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North Carolina I-95 Economic Assessment Study

Task 4: Travel Demand Modeling

prepared for

North Carolina Department of Transportation

prepared by

Cambridge Systematics, Inc.

June 2013

CAMBRIDGE SYSTEMATICS

final report

North Carolina I-95 Economic Impact Study

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Cambridge Systematics, Inc.
38 East 32nd Street, 7th Floor
New York, NY 10016

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1.0 Background

A key component of the North Carolina I-95 Economic Impact Study was to understand existing passenger and truck travel within the I-95 corridor, future traffic growth, and toll sensitivity of travelers to tolls. Cambridge Systematics, Inc. (CS) developed demand forecasts using an enhanced version of the Corridor Travel Demand Model (CTDM) originally developed by the Martin/Alexiou/ Bryson (MAB) and Michael Baker Corporation team as part of the I-95 Corridor Planning and Finance Study.

CS evaluated the existing travel demand model (CTDM) to be used on the NC I-95 Economic Impact Study. The evaluation primarily focused on how well the model replicated observed data, the model structure, growth projections and methodology, and how well the model responded to tolls. Another point of evaluation was the ability of the model to forecast vehicle miles and vehicle hours traveled, which is more in line with what a regional model would produce, as opposed to a corridor model. CS staff reviewed model networks to check for consistency with other available data; reviewed model parameters for reasonableness with respect to acceptable standards; and checked for how well the model results validate against counts, travel times, and trip distribution patterns where data was available. In addition, CS reviewed the post-processing and growth methods documented by the team that developed the model. Finally, the model's sensitivity was analyzed by running two future tolled scenarios.

Based on the model evaluation findings, CS recommended that the model be refined to better suit the needs of the I-95 Economic Impact Study. The evaluation identified three areas to focus on during model refinement. They were:

- Less reliance on "preloads";
- Improved geographic and modal validation; and
- Enhancement of the model structure.

The model refinement entailed the addition of network detail to the CTDM network, re-estimation of the origin-destination (OD) trip table by mode to include traffic counts over the entire model region, altering the model structure to capture sensitivity of the model to tolling, and eliminate the dependence on traffic preloads. The refined model was validated to within industry acceptable standards, and tested for sensitivity to tolling. Once found to be satisfactory, the project alternatives were modeled. Results from the travel demand model, which included traffic growth, vehicle miles and hours traveled, and traffic diversions due to tolls, were fed into the economic analysis and the traffic impact analysis.

This document describes the CTDM evaluation; the refinement by CS, including the methodology and results of the refinement; and the application of the refined model to evaluate the project alternatives.

Section 2.0 describes the methodology adopted by CS to evaluate the model, findings from the evaluation, and the implications of using the model on this study. Section 3.0 describes the model refinement methodology, data used, and the results of the refinement. Section 4.0 discusses results of the project alternatives in more detail.

2.0 Existing Model Evaluation

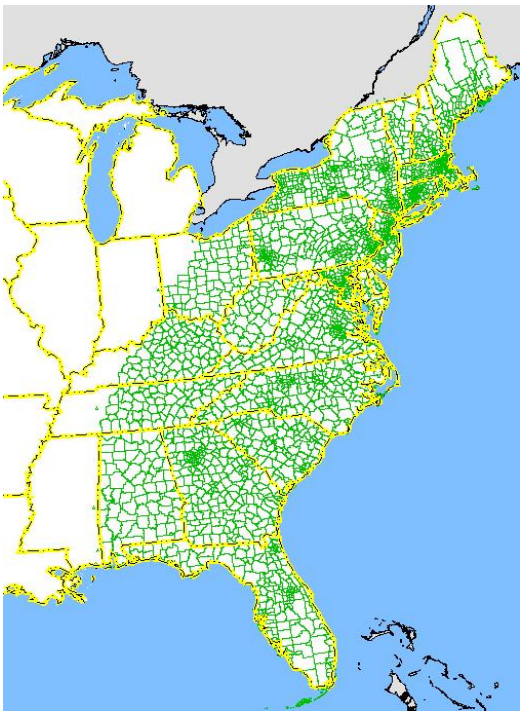
2.1 DATA

The Corridor Travel Demand Model (CTDM), which is the existing model, was evaluated against several sources of data. Model flows were compared against observed count data, and the trip patterns against data from an automated license plate recognition (ALPR) origin-destination survey. Although data from other sources such as the American Community Survey (ACS) and the I-95 Corridor Coalition Traffic Assignment Model (ICAT) were analyzed, these were used only in an indirect manner to validate the model. The ACS data could not be used directly for validation since the model does not develop forecasts by trip purpose, and the ACS data are primarily applicable for journey to work. Since the ICAT model trip tables were developed based on an origin-destination matrix estimation (ODME), it served as a good source of traffic volumes but not much more than that. Since observed data were available, modeled volumes were compared against these data. The count data and ALPR data will be discussed further under the Validation section.

