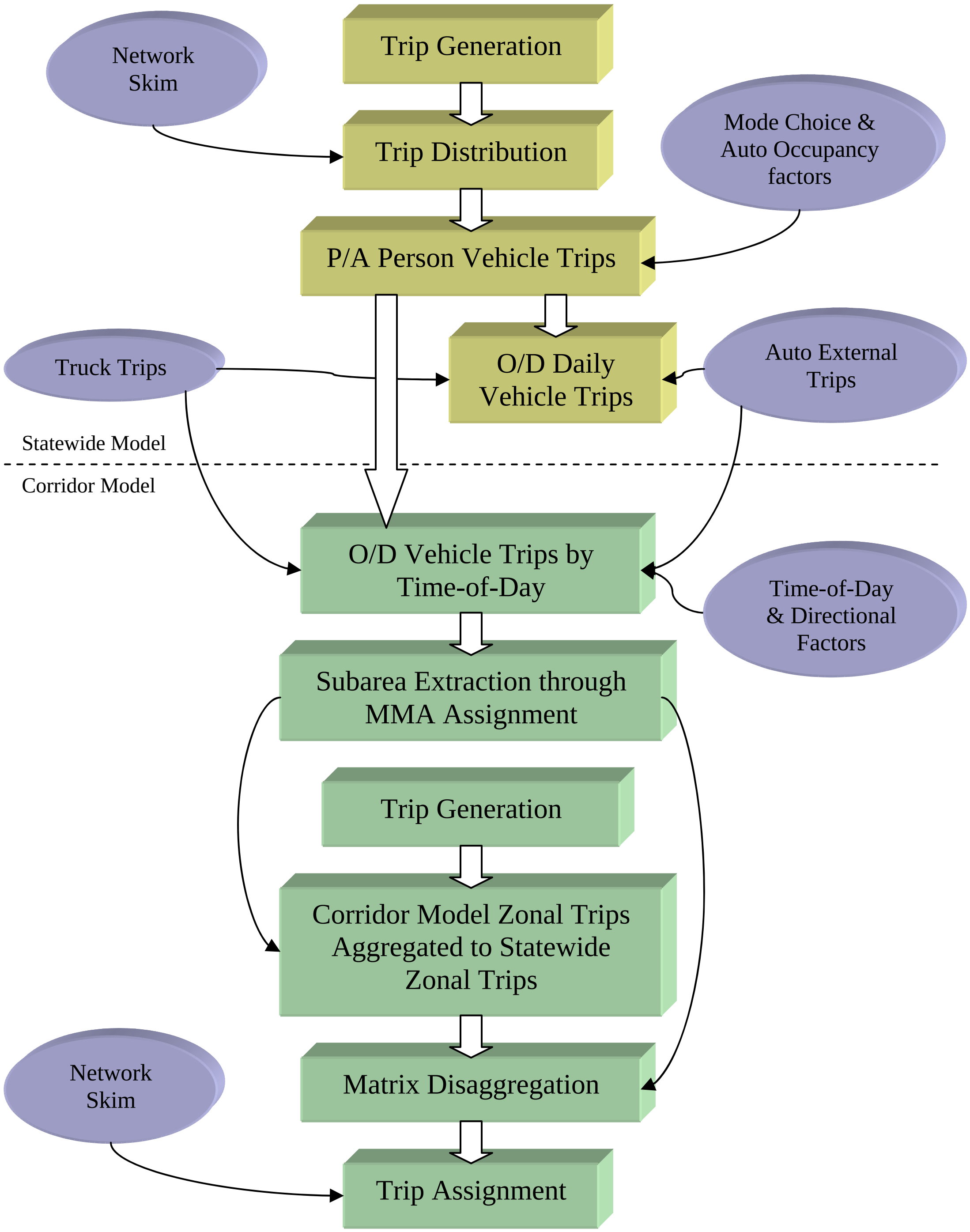


Figure 1. Corridor Modeling Stream

2. MODEL AREA

The ISTDM study area comprises all 92 counties Indiana and parts of neighboring states, Illinois, Kentucky, Ohio and Michigan (**Figure 2**). From the ISTDM study area, the corridor model extracts a subarea in the southwestern Indiana which consists of metro area of Indianapolis, Bloomington and Evansville and the area between (**Figure 3**). The subarea includes the entirety of Marion, Johnson, Morgan, Owen, Monroe, Brown, Greene, Daviess, Pike, Gibson, Posey, Vanderburgh and Warrick counties, and the part of Hamilton, Boone, Madison, Hancock, Shelby, Knox, Bartholomew, Hendricks, Putnam, Clay, Lawrence, Jackson, Martin, Dubois and Spencer counties.

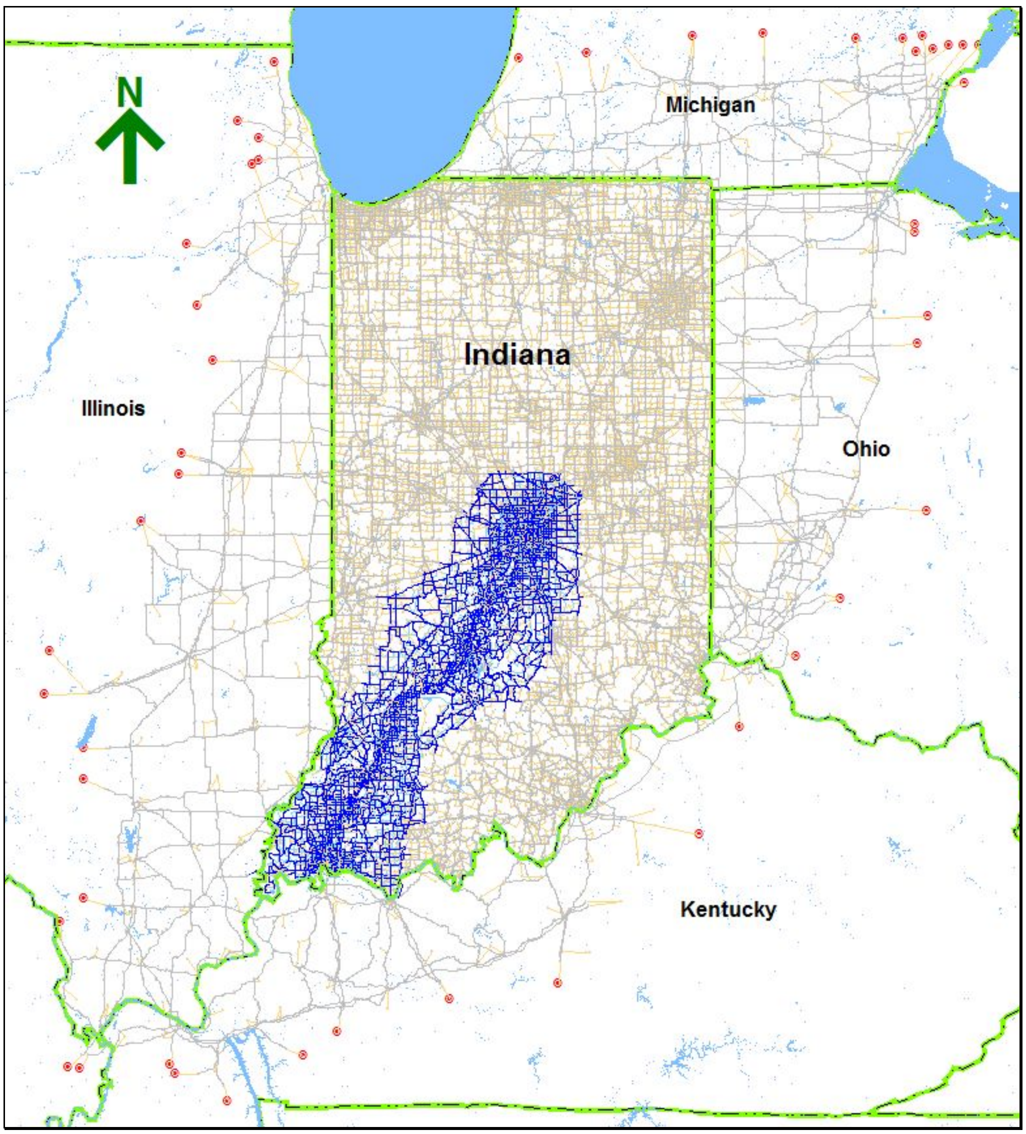


Figure 2. Statewide and Corridor Model Area

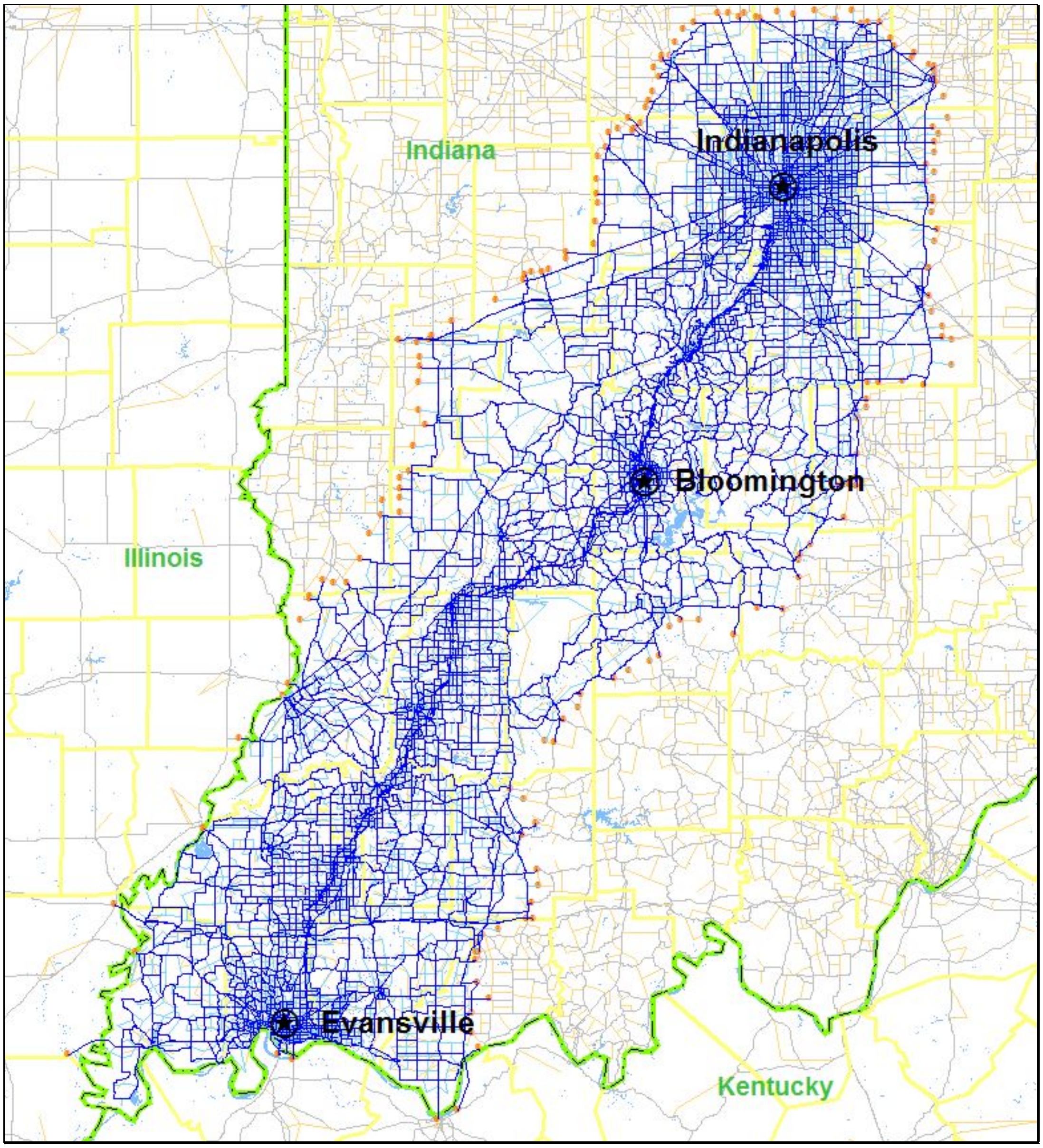


Figure 3. Corridor Model Area

3. NETWORK DEVELOPMENT

A subset of the ISTDM v4 network was the beginning point for the development of the corridor model network. Additional network detail was added to the ISTDM v4 subset to create the corridor model network. The network addition was based on Census 2000 TIGER/Line® Data county roadway files, INDOT Functional Classification maps, and current GIS-based aerial photography.