I-95 Corridor Coalition Traffic Assignment Tool

As part of its ongoing effort to help member agencies look beyond their own jurisdictional boundaries to facilitate regional transportation decision-making, the I-95 Corridor Coalition developed the Integrated Corridor Analysis Tool (ICAT). ICAT is a web-based geographic information system (GIS) and associated transportation databases that enable users to view current transportation infrastructure and traffic patterns, and to project future travel volumes across multiple states within the Coalition region. One component of ICAT is a set of multistate auto and truck trip tables for a study area comprised of all Coalition member states plus major portions of the next tier of states adjacent to the I-95 Corridor, as shown in Figure 2.1.

Figure 2.1 ICAT Study Area



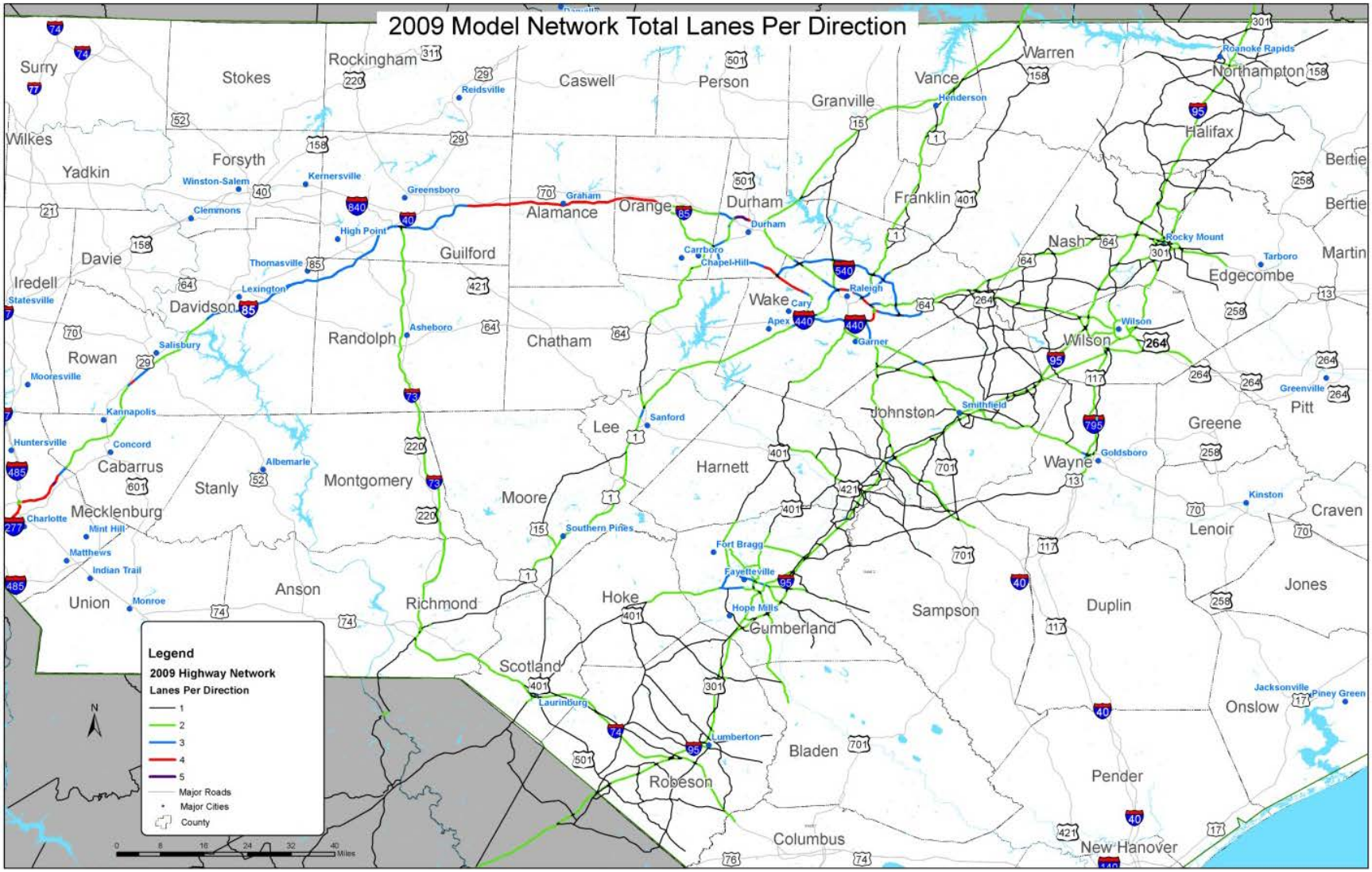
The multistate trip tables were created by first developing a set of base year "seed" matrices using conventional trip generation and distribution models and available auto and truck trip rate data from several of the Coalition states. Separate matrices were developed for short- and long-distance auto and commercial vehicle trips. These seed matrices served as input to a matrix estimation process, which used a combination of state- and national-level vehicle counts (primarily 2007 HPMS and FAF2 auto and truck volumes assigned to the National Highway Planning Network (NHPN)).

Future year seed matrices were developed based on forecasts of population and employment growth for all counties represented by ICAT Analysis Zones. The growth forecasts were obtained from a commercial database (Woods & Poole). Differences in total trips were calculated between the base and forecast year for each OD pair, and these differences were used to growth factor the base year calibrated matrix. The final product was a set of auto and truck vehicle trip tables between all ICAT analysis zones, for a base year of 2007 and future year forecasts from 2010 to 2035, in five-year increments.

2.2 NETWORKS

CS compared the number of lanes on major highways and major roadway links in the model. The base year (2009) and future year (2040) networks as delivered by the previous consultant team were reviewed and found to be consistent with the model documentation. Figure 2.2 depicts the current number of lanes per direction in the study area model network.

Figure 2.2 Study Area Number of Lanes per Direction



Corridor Network

The model network can be considered an agglomeration of two "logical" networks. There is an I-95 corridor-specific network that includes all of I-95 as well as connecting facilities within a 10-mile radius of I-95. There also is a larger diversion network that includes portions of I-40 in North Carolina as well as I-85 through the population centers of North Carolina, including Raleigh and Charlotte. It must be noted that the larger network also includes all of the corridor network as a subset. The diversion network is used to accommodate longer distance diversions to other major highways in North Carolina and surrounding states.

Model Zones/Centroids

Given the separately designated corridor and diversion networks, it was necessary to split the loading zones/centroid locations into corridor (internal) and diversion (external) nodes. The internal loading points consist of all zones located within the I-95 10-mile buffer. The externals were all other zones, including the two zones at the model boundary. The network consists of 71 total zones of which 39 were internal and the remainder external.

Model Link Capacity

Link capacities were checked and found to be consistent with the defined roadway characteristics. Future I-95 capacities on eight-lane segments are coded as 72,650 vehicles per day per direction or around 18,200 vehicles per day per lane. Given that hourly capacity on limited access facilities is in the range of 1,800 to 2,000 vehicles, the number does not seem unreasonable assuming a peak to daily factor of 10.

2.3 MODEL PARAMETERS

Model Value of Time (VOT)

The Departmental Guidance for the Valuation of Travel Time in Economic Analysis from the U.S. Department of Transportation[1] recommends that values of travel time savings (per person-hour as a percentage of total earnings) be 50 percent of the hourly wage rate for local personal travel, with a plausible range of 35 percent to 60 percent, and 100 percent for local business travel, with a plausible range of 80 percent to 120 percent. In 2000 U.S. dollars per person-hour, the recommended values of travel time savings are: $10.60 per hour for

[1] U.S. Department of Transportation. 2003. *Revised Departmental Guidance: Valuation of Travel Time in Economic Analysis*. Memorandum from Emil H. Frankel and Peter Belenky, Assistant Secretary for Transportation Policy, U.S. DOT.

personal local travel; $21.20 per hour for business travel; and $11.20 per hour for all travel purposes. The plausible ranges are $7.40 to $12.70 for personal local travel and $17.00 to $25.40 for business travel. Considering the VOTs were in 2009 dollars, the adopted values, as listed in Table 2.1, appear reasonable. The abbreviations in Table 2.1 are described below:

- **EE –** External to external trips, which are trips that have both origin and destination outside the modeled network;
- **EI –** External to internal trips, which are trips that have either their origin or destination outside the modeled network;
- **II –** Internal to internal trips are those which have both origin and destination within the modeled network region;
- **PC –** Passenger cars; and
- **HV –** Heavy vehicles.