The greatest detail was added for the region proximate to the I-69 corridor, with a decreasing level of detail going out farther from the corridor. In the vicinity of the I-69 corridor, the corridor model includes all roads down to the functional classification of minor collector (in rural areas) and collector (in urban areas). In addition, some local roads are included that could possibly be affected by I-69 (e.g., being considered for closure or grade separation). Farther from the I-69 corridor, network was added in the nearby counties based on maintaining connectivity. Having added the corridor model network, comparisons were made between the corridor model and the Metropolitan Planning Organization (MPO) models for Bloomington, Indianapolis, and Evansville Urban Transportation Study (EUTS) area to verify inclusion of network detail.

The completed corridor model network, covering only the corridor in southwestern Indiana, consists of more than 37,000 links, or 9,000 road miles. In comparison, the ISTDM v4 network comprises 31,900 links, or 19,000 road miles for all of Indiana. This network is conjoined with TAZs via nearly 9,300 centroid connectors that load traffic onto appropriate loading points in the network. In comparison, the ISTDM v4 contained 9,900 centroid connectors.

The centroid connectors were initially added to the network using a centroid connector placement tool. In this tool, the maximum number of connectors per zone was limited to three. The program makes sure that connections are made to different facilities while disallowing connections to any facilities with full or partial access control. It finds the nearest facility and makes connection if access control allows. Then, it rotates 120 degree and looks for a new facility and ensures that none of the connections is made to the same facility. It continues through a full 360 degree rotation to complete the connection procedure. The procedure is fully automated and was useful to do initial placement of centroid connectors. The initial location of centroid connectors was later reexamined and adjusted during model validation based on current aerial photography, Census 2000 TIGER/Line® Data county roadway files, and population and employment densities.

Using the INDOT Functional Classification maps, each added roadway was given a functional classification while the TIGER roadway layer was used for the route name attribute. The remaining link attributes were coded with default values, based on the link's functional classification.

Signals were added to the network based on a point layer derived from the ISTDM network and additional location data from INDOT. The signal layer was tagged to the nodes of the corridor model network. After tagging, the network node layer was manually reviewed to verify that signals were correctly placed at nodes. Current aerial photography was also used to verify signal locations on the network. As a result, almost 1,900 traffic signals were coded in the base year network.

Having placed traffic signals at correct nodes in the model network, link attributes associated with signals were also updated. The signal attributes include the relative priority of signalized approaches and the number of upstream signals. These attributes were used as key inputs to calculate signal delay at the signalized approach as part of estimating link impedance of the approaching link.

Figure 4 shows the I-69 corridor model network with centroid connectors, color-coded with functional classification of the road. **Figure 5** highlights the signalized approaches coded in the base year network.

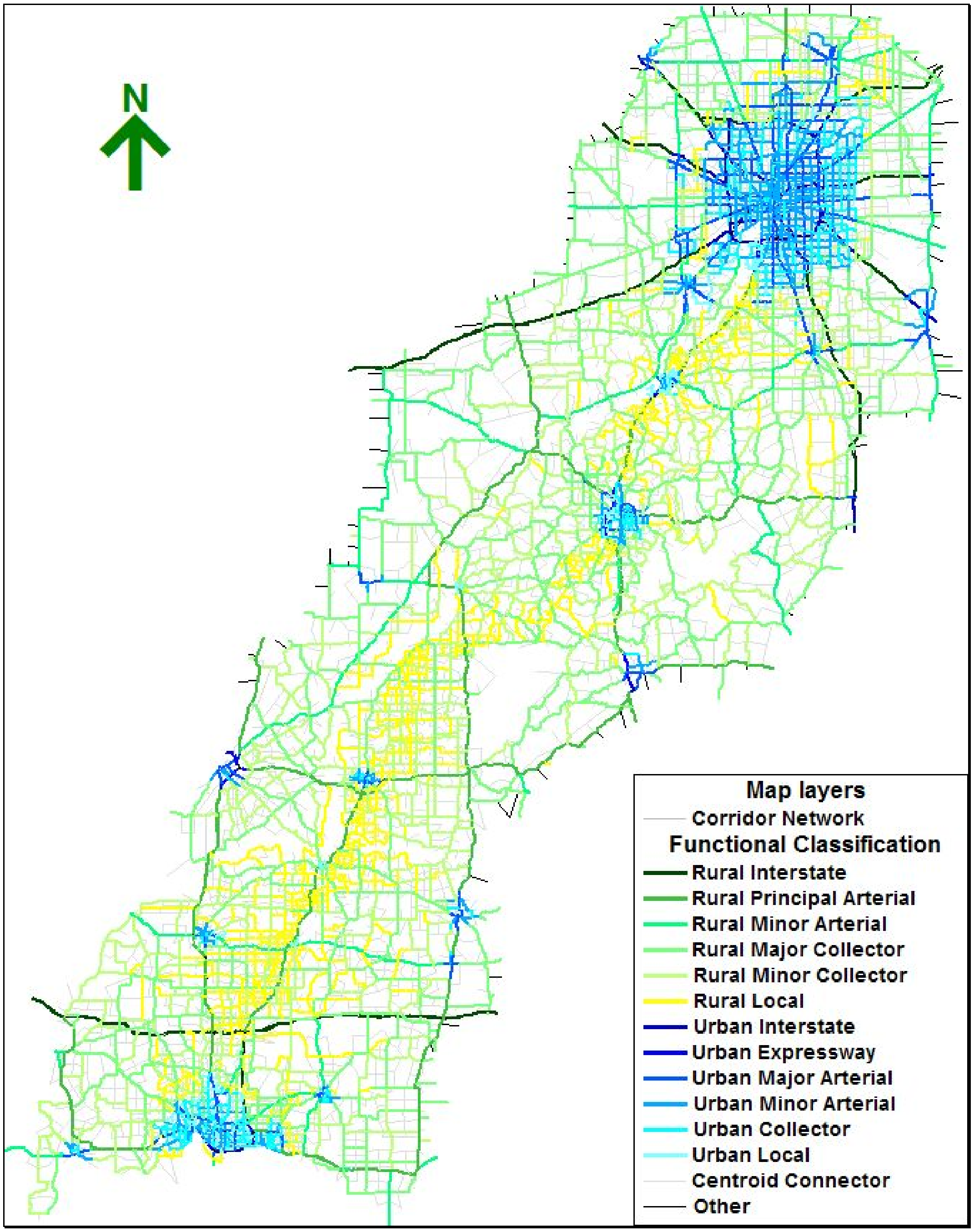


Figure 4. Corridor Model Network with Functional Classification

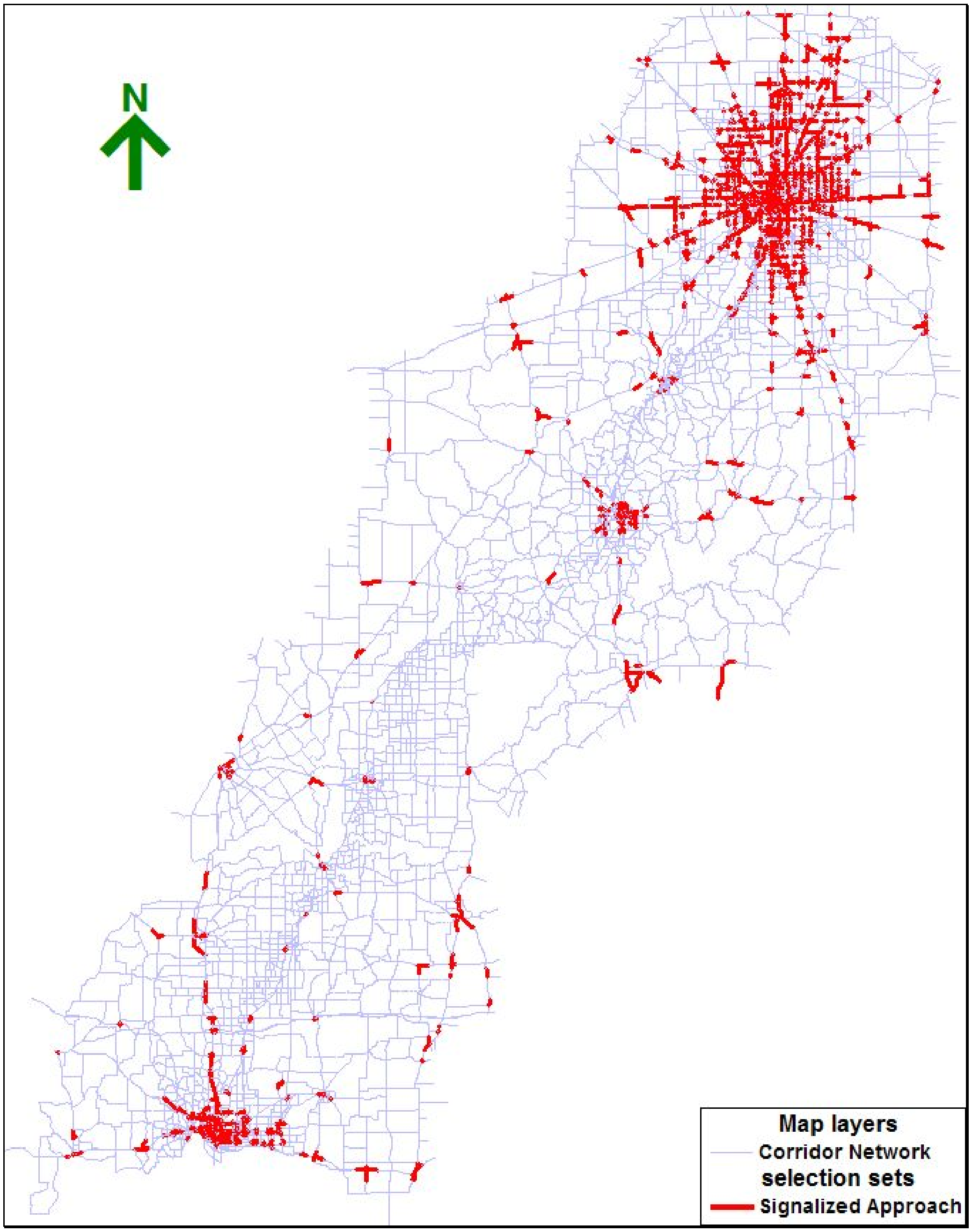


Figure 5. Signalized Approaches in Base Year Network

4. TRAFFIC ANALYSIS ZONE DEVELOPMENT

A subset of the ISTDM v4 TAZ layer was the beginning point for the development of the corridor model TAZ layer. The statewide model TAZs were split, based on Census Block boundaries, for the added network detail. As a result, the corridor model is represented by more than 4,300 TAZs, as compared to 4,600 TAZs for all of Indiana in the ISTDM v4. Correlation between the corridor model and the statewide model is established so that demographic and employment data from the corridor model TAZs aggregate up to the demographic and employment data in the ISTDM TAZs.

The socioeconomic data structure for the corridor model TAZs was built off the data structure of the ISTDM v4 TAZs. Each zone is characterized by approximately 40 zonal attributes. These attributes include Corridor TAZ number, associated ISTDM TAZ number, and detailed categorization of population, households, vehicle ownership, mean household income, and employment by category. The TAZ layer also contains model reference fields that are used to contain trip generation outputs. The socioeconomic variables included in the zonal database are listed in **Table 1**.