Table 2.1 Values of Time by Trip Type

Purpose	VOT Dollars per Minute	VOT Dollars per Hour
EE (PC)	0.302	18.11
EE (HV)	0.500	30.00
E-I Intercity (PC)	0.262	15.72
E-I Local (PC)	0.187	11.23
E-I (HV)	0.500	30.00
I-I Intercity (PC)	0.203	12.16
I-I Local (PC)	0.145	8.68
I-I Local (HV)	0.500	30.00

The CTDM values of time were in accordance with U.S. DOT guidelines for assumed values of time by the nature and distance of travel:

- Intercity personal travel at 70 percent of hourly wage rate;
- Local personal travel at 50 percent of hourly wage rate; and
- Business travel at 100 percent of hourly wage rate.

Bureau of Public Roads Function (BPR Function)

The CTDM uses a multimodal multiclass assignment based on the Bureau of Public Roads (BPR) function for volume delay with default values for alpha and beta where:

Alpha α= 0.83 and Beta β = 5.50 for freeways and Alpha α= 1.00 and Beta β = 5.40 for other facilities.

And the function is $S = t(1+ \propto \left(\frac{v}{c}\right))^{\beta}$ where:

- S = Congested or delayed travel time;
- t = Free-flow travel time;
- v = Link volume; and
- c = Link capacity.

Tolling Diversion

The CTDM handles the effects of tolls on I-95 by the use of a logit diversion procedure to divide the trip table into tolled and nontolled trips prior to traffic assignment. Table 2.2 describes the other parameters used in the utilities for the logit toll diversion calculation. Tolling on non-I-95 facilities is handled via an assumed toll equivalent travel time on the link of concern.

Table 2.2 Logit Toll Diversion Coefficients

Purpose	A	B	cToll	cETC
EE (PC)	0.0838	0.5692	0.2196	-0.2591
EE (HV)	0.0884	0.176	0.3375	0
E-I Intercity (PC)	0.0838	0.6387	0.2196	-0.2591
E-I Local (PC)	0.0789	0.7602	0.219	-0.2522
E-I (HV)	0.0884	0.176	0.3375	0
I-I Intercity (PC)	0.0838	0.7871	0.2196	-0.2591
I-I Local (PC)	0.0789	0.9424	0.219	-0.2522

Parameters cToll and cETC represent the toll road bias constant and the Electronic Toll Road (ETR) bias constant respectively whereas Parameters a and b represent toll coefficients.

2.4 VALIDATION

The CTDM was evaluated based on how it compared against a variety of data. Volumes were compared at a screenline level as well as at individual link locations. The following sections describe the results of the validation at both levels.

Volumes

Screenline Volume Validation

The screenlines defined by the previous consultants are illustrated in Figure 2.3. Table 2.3 shows that the modeled screenline volumes compare reasonably well. However, there are a few locations where the model is over-assigning, listed below:

- Screenline 8 (I-40 East of I-95);
- Screenline 10 (I-95 North of I-40);
- Screenline 12 (Fayetteville West of U.S. 301); and
- Screenline 14 (West of I-95, East of U.S. 64/264).

Table 2.3 Comparison of Screenline Model Volumes to Annual Average Daily Traffic (AADT) Counts

Index	By Screenline	Total AADT	Link Volume Having AADT	Daily Modeled Volume/ Counts (AADT)
1	I-95 SC Border	42,203	45,502	1.08
3	I-95 South of Fayetteville	76,778	86,277	1.12
4	I-95 North of Fayetteville	82,744	80,245	0.97
5	I-95 North of Rocky Mount	54,011	54,790	1.01
6	I-95 VA Border	40,050	41,882	1.05
7	West of Goldsboro	45,854	43,880	0.96
8	I-40 East of I-95	38,380	42,729	1.11
10	I-95 North of I-40	46,726	59,660	1.28
11	I-95 South of I-40	67,615	68,812	1.02
12	Fayetteville West of U.S. 301	73,730	108,417	1.47
13	East of Raleigh	182,930	181,177	0.99
14	West of I-95, East of U.S. 64/264	57,468	73,180	1.27

Source: CTDM Model (Performed by Cambridge Systematics, Inc.).

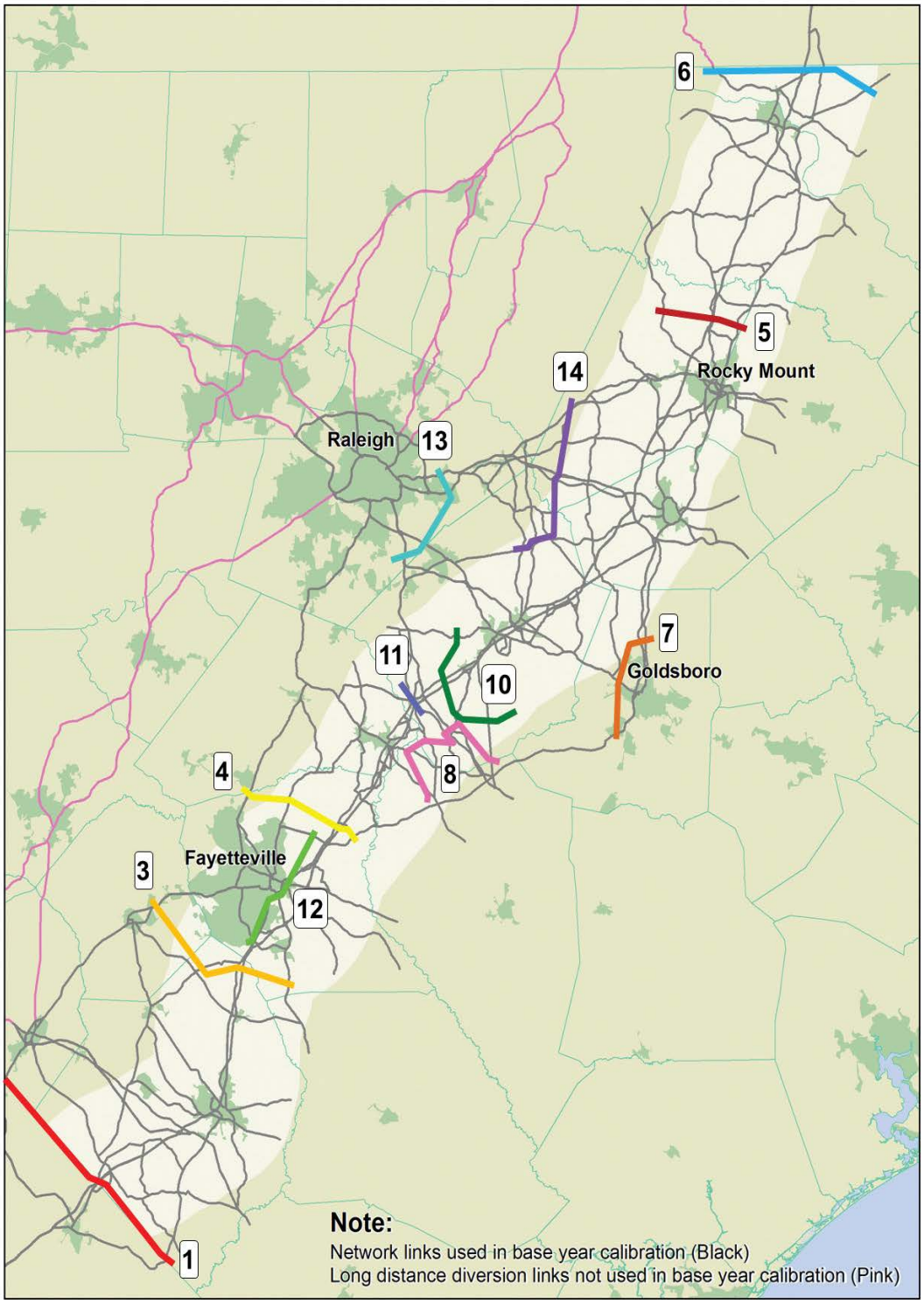
As can be seen from Figure 2.3, the over-assigning screenlines are mainly those capturing east-west traffic entering the I-95 Corridor. Screenline 10 is the exception however being 28 percent over-assigned. The other north-south screenlines across the I-95 corridor are all within 20 percent (or better) of the AADT counts.

Link Volume Validation

Volumes also were validated at the 10 ALPR locations listed below and illustrated in Figure 2.4.