Table 1. Traffic Analysis Zone Attributes

Name	Type	Description
ID	Integer (4 bytes)	TransCAD ID Field
Area	Real (8 bytes)	GIS based area
I69taz	Integer (4 bytes)	Corridor TAZ ID Number
Ext_st	Integer (4 bytes)	External Station
ISTDMtaz	Integer (4 bytes)	ISTDM TAZ ID Number
HCLASS	Integer (4 bytes)	Reference Field for Disaggregation
CO_FIPS	Character	Indiana County FIPS Code
COUNTY_NUM	Character	Indiana County Number
POP	Integer (4 bytes)	Total Population
HH	Integer (4 bytes)	Total Households
HHPOP	Integer (4 bytes)	Population in Households
AVGHHSIZE	Real (8 bytes)	Average Persons per Household
MEANHHINC	Integer (4 bytes)	Mean Household Income
VEH_PER_HH	Real (8 bytes)	Average Vehicles Available per Household
GQPOP	Integer (4 bytes)	Total Group Quarters Populations
A_AGFORFIS	Integer (4 bytes)	Agricultural Employment (SIC 01-09)
B_MINING	Integer (4 bytes)	Mining Employment (SIC 10-14)
C_CONSTRUC	Integer (4 bytes)	Construction Employment (SIC 15-17)
D_MANUFACT	Integer (4 bytes)	Manufacturing Employment (SIC 20-39)
E_TRANSPUB	Integer (4 bytes)	Transportation/Communications/Utilities Emp (SIC 40-49)
F_WHOLESAL	Integer (4 bytes)	Wholesale Trade Employment (SIC 50-51)
G_RETAILTR	Integer (4 bytes)	Retail Trade Employment (SIC 52-59)
H_FIRE	Integer (4 bytes)	Finance/Insurance/Real Estate Employment (SIC 60-67)
I_SVCS	Integer (4 bytes)	Services Employment (SIC 70-89)
J_PUBADMN_	Integer (4 bytes)	Public Administration Sector Employment (SIC 91-97)
TOT_EMP	Integer (4 bytes)	Total Employment
EDUCATION	Integer (4 bytes)	Education Employment

Table 1. Traffic Analysis Zone Attributes (Cont'd)

Name	Type	Description
County	Character	County Name
Zonal Class	Character	Area Type
Label	Integer (4 bytes)	External Zone Name Label
Area_Type	Integer (4 bytes)	Area Type Code (1: Urban; 2: Suburban; 3: Rural)
State_ID	Integer (4 bytes)	State ID Code (1: Indiana; 2: Outside Indiana)
SZ_ID	Integer (4 bytes)	SuperZone ID
CAR_AM	Real (8 bytes)	Trip Generation Output
CAR_PM	Real (8 bytes)	Trip Generation Output
CAR_Dly	Real (8 bytes)	Trip Generation Output
TRK_AM	Real (8 bytes)	Trip Generation Output
TRK_PM	Real (8 bytes)	Trip Generation Output
TRK_Dly	Real (8 bytes)	Trip Generation Output

For the development of the zonal attributes, two main data sources, Census 2000 demographic data and ES-202 Employment data, were used. Data for the population and household variables (POP, HH, HHPOP, AVGHHSIZE, and GQPOP) were obtained from the Census SF1 Block data. The Census SF3 Block Group data were used to populate the income and vehicle variables (MEANHHINC and VEH_PER_HH). The Census Block Group data were then allocated to their respective Census Blocks. The Census Block data were aggregated to form the corridor model TAZs. **Figure 6** shows the I-69 corridor model TAZs, color-coded with zonal population density in persons per square mile.

To populate the employment variables, the ES202 Employment data containing number of employees by SIC classification were geocoded to point locations. The point-location data and the data from local Chambers of Commerce were then aggregated for each corridor model TAZ, and factored to county control totals. The EDUCATION employment data were initially obtained from the ES202 data and supplemented with data from the U.S. Department of Education's National Center for Education Statistics and the Indiana Department of Education.

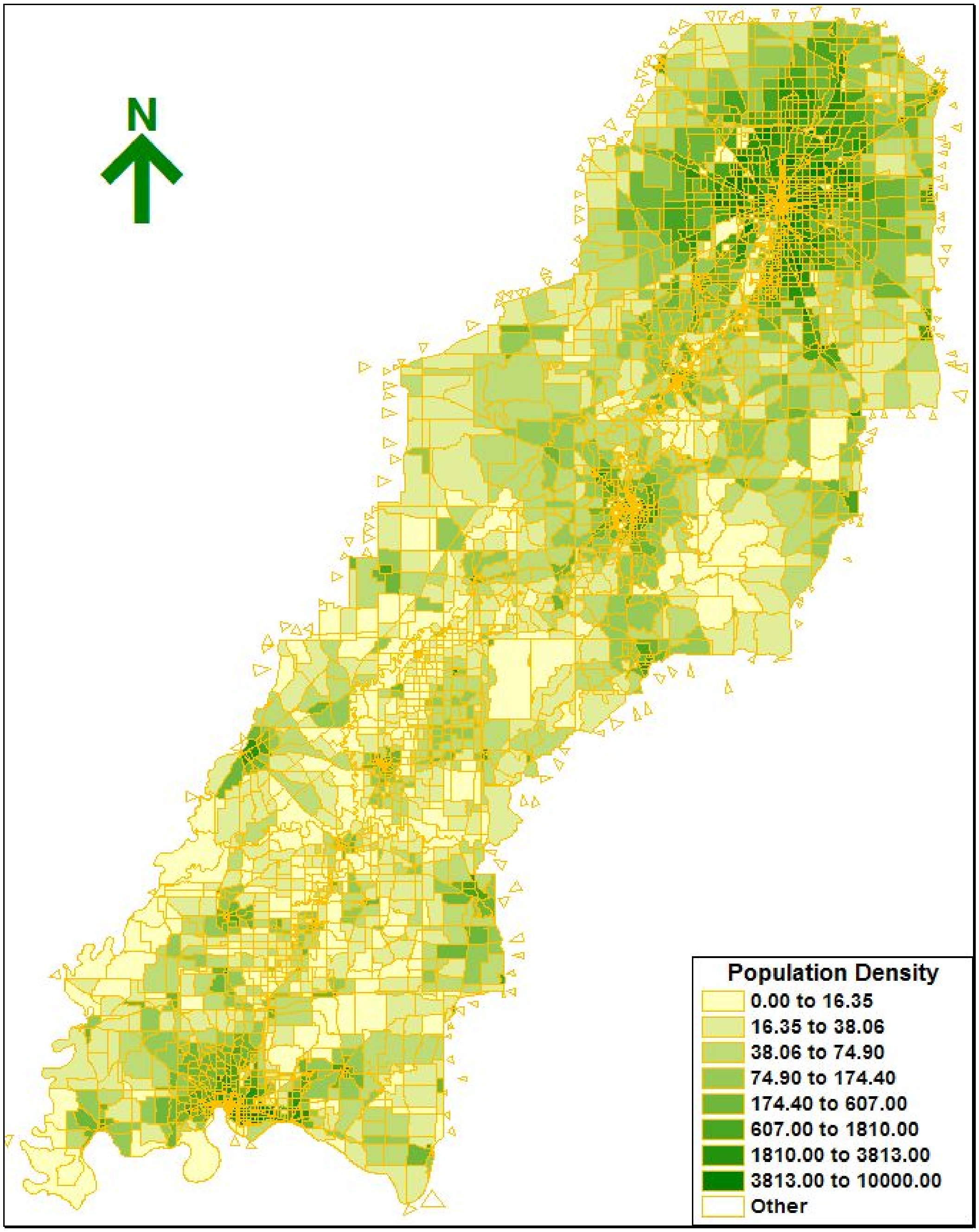


Figure 6. Corridor Model Traffic Analysis Zones with Population Density

5. MODEL COMPONENTS

a. Free-Flow Speed Estimation

The speed estimation procedure adopted for the corridor model is consistent with the procedure used for ISTDM.

The procedure was developed from the speed survey conducted as part of the I-69 Tier 1 Study. The survey, implemented at 64 locations in the southwestern Indiana, resulted in extensive records that contained vehicle speeds by roadway functional classification, posted speed, area type, access control type and number of lanes. For each survey location, a facility type was determined and the posted speed limit and hourly traffic volumes were recorded. Based on the Highway Capacity Manual (HCM)'s definition of free-flow condition using hourly traffic volumes, the records that only represent the free-flow condition were extracted and analyzed.

With the selected speed and geometric data, a test using Analysis of Variance (ANOVA) technique was conducted to check if there is a significant difference in speeds between 2-lane and multilane facilities. The test confirmed that the speeds on these two facilities are statistically different. Following the test, for each facility type, the relationship between posted speed and free-flow speed was identified using nonlinear regression analysis.

Table 2 lists the nonlinear formula developed for major facility types. The speeds for other minor variations in facility type such as one-way streets were derived from these formula based on similarity in geometric and functional characteristics of roadway.

The speed survey that led to the **Table 2** formula was mainly done for the highly classified roads such as interstates, arterials and major collectors. This survey was appropriate for the statewide model since it is focused more on vehicle trips that use the major roads. In the corridor model, on the other hand, the perspective of modeling is changed so that it can address different types of trips ranging from the regional trips to short-distance daily routine trips such as shopping, entertainment and social activities. Thus, the corridor model network was constructed with more details by including the major roads and the lower class roads such as minor collectors, local roads and urban streets. With the addition of minor roads, it was necessary to supplement the speed survey so that the model can represent correct free-flow speeds of the low class roads.

For this purpose, the speed survey conducted by the Association of Monterey Bay Area Governments (AMBAG) was borrowed. Conducted for Monterey, San Benito and Santa Cruz Counties in California in 2002, this survey used Global Positioning Systems (GPS) to capture the speed of vehicles on urban streets through freeways. The corridor model used the average speeds from the GPS survey for lower class roads.

Table 2. Free-Flow Speed Estimation Formula

Area Type	Free-Flow Speed [1, 2]	Condition	Note
2-lane 2-way undivided highways			
Rural	$0.009751 \cdot PSPD^2 + 30.03397$	25 ≤ PSPD ≤ 55	No or Partial Access Control
	25	PSPD < 25	
Suburban	$117.640917 \cdot PSPD^{0.0015+0.001279 \cdot PSPD} - 98.065483$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$6.189 + 0.9437 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
2-lane 2-way divided highways			
Rural	$\left(0.000017 \cdot (PSPD - 72.323105)^2 + 0.019702\right)^{-1} + 19.835323$	25 ≤ PSPD ≤ 55	No Access Control
	25	PSPD < 25	
Suburban	$3.180682 \cdot PSPD^{0.857638} - 84.105587 \cdot e^{-41.803252 / PSPD}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.119687 - 0.023365 \cdot \ln(PSPD)\right)^{-1} + 0.373821 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Multilane undivided highways			
Rural	$\left(0.000017 \cdot (PSPD - 72.323105)^2 + 0.019702\right)^{-1} + 19.835323$	25 ≤ PSPD ≤ 65	
	25	PSPD < 25	
Suburban	$3.180682 \cdot PSPD^{0.857638} - 84.105587 \cdot e^{-41.803252 / PSPD}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.119687 - 0.023365 \cdot \ln(PSPD)\right)^{-1} + 0.373821 \cdot PSPD$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Multilane divided highways			
Rural	$2.836165 \cdot PSPD - 0.071256 \cdot PSPD^2 + 0.000744 \cdot PSPD^3$	25 ≤ PSPD ≤ 50	No or Partial Access Control
	$16.0359 + 0.8223 \cdot PSPD$	50 < PSPD ≤ 65	
	25	PSPD < 25	
Suburban	$\left(0.000071 \cdot (PSPD - 64.166165)^2 + 0.035258\right)^{-1} + 9.061039 \cdot \ln(PSPD)$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	
Urban	$\left(0.081714 - 0.016217 \cdot \ln(PSPD)\right)^{-1}$	25 ≤ PSPD ≤ 55	
	25	PSPD < 25	

Table 1. Free-Flow Speed Estimation Formula (Cont'd)

Area Type	Free-Flow Speed [1, 2]	Condition	Note
Full access controlled multilane highways			
All	64.00	PSPD = 55	
	67.06	PSPD = 60	
	70.21	PSPD = 65	
	73.30	PSPD = 70	

Note: [1] Free-flow speeds in mph, [2] PSPD: Posted speeds in mph
Source: Bernardin, Lochmueller & Associates, Inc., 2004

b. Capacity Estimation

The corridor model uses a capacity-restraint method for its trip assignment, thus the importance of using correct link capacities cannot be overstated. The trip assignment process utilizes a series of volume-delay functions in which the capacity is expressed for level-of-service (LOS) E.

Like the free-flow speed estimation, the capacity estimation for the corridor model follows the procedure used for ISTDM to maintain consistency between two hierarchical models. The following paragraphs describe the procedure in detail.

First, all links in the model area were set to "maximum hourly service flows" as specified in HCM with respect to their facility type. Then, the maximum service flows were adjusted to "hourly service flows" based on several limiting factors. These factors included: right-shoulder lateral clearance, heavy vehicles, driver population, lane width, number of lanes, interchange density, median type, access points, and directional distribution.

A significant effort was given to develop these limiting factors from HCM 2000. For each of these factors, the HCM provides adjustments (or reductions) in free-flow speed that reflect the negative effect of the factor. The reductions are determined based on geometric features of the roadway. For example, for adjustments for lateral clearance for freeways, two geometric variables (right-shoulder lateral clearance and number of lanes) are cross-referenced to estimate the reduction of free-flow speed. These adjustments are then applied to the base free-flow speed to obtain an adjusted free-flow speed that takes into consideration the unique physical conditions of the roadway. Exhibit 23-5 in HCM 2000 show the adjustments.

As the first step to derive the capacity reduction factors, a possible range of free-flow speeds was set based on facility type. In the above example for freeways, speeds from 55 mph to 75 mph in an increment of 2.5 mph were used. For each combination of these preset speeds and the geometric variables, a ratio of the reduced free-flow speed to the base (unadjusted) free-flow speed was calculated. This process resulted in a two-dimensional table (i.e., one dimension containing a range of free-flow speeds and the other containing a geometric variable) that is populated with the ratios, or free-flow speed reduction factors. An example of this table is shown in **Table 3**.

Given the assumption that the service flow is directly proportional to free-flow speed, it follows that the maximum service flow can be adjusted to the service flow with the same reduction percentage as the free-flow speed reduction factor. In this way the speed reduction factors were used to adjust the maximum hourly service flows to derive the hourly service flows.