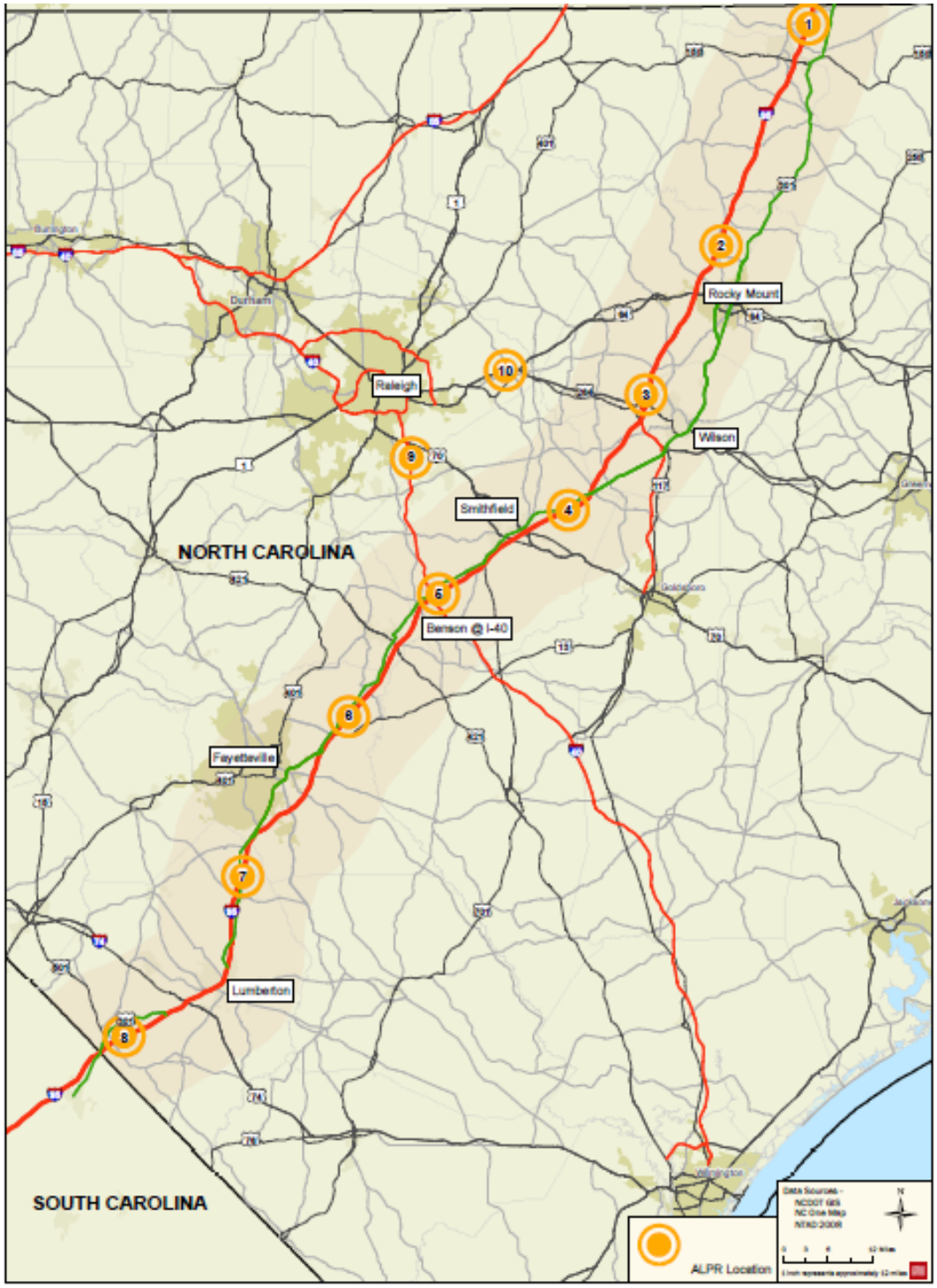
1. I-95 South of Exit 180 (at SR 1201);
2. I-95 North of Exit 145 (at SR 1510);
3. I-95 North of Exit 121 (at SR 1309);
4. I-95 North of Exit 102 (at SR 2141);
5. I-95 North of I-40 (at SR 1171);
6. I-95 North of Exit 61 (at SR 1813);
7. I-95 North of Exit 33 (at SR 1726);
8. I-95 North of Exit 2 (at SR 2459);
9. I-40 North of Exit 309 (at SR 2700); and
10. U.S. 64 West of NC 96 (at SR 2368).

Figure 2.3 Study Area Screenline Locations



Source: Memo E: Overview of I-95 CTDM and Calibration/Validation (Martin/Alexiou/Bryson and Michael Baker Corporation).