The two-dimensional table can be represented in a 3-dimensional space as shown in **Figure 7**. The factors in this space were then smoothed by curve fitting the factors using bi-factor nonlinear regression techniques. As an example, **Table 4** lists curve-fitted formulas for capacity reduction factors for lateral clearance. This procedure was applied to other capacity adjustment factors such as adjustments for access point densities, lane widths, etc.

Table 3. Capacity Reduction Factors for Freeways (for 2 lanes in one direction)

right-shoulder lateral clearance (ft)	reduction in free-flow speed (mph)	free-flow speed (mph)								
		75	72.5	70	67.5	65	62.5	60	57.5	55
6	0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.6	0.9920	0.9917	0.9914	0.9911	0.9908	0.9904	0.9900	0.9896	0.9891
4	1.2	0.9840	0.9834	0.9829	0.9822	0.9815	0.9808	0.9800	0.9791	0.9782
3	1.8	0.9760	0.9752	0.9743	0.9733	0.9723	0.9712	0.9700	0.9687	0.9673
2	2.4	0.9680	0.9669	0.9657	0.9644	0.9631	0.9616	0.9600	0.9583	0.9564
1	3	0.9600	0.9586	0.9571	0.9556	0.9538	0.9520	0.9500	0.9478	0.9455
0	3.6	0.9520	0.9503	0.9486	0.9467	0.9446	0.9424	0.9400	0.9374	0.9345

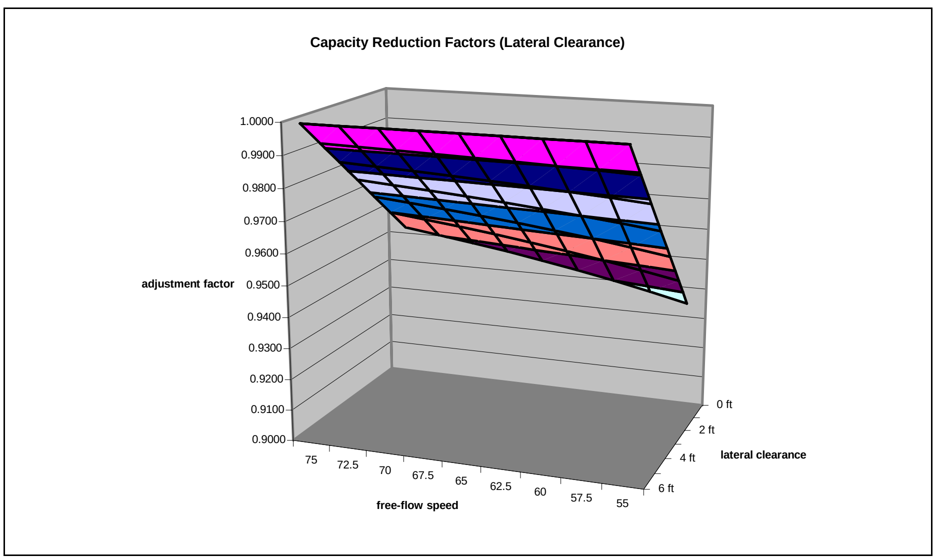


Figure 7. Capacity Reduction Factors for Lateral Clearance (Freeways)

Table 4. Capacity Reduction Factors for Lateral Clearance

Facility Type	Reduction Factor	Condition
Interstates and Freeways		
2 lanes in one direction	$\frac{-6.00001+RSLC}{0.0001+1.66667*FFSpeed}+1$	Min. 0.9345
3 lanes in one direction	$\frac{-5.99999+RSLC}{-0.00084+2.50001*FFSpeed}+1$	Min. 0.9564
4 lanes in one direction	$\frac{-6.00001+RSLC}{-0.00002+5*FFSpeed}+1$	Min. 0.9782
5+ lanes in one direction	$\frac{-6.00002+RSLC}{0.00371+9.99994*FFSpeed}+1$	Min. 0.9891
Multilane Highways		
4 total lanes	$\frac{1095.74797+FFSpeed}{1280.33942+6.53454*RSLC^2}+0.03975*RSLC$	Min. 0.8800
6 total lanes	$\frac{1485.4381+FFSpeed}{1660.34815+3.0981*RSLC^2}+0.02166*RSLC$	Min. 0.9133
Two-lane Highways		
Shoulder width < 2 ft	$1.20306*FFSpeed^{(0.27207-0.08633*\ln(LW))}-\frac{7.09882}{LW}$	Min. 0.8400
Shoulder width < 4 ft	$1.43621*FFSpeed^{(0.26354-0.09366*\ln(LW))}-\frac{8.06484}{LW}$	Min. 0.8800
Shoulder width < 6 ft	$1.58362*FFSpeed^{(0.24881-0.09472*\ln(LW))}-\frac{8.34158}{LW}$	Min. 0.9125

Note: RSLC: right-shoulder lateral clearance (ft)
FFSpeed: free-flow speed (mph)
LW: lane width (ft)

c. Time-of-Day (TOD) Model

The I-69 corridor model is designed to report daily auto and truck volumes assigned to the network. In addition, to accurately determine the measures of performance calculated for the *worst* hours of the day, the corridor model is required to report AM and PM peak hour traffic volumes for each link. For the time-of-day (AM peak, PM peak and Daily) assignments, a trip table that contains autos and trucks by TOD needs to be created. While the first modeling step for the corridor model on supply side is to construct the model network with estimation of correct link speeds and capacities, on demand side, the modeling starts with the development of the TOD trip table.

i. Calibration of Time-of-Day and Directional Factors

As explained in the earlier section of this report, the trip distribution and the mode choice phases of the statewide modeling process result in auto trip tables by trip purpose in a production-attraction (P-A) format. These trip tables are inputted into the corridor modeling stream, converted to origin-destination (O-D) trips, and split by TOD. In parallel, auto external and truck trip tables developed for the statewide model are entered into the corridor model and split by TOD.

This transformation and TOD process is facilitated by using a hourly lookup table that contains time-of-day and directional factors. The lookup table used in ISTDM v3 served as the starting point. The table was transformed from peak periods to peak hours by adjusting the percentage of departure and return for all trip purposes.

After the transformation, an iterative process was taken to calibrate the hourly lookup table. First, a model run was made with the existing set of TOD and departure and return, or directional, factors. Then the assigned peak hour volumes were compared with the respective peak hour counts, and the TOD and directional factors were adjusted. Using the adjusted factors, another model run was made. This process was repeated until the model can produce the assignments in good agreement with the counts.

The AM and PM peak hour counts were collected at different locations along the corridor. The count stations located between Indianapolis and Martinsville area are shown in **Figure 8**. All counts were directional and classified by mode (auto and truck). The counts were also grouped based on the roadway's area type (urban, suburban, and rural). The comparison between the model assignments and the counts was made by facility type for three measures; peak-hour volumes, peak-direction (D) factors, and peak-hour proportion (K) factors.

Table 5 presents the hourly lookup table calibrated for the corridor model. **Tables 6** through **8** summarize the D and K factors generated from the model run using the calibrated hourly lookup table shown in **Table 5**.

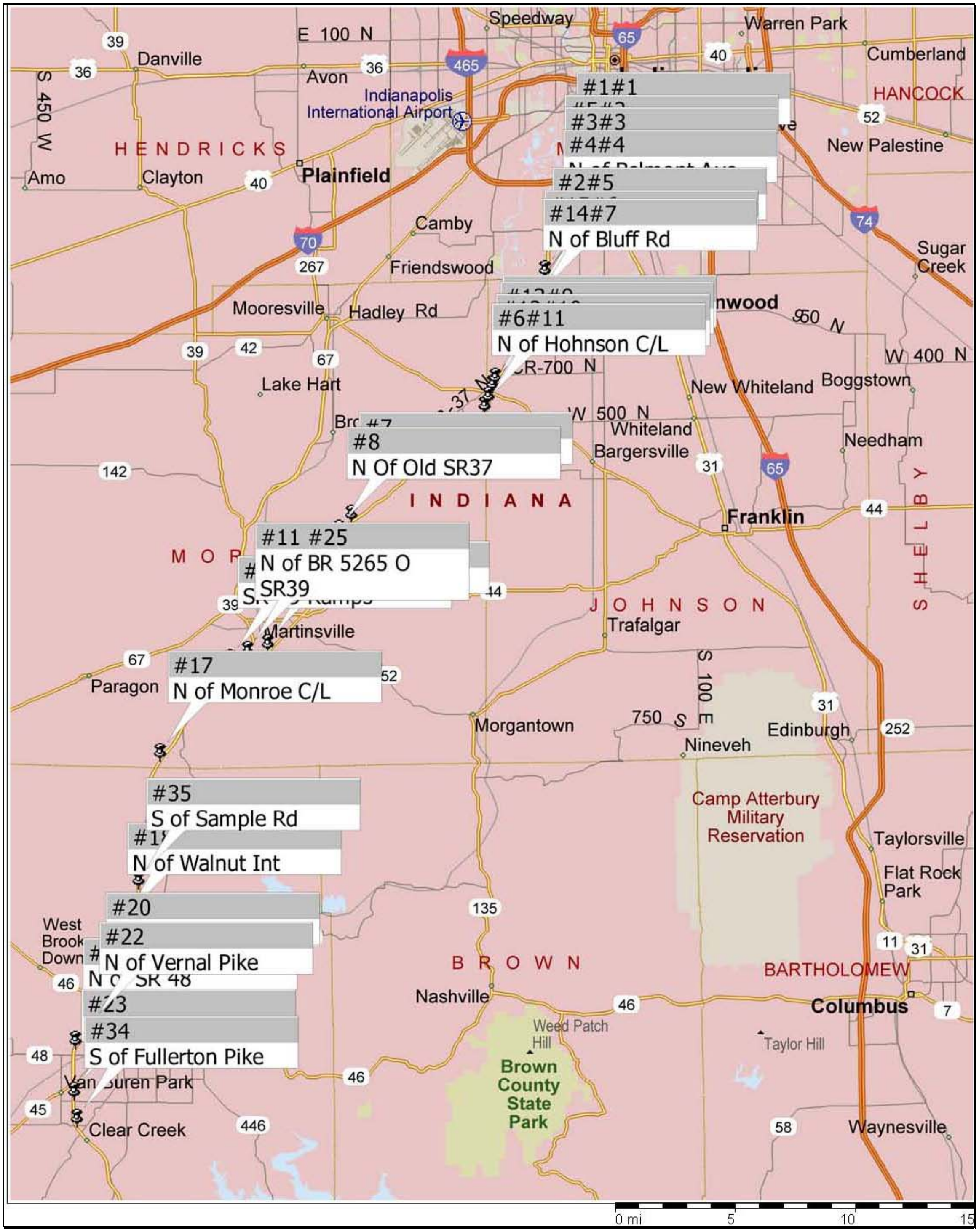


Figure 8. Count Station Locations between Indianapolis and Martinsville

Table 5. Time-of-Day and Directional Factors

HOUR	Off-Peak Hours	AM-Peak Hour	PM-Peak Hour
DEPARTURE_HBW	40.93%	8.20%	0.87%
RETURN_HBW	42.15%	1.20%	6.65%
DEPARTURE_HBO	42.84%	5.46%	1.70%
RETURN_HBO	45.75%	1.09%	3.16%
DEPARTURE_NHB	42.59%	2.41%	5.00%
RETURN_NHB	42.55%	2.41%	5.04%
DEPARTURE_LNG	42.83%	2.75%	4.42%
RETURN_LNG	44.87%	0.05%	5.08%
DEPARTURE_EXT	41.13%	4.12%	4.75%
RETURN_EXT	41.13%	4.13%	4.74%
DEPARTURE_TRK	44.42%	2.94%	2.64%
RETURN_TRK	44.62%	2.57%	2.81%

Note: HBW: home-based work, HBO: home-based other, NHB: non-home-based, LNG: long trip, EXT: external trip, TRK: truck

Table 6. Model-Generated Directional and Peak-Hour Factors (Rural)

Station	Counts				Final Run - Total				Final Run - Car				Final Run - Truck			
	AM		PM		AM		PM		AM		PM		AM		PM	
	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K
6	68%	6%	60%	7%	72%	6%	69%	7%	74%	7%	70%	7%	52%	5%	53%	5%
7	66%	7%	62%	8%	65%	6%	64%	7%	66%	6%	65%	7%	51%	5%	54%	5%
8	68%	7%	58%	8%	64%	6%	64%	7%	65%	6%	64%	7%	52%	5%	54%	5%
17	63%	7%	61%	7%	57%	7%	52%	7%	58%	7%	52%	7%	50%	5%	50%	5%
35	60%	7%	57%	8%	60%	7%	54%	7%	61%	7%	55%	7%	50%	5%	50%	5%
18	53%	6%	66%	6%	60%	7%	52%	7%	61%	7%	55%	7%	50%	5%	50%	5%
20	58%	7%	58%	7%	57%	6%	52%	7%	58%	6%	52%	7%	51%	5%	50%	5%
36	65%	6%	54%	9%	57%	7%	54%	8%	57%	7%	54%	8%	50%	6%	50%	6%
33	62%	6%	54%	5%	57%	7%	54%	8%	58%	7%	54%	9%	50%	6%	50%	6%
29	61%	7%	57%	9%	56%	7%	55%	8%	57%	7%	55%	8%	50%	6%	51%	6%
Average	**62%**	**7%**	**59%**	**7%**	**61%**	**7%**	**57%**	**7%**	**62%**	**7%**	**58%**	**8%**	**51%**	**5%**	**51%**	**5%**

Table 7. Model-Generated Directional and Peak-Hour Factors (Suburban)

Station	Counts				Final Run - Total				Final Run - Car				Final Run - Truck			
	AM		PM		AM		PM		AM		PM		AM		PM	
	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K
1	69%	7%	57%	7%	67%	7%	65%	7%	68%	7%	66%	8%	50%	5%	51%	5%
5	75%	7%	61%	8%	73%	7%	71%	7%	76%	8%	73%	7%	50%	5%	52%	5%
3	74%	7%	64%	8%	74%	7%	72%	7%	77%	8%	74%	7%	50%	5%	52%	5%
4	74%	7%	62%	7%	75%	7%	72%	7%	78%	8%	74%	7%	50%	5%	52%	5%
2	75%	7%	69%	7%	74%	7%	71%	7%	77%	8%	73%	7%	50%	5%	52%	5%
15	73%	7%	63%	8%	75%	7%	73%	7%	77%	7%	74%	7%	51%	5%	54%	5%
14	71%	7%	65%	7%	74%	7%	73%	7%	76%	7%	75%	7%	51%	5%	54%	5%
16	70%	6%	59%	8%	73%	7%	70%	7%	75%	7%	71%	7%	51%	5%	53%	5%
13	74%	7%	67%	9%	72%	7%	70%	7%	74%	7%	71%	7%	51%	5%	53%	5%
12	72%	6%	61%	8%	72%	7%	69%	7%	74%	7%	70%	7%	52%	5%	53%	5%
23	71%	6%	51%	8%	63%	6%	62%	7%	64%	6%	62%	7%	51%	5%	51%	5%
34	75%	6%	57%	8%	67%	7%	61%	7%	68%	7%	62%	7%	51%	5%	51%	5%
37	70%	5%	62%	9%	59%	7%	55%	8%	60%	7%	55%	8%	50%	6%	50%	6%
30	68%	8%	63%	9%	69%	7%	63%	8%	70%	8%	64%	9%	50%	6%	50%	6%
31	61%	7%	73%	4%	69%	7%	63%	8%	71%	8%	64%	9%	50%	6%	50%	6%
Average	**71%**	**7%**	**62%**	**8%**	**70%**	**7%**	**67%**	**7%**	**72%**	**7%**	**69%**	**8%**	**51%**	**5%**	**52%**	**5%**

Table 8. Model-Generated Directional and Peak-Hour Factors (Urban)

Station	Counts				Final Run - Total				Final Run - Car				Final Run - Truck			
	AM		PM		AM		PM		AM		PM		AM		PM	
	D	K	D	K	D	K	D	K	D	K	D	K	D	K	D	K
9	55%	5%	57%	8%	52%	6%	55%	7%	52%	6%	55%	7%	53%	5%	53%	5%
11	60%	6%	51%	7%	51%	6%	55%	7%	50%	6%	55%	7%	52%	5%	53%	5%
10	67%	7%	56%	8%	52%	7%	51%	7%	53%	7%	51%	7%	50%	5%	50%	5%
22	51%	8%	51%	8%	55%	7%	55%	8%	55%	7%	55%	8%	55%	6%	52%	5%
21	55%	6%	54%	7%	58%	7%	53%	8%	58%	7%	53%	8%	55%	6%	53%	5%
26	57%	6%	57%	8%	61%	6%	55%	9%	61%	6%	55%	9%	50%	6%	50%	6%
28	55%	6%	56%	7%	50%	7%	54%	8%	50%	7%	54%	8%	54%	6%	52%	6%
27	56%	6%	51%	7%	55%	7%	53%	8%	55%	7%	53%	8%	50%	6%	50%	6%
Average	**57%**	**6%**	**54%**	**8%**	**54%**	**7%**	**54%**	**8%**	**54%**	**7%**	**54%**	**8%**	**52%**	**5%**	**52%**	**6%**

ii. Time-of-Day Transformation

For each of internal trip purposes, the calibrated TOD and directional factors for the corresponding trip purpose are applied to the auto production-attraction trip table to generate origin-destination trip tables by TOD. The internal trip purposes comprise home-based work, home-based other, non-home-based and long trips. Auto external and truck trip tables are also disaggregated into TOD trip tables by applying the respective factors.

The auto internal and external trip tables are then aggregated by TOD to produce auto AM, auto PM, and auto daily trips. Likewise, the truck TOD trip table contains truck AM, truck PM, and truck daily trips. In the final step, these auto and truck trip tables by TOD are brought into a single matrix. The matrix is used for the subarea analysis to extract trip tables for the corridor modeling area.

d. Subarea Modeling

i. Subarea Extraction

The I-69 corridor model is a subordinate model of ISTDM v4. A subarea modeling is performed on the statewide model to facilitate more detailed analyses within the subarea, or the I-69 corridor model area. On supply side, the detailed subarea corridor model network and the associated TAZ database layer were created as described in Sections 3 and 4 of this report. On demand side, subarea trip tables are extracted from the statewide time-of-day trip tables obtained from the previous step and used to feed the corridor network. This section describes details of the latter.

The subarea modeling is based on TransCAD's procedure of creating a subarea O-D matrix. As the first step in the procedure, a cordon line that circumscribes the I-69 corridor model area in the statewide model network was specified. The specification was made by a set of internal centroids, cross links and external stations. The internal centroids represent TAZ centroids located inside the cordon line. In the base year statewide network, 1,008 internal centroids are observed.

The cross link are the link that crosses the cordon line. The outside node of the cross link is defined as the external station. The external station in the corridor model network can be either a node of the link or a TAZ centroid in the statewide model network. In the base year network, 168 external stations are observed. **Figure 9** shows the defined subarea with these three components.

With the subarea specification and the statewide time-of-day vehicle trip tables, the subarea extraction is performed using the multi-modal multi-class assignment (MMA) procedure. This procedure is fully automated through the use of GIS-DK's batch mode, resulting in trip tables by time-of-day representing only the specified subarea. At this point, the origin-destination of the resulting trip tables is still expressed by the statewide zone system, or specifically, by the internal centroids and external stations designated in the statewide model network.

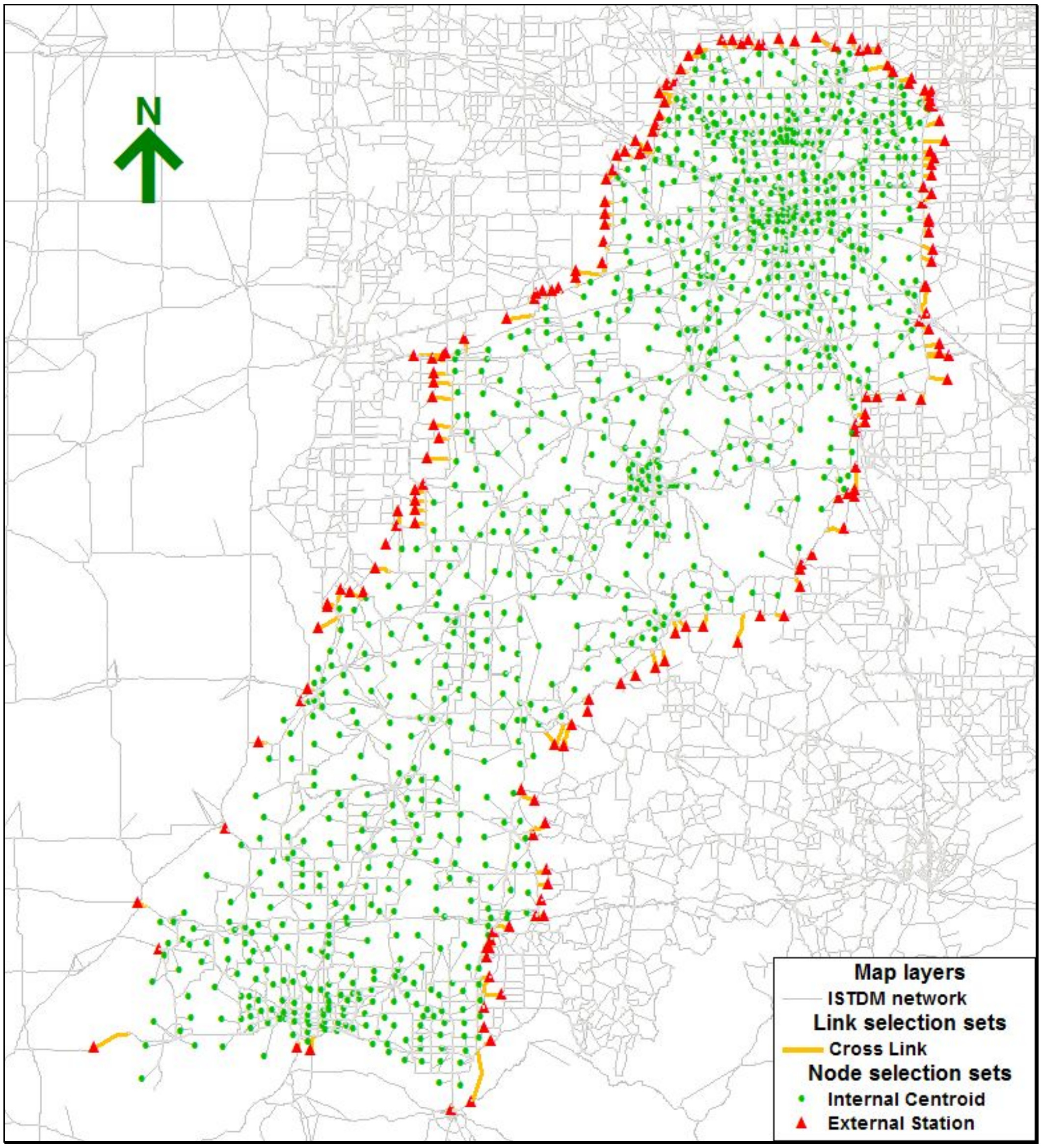


Figure 9. Definition of Subarea

ii. Matrix Disaggregation

The extracted origin-destination trip tables generated in the previous step are expressed by the statewide model zones, thus they need to be converted to match the zonal system of the corridor model. Since TAZs of the corridor model were created by disaggregating ISTDM TAZs, the conversion needs to involve an appropriate disaggregation process. The process utilizes the matrix vector multiplication function in TransCAD. This function disaggregates the rows and columns of the matrices in a matrix file and generates a new matrix file that contains disaggregated values. For disaggregating, this function requires the factor that indicates what proportion each disaggregated rows and columns is of the original rows and columns. The factor ranges between 0 and 1.

The disaggregation is only applied to the internal centroids while the external stations of the extracted subarea are carried over to the corridor model network without any modifications. The factors by which each internal centroid is disaggregated are derived based on socioeconomic data of the corridor model TAZs. As the first step to derive the factors, trip generation is run for the corridor model TAZs. The combination of production and attraction, or demand, at the corridor TAZ level are then compared with the demand of the associated ISTDM TAZ. Following the comparison, the demands of the corridor model TAZs are then adjusted upward or downward so that the sum of the demands matches the demand of the associated ISTDM TAZ. Next, the disaggregation factor for each corridor model TAZ is derived as the ratio of the adjusted corridor model zone demand to the demand of the corresponding ISTDM TAZ.

The disaggregation factors are derived by vehicle type and time-of-day. These factors are applied to the associated statewide origin-destination trip tables by using the vector multiplication method. This process produces disaggregated origin-destination trip tables by vehicle type and time-of-day for the corridor model TAZs.

Figures 10 and **11** exemplify the disaggregation process. **Figure 10** indicates that the statewide model TAZ 49007 is disaggregated into 8 corridor model TAZs that are numbered 4900701 through 4900708. The figure also shows vertical bars that indicate the relative magnitude of the disaggregation factors among the corridor TAZs. In this example, the corridor model TAZ 4900701 is allotted the highest portion of the origin-destination trips associated with the ISTDM TAZ 49007, while the TAZ 4900708 is assigned the lowest.