Figure 2.4 Automated License Plate Recognition Survey Station Locations



Source: Model Design Memo, I-95 Corridor Planning and Finance Study.

The first eight station locations are along I-95. Except for Location 3 (interchange with I-264) and Location 4 (north of the interchange with U.S. 70), the model compares reasonably well (less than 11 percent difference between the model versus counts) to observed volumes, with respect to the total (auto and truck) volume as depicted in Table 2.4. Also depicted are modeled versus observed comparisons and differences by ALPR location along I-95, by vehicle type. While the total AADT volumes compare reasonably well at the majority of ALPR locations, the comparison of modeled to count volumes by vehicle type differ considerably, ranging from approximately -1 to 25 percent for the autos and approximately -2 to 34 for the trucks.

Table 2.4 Comparison of Modeled versus Observed Daily Volumes on I-95 at ALPR Locations by Vehicle Type

		Observed			Modeled			Percentage Difference		
Stations	Location	Auto	Truck	Total	Auto	Truck	Total	Auto	Truck	Total
1	I-95 South of Exit 180 (at SR 1201)	25,500	8,500	34,000	25,212	8,561	33,773	-1.1%	0.7%	-0.7%
2	I-95 North of Exit 145 (at SR 1510)	29,250	9,750	39,000	32,954	10,200	43,154	12.7%	4.6%	10.7%
3	I-95 North of Exit 121 (at SR 1309)	27,000	9,000	36,000	33,956	9,633	43,589	25.8%	7.0%	21.1%
4	I-95 North of Exit 102 (at SR 2141)	27,000	9,000	36,000	33,900	9,631	43,531	25.6%	7.0%	20.9%
5	I-95 North of I-40 (at SR 1171)	25,500	8,500	34,000	28,327	9,322	37,649	11.1%	9.7%	10.7%
6	I-95 North of Exit 61 (at SR 1813)	35,250	11,750	47,000	36,449	11,498	47,947	3.4%	-2.1%	2.0%
7	I-95 North of Exit 33 (at SR 1726)	30,750	10,250	41,000	31,097	11,498	42,595	1.1%	12.2%	3.9%
8	I-95 North of Exit 2 (at SR 2459)	23,250	7,750	31,000	23,601	10,378	33,979	1.5%	33.9%	9.6%
9	I-40 North of Exit 309 (at SR 2700)	56,318	12,362	68,680	61,876	9,781	71,657	9.9%	-20.9%	4.3%
10	U.S. 64 West of NC 96 (at SR 2368)	–	–		47,391	4,062	51,453	–	–	–

Source: CTDM 2009 Model Run and Network AADT.

Table 2.5 presents a comparison of modeled versus observed volumes along U.S. 301. The locations selected along U.S. 301 were as close to the ALPR station locations on I-95, depending on the availability of count data. From documentation provided to CS by the model development team, it is understood that volumes, on roadways other than I-95, were preloaded onto the network approximately equal to the difference between modeled volumes and observed volumes. Preloading of trips in travel demand forecasting practice is typically limited to through trips or long-distance truck traffic.

Table 2.5 Comparison of Modeled versus Observed Daily Volumes on U.S. 301

U.S. 301	Observed AADT Volumes	Modeled Volumes	Percentage Difference
Near Station 1	1,200	2,146	79%
Near Station 2	1,800	414	-77%
Near Station 3	8,800	19,895	126%
Near Station 4	2,900	3,322	15%
Near Station 5	3,500	2,838	-19%
Near Station 6	Unavailable	–	Unavailable
Near Station 7	2,500	2,400	-4%
Near Station 8	880	888	1%

Source: CTDM 2009 Model Run and Network AADT.

Volume to Count Ratios

A review of volume-over-count ratios identified several key discrepancies, as follows:

- Areas to the west of the I-95/U.S. 301 corridor tend to have very high volume-over-count ratios, particularly I-85. This could be attributed to the lower levels of validation further away from the I-95 corridor, as well as lack of detail (such as loading zones) in the vicinity of I-85.
- Tendency for I-95 to under assign while U.S. 301 over assigns. This might result in the model diverting more trips from I-95 during a toll scenario than would happen otherwise. Even volumes within acceptable ranges of accuracy tend to reflect this pattern between the two parallel highways.
- A number of external zones are over assigning trips.