Figure 11 illustrates how ISTDM trip tables are disaggregated to create corridor model trip tables with the example of the ISTDM TAZ 49007 shown in **Figure 10**. In the figure, the ISTDM trip tables are expanded and relabeled to match the corridor model TAZ numbering system. In this example, the intrazonal trip of the TAZ 49007 is split and distributed to the 8 corridor model TAZs (TAZs 4900701 through 4900708) using the factors shown in **Figure 10**. In other words, intrazonal trips in the statewide zone system are now expressed to directional interzonal trips in the corridor model zone system. The disaggregation is applied to both intra- and interzonal trips in the statewide zone system.

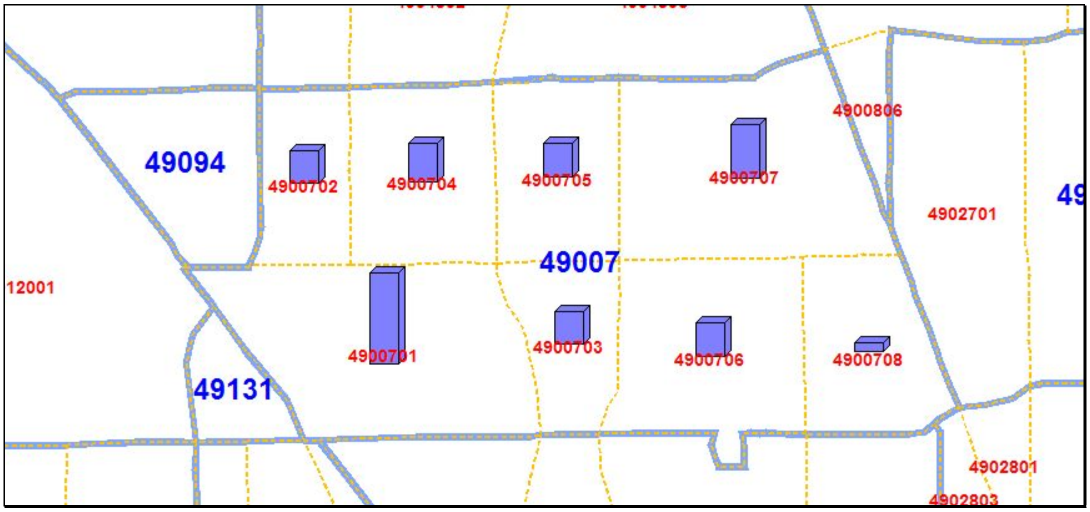
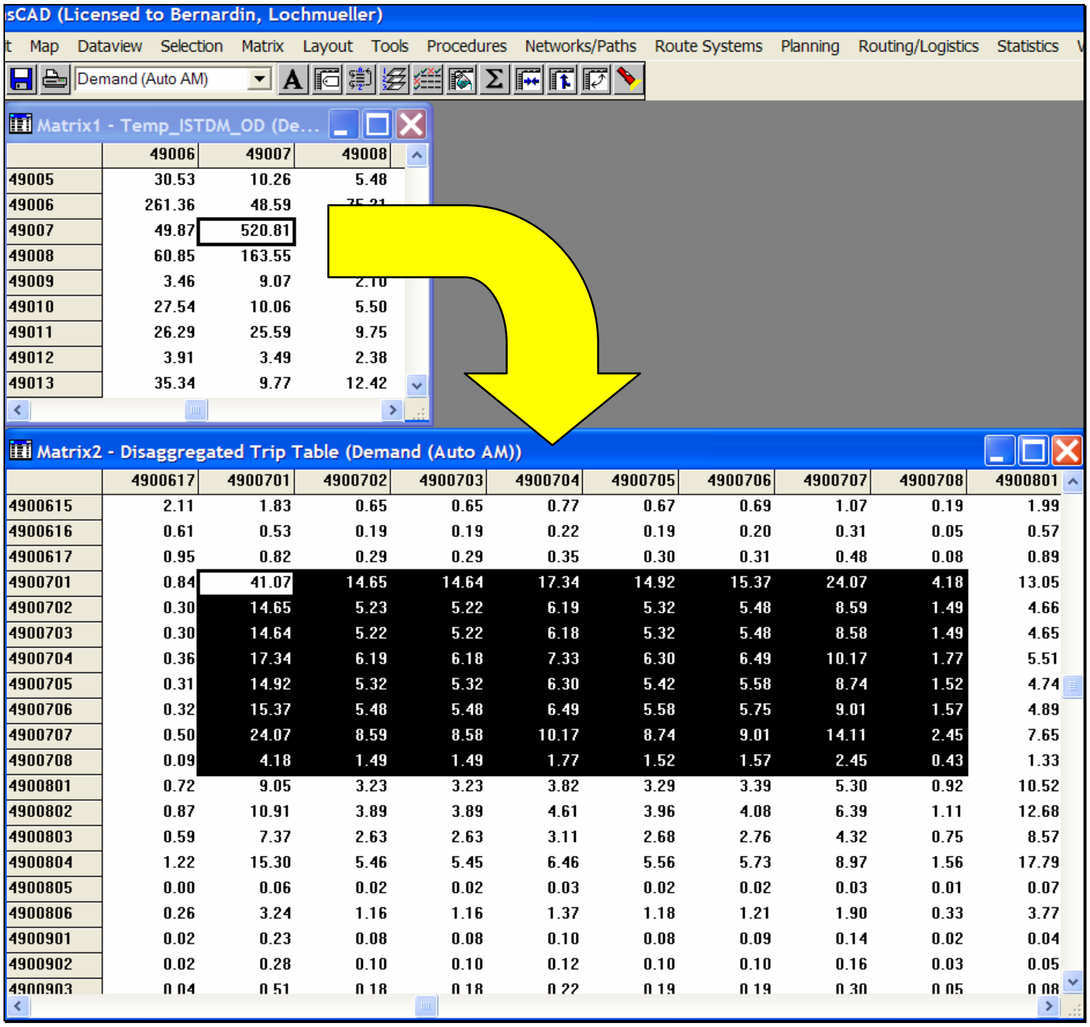


Figure 10. Derivation of Subarea Trip Table (1)



	49006	49007	49008
49005	30.53	10.26	5.48
49006	261.36	48.59	[illegible]
49007	49.87	520.81	[illegible]
49008	60.85	163.55	[illegible]
49009	3.46	9.07	[illegible]
49010	27.54	10.06	5.50
49011	26.29	25.59	9.75
49012	3.91	3.49	2.38
49013	35.34	9.77	12.42

	4900617	4900701	4900702	4900703	4900704	4900705	4900706	4900707	4900708	4900801
4900615	2.11	1.83	0.65	0.65	0.77	0.67	0.69	1.07	0.19	1.99
4900616	0.61	0.53	0.19	0.19	0.22	0.19	0.20	0.31	0.05	0.57
4900617	0.95	0.82	0.29	0.29	0.35	0.30	0.31	0.48	0.08	0.89
4900701	0.84	41.07	14.65	14.64	17.34	14.92	15.37	24.07	4.18	13.05
4900702	0.30	14.65	5.23	5.22	6.19	5.32	5.48	8.59	1.49	4.66
4900703	0.30	14.64	5.22	5.22	6.18	5.32	5.48	8.58	1.49	4.65
4900704	0.36	17.34	6.19	6.18	7.33	6.30	6.49	10.17	1.77	5.51
4900705	0.31	14.92	5.32	5.32	6.30	5.42	5.58	8.74	1.52	4.74
4900706	0.32	15.37	5.48	5.48	6.49	5.58	5.75	9.01	1.57	4.89
4900707	0.50	24.07	8.59	8.58	10.17	8.74	9.01	14.11	2.45	7.65
4900708	0.09	4.18	1.49	1.49	1.77	1.52	1.57	2.45	0.43	1.33
4900801	0.72	9.05	3.23	3.23	3.82	3.29	3.39	5.30	0.92	10.52
4900802	0.87	10.91	3.89	3.89	4.61	3.96	4.08	6.39	1.11	12.68
4900803	0.59	7.37	2.63	2.63	3.11	2.68	2.76	4.32	0.75	8.57
4900804	1.22	15.30	5.46	5.45	6.46	5.56	5.73	8.97	1.56	17.79
4900805	0.00	0.06	0.02	0.02	0.03	0.02	0.02	0.03	0.01	0.07
4900806	0.26	3.24	1.16	1.16	1.37	1.18	1.21	1.90	0.33	3.77
4900901	0.02	0.23	0.08	0.08	0.10	0.08	0.09	0.14	0.02	0.04
4900902	0.02	0.28	0.10	0.10	0.12	0.10	0.10	0.16	0.03	0.05
4900903	0.04	0.51	0.18	0.18	0.22	0.19	0.19	0.30	0.05	0.08

Figure 11. Derivation of Subarea Trip Table (2)

e. Trip Assignment

i. TOD Assignment

Whereas the trip assignment procedure for ISTDM v4 was based on a single daily assignment, the corridor model adds two additional time periods, AM and PM peak hours. The addition of the peak hour assignments was necessary since the corridor model is mainly used for design purpose.

ii. MMA Assignment

Trips are assigned to the network in the sequence of AM peak hour, PM peak hour and Total Daily. For each time-of-day, passenger vehicles and trucks are assigned simultaneously through Multi-Modal Multi-Class Assignment (MMA). The MMA method is *a generalized cost assignment by which trips are assigned by individual modes or user classes to the network simultaneously* (Source: Advanced Traffic Assignment Methods, Travel Demand Modeling with TransCAD 4.7). As a common way, trucks are assigned prior to passenger vehicles without being affected by congestion induced by the vehicles. Since the "free-flow" or "pre-load" method cannot provide congestion-based diversion of traffic, trucks can be assigned unrealistically especially in the urban area where main arterials and bypassing highway alternatives coexist. The MMA method avoids the assignment problem by loading all vehicle classes to the network at the same time.

iii. Volume-Delay Function

The assignment is a continuous feedback process based on the relationship between traffic volume loading and the resulting delay caused by congestion. In this relationship, as congestion increases as traffic volumes increase, travel speeds decrease. Various types of volume-delay function are used to estimate the traffic volume-speed relationship, which includes the Bureau of Public Roads (BPR) function, Conical Delay Function, and Akcelik/Davidson Formula.

The corridor model uses the BPR function, the most commonly used formula, with improved BPR coefficients. Multiple BPR functions were specified by functional classification through extensive experimentation during model validation. Each roadway is unique in terms of geometric characteristics and the response to increasing traffic volume. Thus, applying a single BPR function (or a single set of BPR coefficients) to various types of roadway most likely causes incorrect representation of congested speeds. A range of BPR functions used for the corridor model assignment are shown in **Figure 12**.

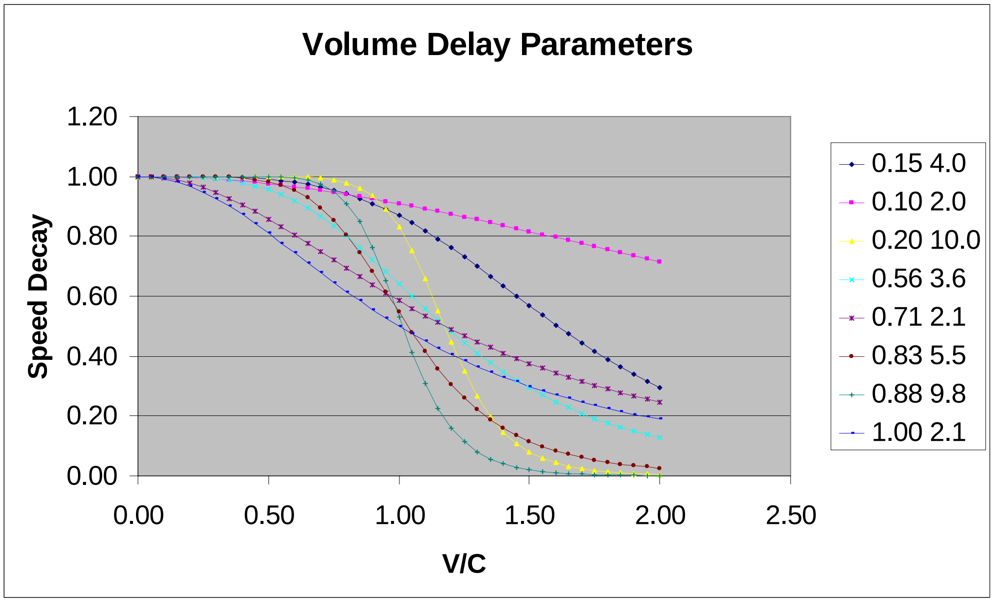


Figure 12. Volume-Delay Functions
(**Source**: Bernardin, Lochmueller & Associates, Inc., 2006)

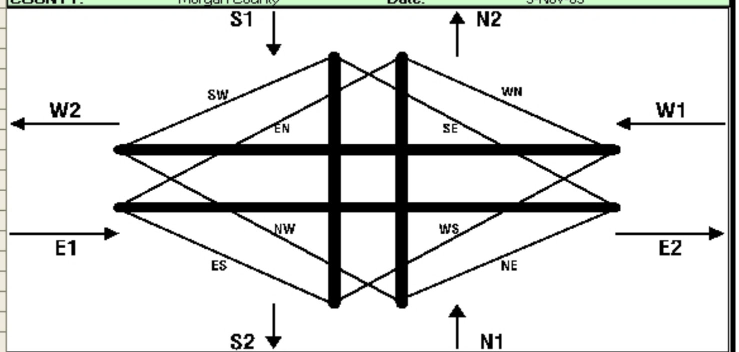
iv. Turning Movement Volumes

Turning movement volumes were needed to support the design phase of the I-69 study. The turn volumes by time-of-day were extracted during traffic assignment mainly for interchange ramp intersections in the I-69 corridor. For example, for a diamond interchange, turning movements at ramp intersections on both sides of the I-69 corridor were obtained. In the same example, the interchange area comprises 12 different turning movements, or 3 movements from one approach. TransCAD automatically generates turning volumes at designated nodes in the format of a table that shows the volume coming from link A and going to link C through node B. Although the table is a convenient way to analyze turning volumes at a "point", it does not show interaction between two points or the two ramp intersections in this example.

Because of the complexity involving two intersections, a special spreadsheet program was made to read the TransCAD-generated turning movements, to analyze appropriate collection of turning volumes, and to show the result in an INDOT's turning movement worksheet format as shown in **Figure 13**. The spreadsheet contains basic information such as location of the intersection and a specific scenario. The spreadsheet provides turning volumes by mode (i.e., trucks and passenger vehicles) and by time-of-day.

INTERSECTION FORECAST SUMMARY DATA SHEET

PROJECT:		DES NO.:	
INTERCHANGE: ID:		ALTERNATIVE:	Sec 6 Alternative 6
INTERSECTION:	I-69 at SR 252	TAZ Forecast:	Build 3C
COUNTY:	Morgan County	Date:	3-Nov-05



LOCATION:
I-69 N-S
SR 252 E-W

	2030 ADT			2030 AM Peak Hour			2030 PM Peak Hour		
MOVEMENT	Total	Auto	Truck	Total	Auto	Truck	Total	Auto	Truck
N1	25,070	20,873	4,197	1,669	1,442	227	1,899	1,678	221
S2	25,317	21,309	4,008	1,633	1,408	225	2,003	1,780	223
S1	26,336	21,921	4,415	1,589	1,339	251	2,212	1,964	248
N2	26,411	21,762	4,649	1,946	1,695	251	1,861	1,616	246
E1	9,998	9,357	641	722	687	35	713	678	34
W2	9,622	9,009	613	694	659	35	732	698	34
W1	9,371	8,808	563	829	799	31	571	539	32
E2	9,424	8,878	546	537	504	33	798	766	32
NE	2,940	2,742	198	153	142	11	257	246	11
NW	1,754	1,682	72	119	115	4	137	133	4
NT	20,376	16,449	3,927	1,397	1,186	211	1,505	1,299	206
SE	2,140	1,899	240	124	108	16	198	183	15
SW	3,672	3,235	437	242	218	25	313	288	25
ST	20,524	16,787	3,737	1,223	1,013	210	1,701	1,493	208
ES	1,794	1,720	74	129	125	4	129	125	4
EN	3,860	3,400	460	333	308	25	241	216	25
ET	4,344	4,237	107	260	254	6	343	337	6
WN	2,175	1,913	262	216	202	14	116	101	15
WS	3,000	2,802	197	281	270	11	173	162	11
WT	4,196	4,093	103	333	327	6	282	277	5

Figure 13. Turning Movement Spreadsheet

v. Exclusion Set

In general, while passenger vehicles are allowed to travel on almost all roadways, trucks (especially heavy trucks) are prohibited on certain routes due to specific restrictions such as unsuitable roadway and bridge designs, congestion, or site local access plan. Special restrictions on truck routes in the Crane Naval Surface Warfare Center are reflected in the corridor model, and a set of links were excluded from truck assignment.

6. MODEL VALIDATION

a. Method

This section describes the process and the results of the base year corridor model validation. The focus of model validation is to reduce the difference between observed traffic counts and estimated model volumes on the model network. In reality, it is impossible to eliminate the loading errors for all links in the network. Beyond that, achieving the perfect "zero-error" assignment is undesirable because of a number of unknown factors which cannot be accounted for. Rather, we set some "tolerance" limits within which the model is regarded as a good representation of real-world traffic loadings in the modeled area.

Although the corridor model is a time-of-day model which estimates AM peak hour, PM peak hour and total daily volumes, the validation was restricted only to the daily volumes due to unavailability of the peak hour traffic counts. The daily traffic counts coded in the network were carefully examined for their validity. The common problems associated with the counts travel demand models use include …

- Variation in counts between crossroads,
- Identical counts before and after crossroad, and
- Identical mainline and ramp counts on the same roadway.

To eliminate these count-related problems, a special GIS-DK program was written to remove the count coding errors associated with crossroad. This program first identifies the links that show varying counts between intersections. Then, for the identified links, the program implements an automated smoothing process by computing an average count weighted by link distance and by recording the average value to these links. After this automated process, manual judgmental adjustments were made for the links that show other abnormalities.

The assignment validation involved repetitive effort of comparing the model assignments with the smoothed counts from various angles. It was required to make various categorical comparisons to avoid one-dimensional judgmental mistake. For example, the model can reveal serious flaws in one area even though it is within error thresholds in other areas. The category under which the comparisons were made included roadway functional classification, volume-group range, cutline and area type. **Figure 14** shows the cutlines that are consist of major highways in the corridor.

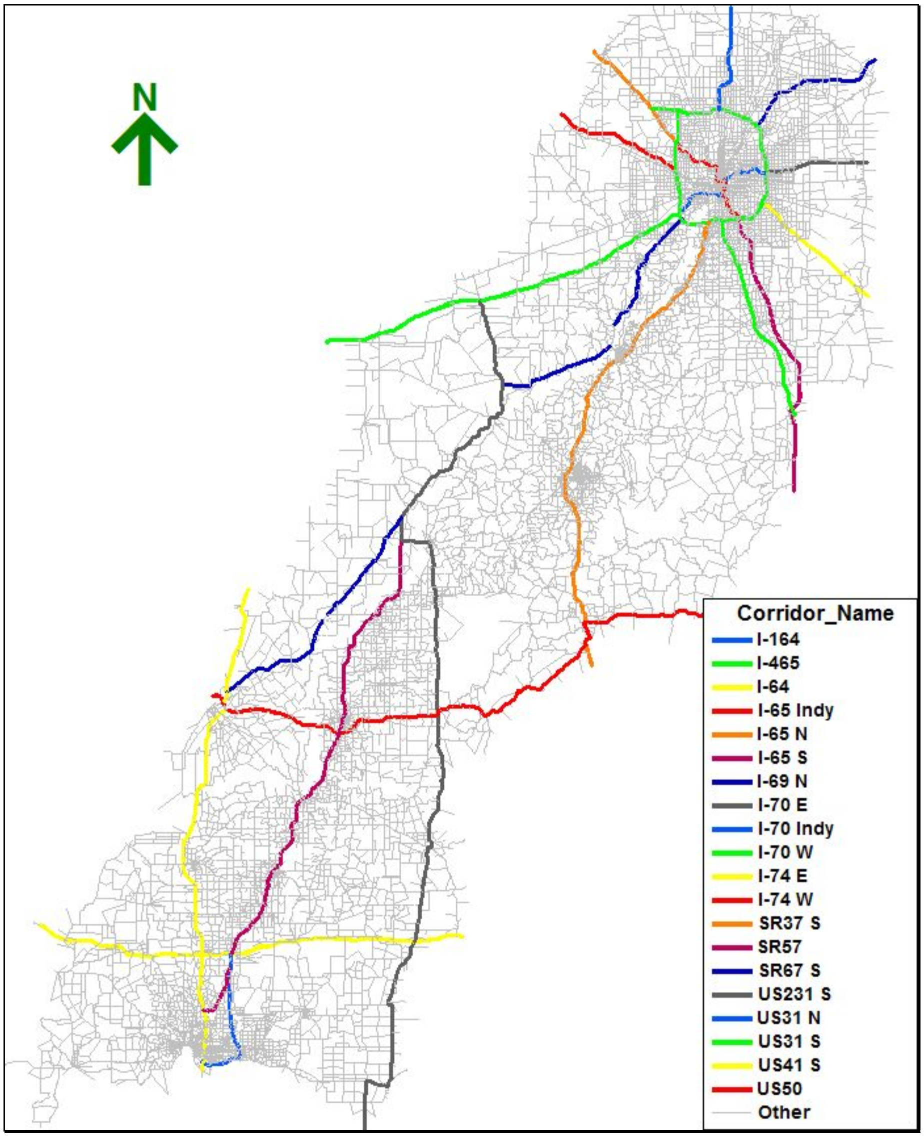


Figure 14. Major Highways

The corridor model utilized a special calibration/validation report program, CAL_REP. CAL_REP was originally developed by Bernardin, Lochmueller & Associates, Inc. as part of the Indiana Reference Modeling System (IRMS) for the purpose of quantifying model errors and assisting in the diagnosis of assignment problems. For ISTDM v4, a new version of CAL_REP was customized in GIS-DK script to best fit to the model and the program was then embedded as a post-processing module in the user model interface for easy access and implementation. For the corridor model, CAL_REP was customized and used for generating various error statistics. While the statewide version of CAL_REP reports both state jurisdictional roads only and all roads including county and local roads, the corridor model version takes all roads whose average daily traffic counts are greater than 1,000 vehicles.

Error statistics reported and used for diagnosing the possible sources of model errors include:

- percent root mean square errors (% RMSE),
- systemwide average error,
- mean loading errors and percentage errors, and
- total VMT errors and percentage errors.

The % RMSE is the traditional and single best overall error statistic used for comparing loadings to counts. It has the following mathematical formulation:

$$\%\text{RMSE} = \frac{\sqrt{\sum(\text{Count} - \text{Loading})^2 / \text{n}}}{\text{Mean Count}} \times 100$$

When evaluating % RMSE for groups of links disaggregated by volume ranges, relatively large errors are acceptable for low volume groups. But, the errors should become smaller as volume increases.

The overall validation approach for the corridor model is different from other traditional 4-step models. The corridor model is not a standalone 4-step model, but a subordinate model to the statewide model. The corridor model itself does not include trip generation, trip distribution and mode choice components. These three steps are taken in the statewide model and their outputs are flown into the corridor model stream. Thus, validation techniques for the corridor model are limited, and the overall quality of the model depends much on the statewide model.

Considering the demand side of the model is already determined, the validation efforts for the corridor model were focused on arriving at correct network representation of the corridor, which included:

- Verification/Correction of capacity-related link attributes,
- Verification/Correction of speed-related link attributes,
- Adjustment of volume-delay functions, and
- Verification/Correction of centroid connections.

b. Output

The validation outputs from the base year corridor model were prepared by functional classification, volume group, cutline and area type. **Tables 9** through **12** show error statistics for each category obtained from CAL_REP. In these tables, "% Loading Error" represents percentage difference between ground counts ("Avg. Count") and model estimates ("Avg. Loading"). Likewise, "% VMT Error" indicates percentage difference in vehicle miles of travel between the counts and the loadings.

Validation statistics by functional classification (Table 1) verifies that higher class roads such as Interstates and Principal Arterials show smaller % Loading Error, % VMT Error and % RMSE than those of lower class roads. The overall model generates significantly low errors as indicated by -0.7% of Loading Error, -0.9% of VMT Error, and 41% of RMSE.

Table 9. Validation Statistics by Functional Classification

CLASS	Avg. Count	Avg. Loading	% Loading Err	% VMT Err	% RMSE
Rural Interstates (1)	20,325	19,723	-2.96	1.19	28.55
Rural Prin. Arterials (2)	8,954	9,337	4.28	5.95	25.31
Rural Minor Arterials (6)	8,004	7,905	-1.25	-1.06	40.75
Rural Major Collectors (7)	3,919	3,873	-1.17	-0.10	54.07
Rural Minor Collectors (8)	3,642	4,218	15.80	17.05	66.20
Rural Local Roads (9)	3,787	1,768	-53.32	-17.99	97.47
Urban Interstates (11)	61,435	57,465	-6.46	-6.10	18.50
Urban Freeways (12)	12,204	12,992	6.46	6.03	31.17
Urban Prin. Arterials (14)	18,909	19,391	2.55	0.20	38.24
Urban Minor Arterials (16)	10,747	8,748	-18.60	-12.60	42.23
Urban Collectors (17)	4,282	1,542	-63.98	-67.06	83.85
Urban Local Roads (19)	6,776	10,807	59.49	59.49	59.49
All	**10,863**	**10,786**	**-0.70**	**-0.90**	**41.11**

Table 10 indicates that, as volumes increase, smaller % RMSE's are observed. The loading and VMT errors are consistently low in the ranges over 3,000 AADT. In addition, this table show average errors for the roads whose AADTs exceed 5,000 vehicles. For this group of high volume links, the overall % RMSE drops by 6% while both loading and VMT errors are kept low. From this result, it can be interpreted that the corridor model performs well for significant roads that carry high volumes.

Table 10. Validation Statistics by Volume Group

CLASS	Avg. Count	Avg. Loading	% Loading Err	% VMT Err	% RMSE
1,001 to 2,000 AADT	1,473	1,942	31.80	32.61	91.78
2,001 to 3,000 AADT	2,500	2,980	19.21	18.42	75.99
3,001 to 4,000 AADT	3,547	3,715	4.72	1.34	46.91
4,001 to 5,000 AADT	4,480	4,947	10.43	9.09	44.56
5,001 to 6,000 AADT	5,509	5,311	-3.59	0.00	37.42
6,001 to 8,000 AADT	6,918	7,326	5.90	4.12	37.42
8,001 to 10,000 AADT	8,960	9,016	0.62	-1.50	37.54
10,001 to 15,000 AADT	12,128	11,877	-2.07	-0.17	29.79
15,001 to 20,000 AADT	17,256	16,449	-4.68	-2.98	34.53
20,001 to 25,000 AADT	22,307	21,897	-1.84	-4.32	28.27
25,001 to 30,000 AADT	27,439	26,651	-2.87	-2.20	26.99
30,001 to 40,000 AADT	34,979	37,257	6.51	2.27	29.82
40,001 to 50,000 AADT	45,195	43,360	-4.06	0.61	20.16
50,001 to 75,000 AADT	56,717	49,898	-12.02	-9.98	22.41
75,001 to 100,000 AADT	86,861	77,031	-11.32	-8.18	20.64
> 100,000 AADT	127,235	114,612	-9.92	-9.65	15.28
All	**10,863**	**10,786**	**-0.70**	**-0.90**	**41.11**
Over 5,000 AADT	**16,470**	**16,058**	**-2.50**	**-2.75**	**35.24**

Error statistics for major highways highlighted in **Figure 14** are found in **Table 11**. % RMSE's for these highways range from 6% to 36% and both loading and VMT errors fall below ±10% for most highways. These statistics reconfirms that the corridor model is highly accurate for major highways.

Table 11. Validation Statistics by Major Highway

CLASS	Avg. Count	Avg. Loading	% Loading Err	% VMT Err	% RMSE
I-465	77,551	72,070	-7.07	-7.13	16.20
I-64	6,744	6,822	1.15	4.69	17.56
I-65 Indy	85,632	74,893	-12.54	-12.35	24.74
I-65 N	48,853	47,336	-3.11	-0.72	10.86
I-65 S	26,360	24,435	-7.30	-4.23	18.90
I-69 N	73,285	72,451	-1.14	0.65	10.16
I-70 E	46,211	44,917	-2.80	-2.27	6.67
I-70 Indy	74,566	70,946	-4.85	-5.98	6.66
I-70 W	20,059	20,568	2.54	0.98	7.82
I-74 E	32,996	36,721	11.29	9.75	13.67
I-74 W	23,343	25,847	10.73	10.43	15.72
SR37 S	12,312	12,663	2.85	0.38	20.45
SR57	6,658	7,178	7.81	11.43	34.40
SR67 S	7,809	7,603	-2.64	-0.29	35.84
US231 S	7,976	8,251	3.44	10.72	28.57
US31 N	37,556	37,483	-0.20	-1.80	19.52
US31 S	26,637	29,198	9.61	10.93	32.72
US41 S	10,973	12,608	14.91	16.97	32.68
I-164	10,527	10,464	-0.59	-3.69	27.24
US50	7,603	7,925	4.23	8.45	29.36

Error statistics by area type (**Table 12**) indicates low loading and VMT errors for urban, suburban and rural areas. % RMSE's are within 36% for all area types.

Table 12. Validation Statistics by Area Type

CLASS	Avg. Count	Avg. Loading	% Loading Err	% VMT Err	% RMSE
Maj Employment District	54,841	47,447	-13.48	-8.28	25.73
Urban Area	24,536	24,666	0.53	-4.20	33.14
Suburban Area	14,030	13,432	-4.26	-0.99	33.73
Rural Area	5,707	5,759	0.91	2.17	35.83

The validation status of the corridor model can be further visualized as seen in **Figure 15**. This figure illustrates the discrepancy between model estimates and traffic counts from the base year validated network. The map highlights 5,000 vehicles/day over-assigned links in red and 5,000 vehicles under-assigned in blue. Although urbanized areas in Indianapolis and Evansville show some over- or under-loading errors, this graphic indicates that the study corridor between Indianapolis and Evansville is in minimal error.

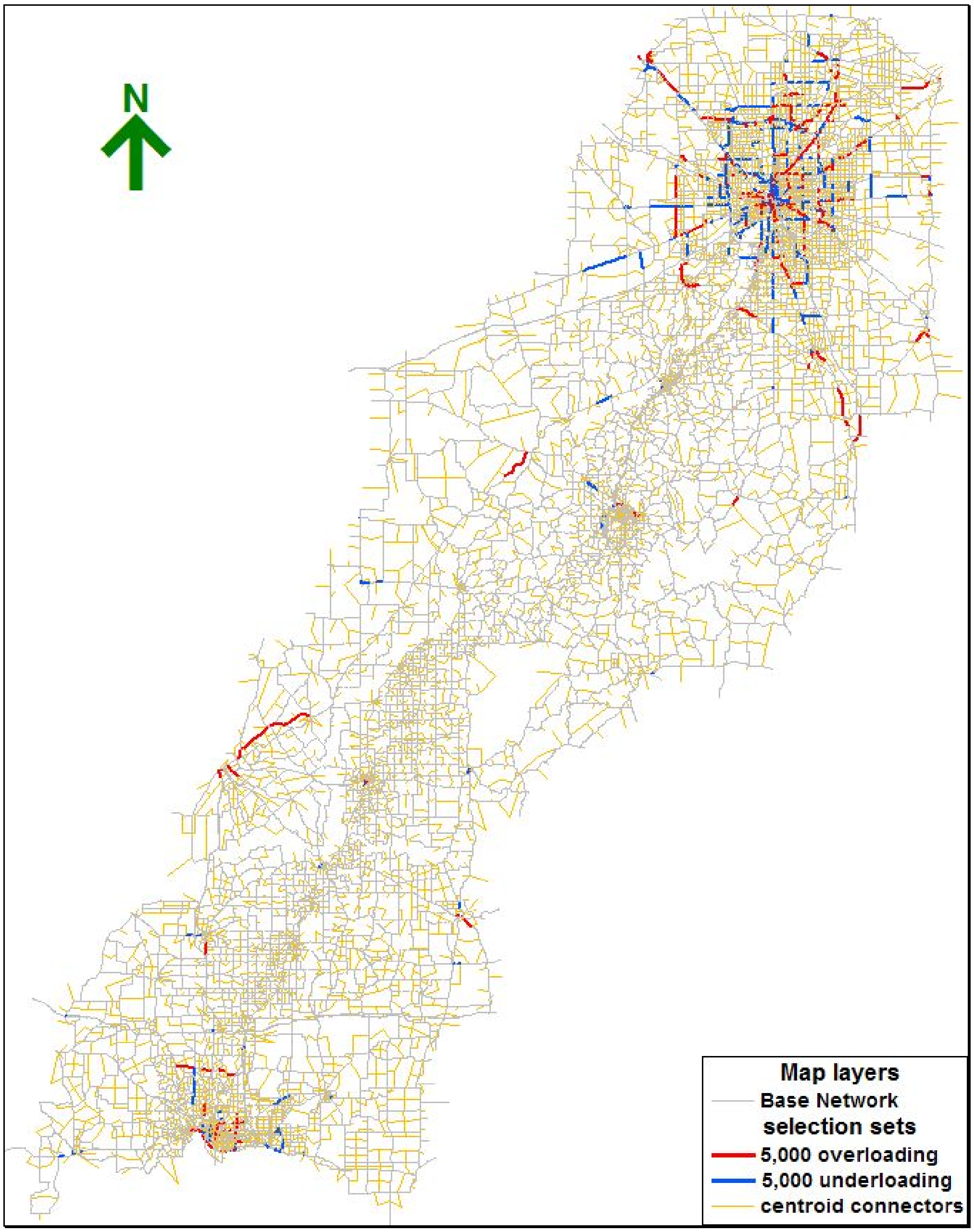


Figure 15. Base Year Network Loading Errors

Figure 16 expresses the validated network which is color-coded with daily traffic volumes. In this graphic, the distinction between high and low class roads in terms of their assigned volumes is clear.

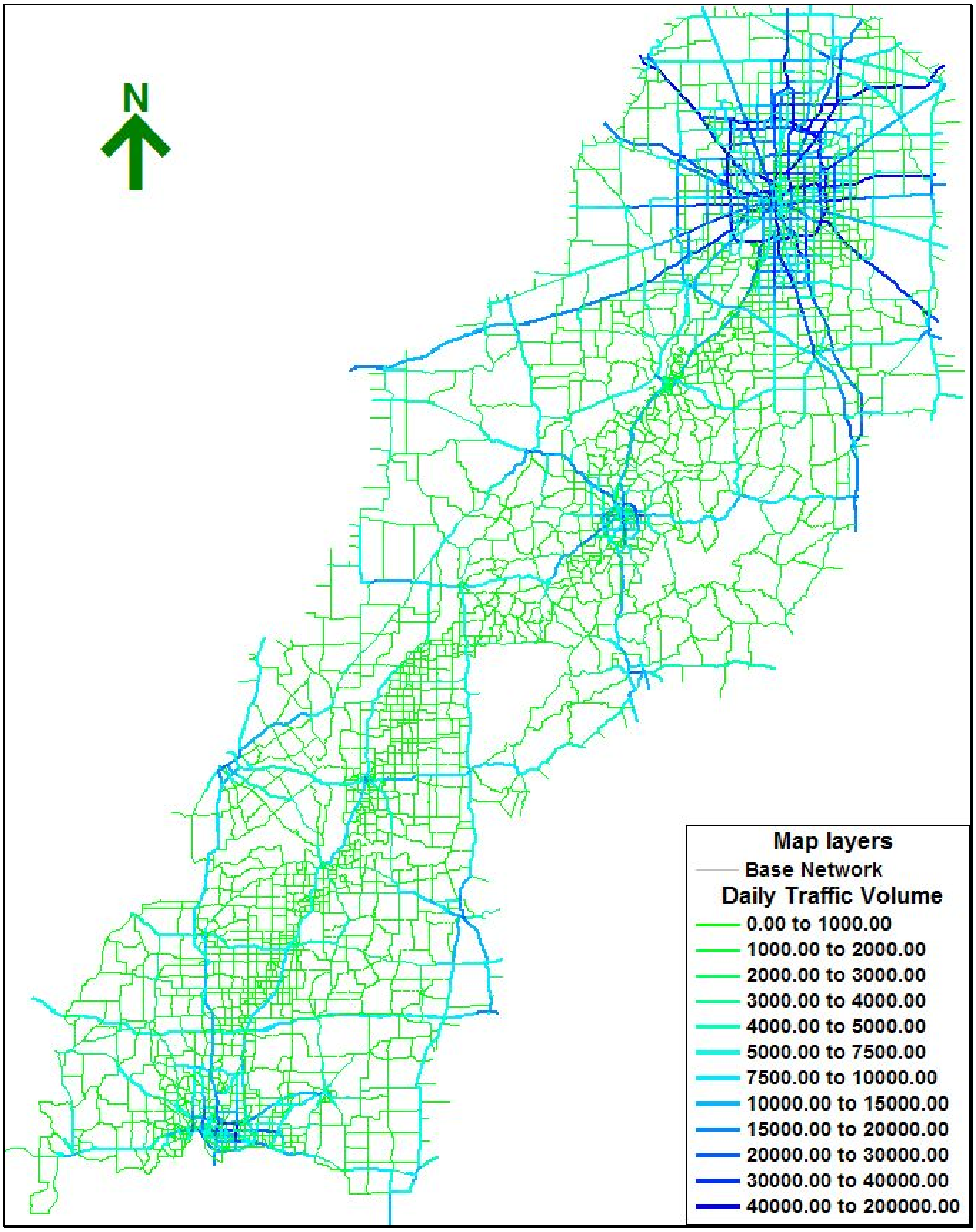


Figure 16. Base Year Loaded Network