Figures 2.5 through 2.8 depict volume-over-count ratios for each link in the highway network. In general, the links depicted in black are significantly under-assigning while the links in red are over-assigning substantially. Figure 2.5 depicts the regionwide volume to count ratios. Figure 2.6 depicts ratios for the southernmost corridor segments, while Figure 2.7 depicts mid-corridor segments and Figure 2.8 covers the northernmost corridor segments.

Figure 2.5 Volume-over-Count Ratios Model Region

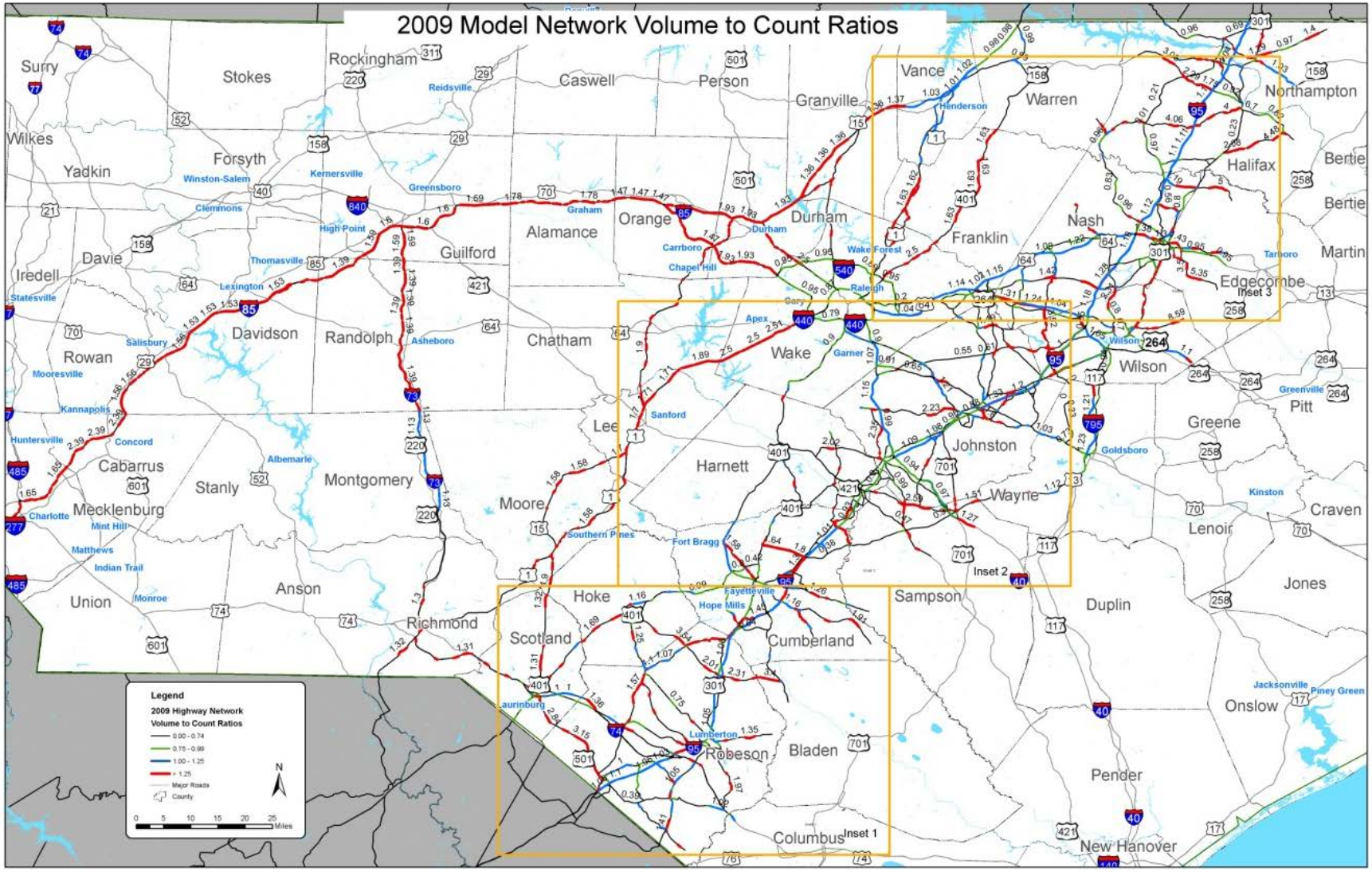


Figure 2.6 Volume-over-Count Ratios Southernmost Corridor Segments

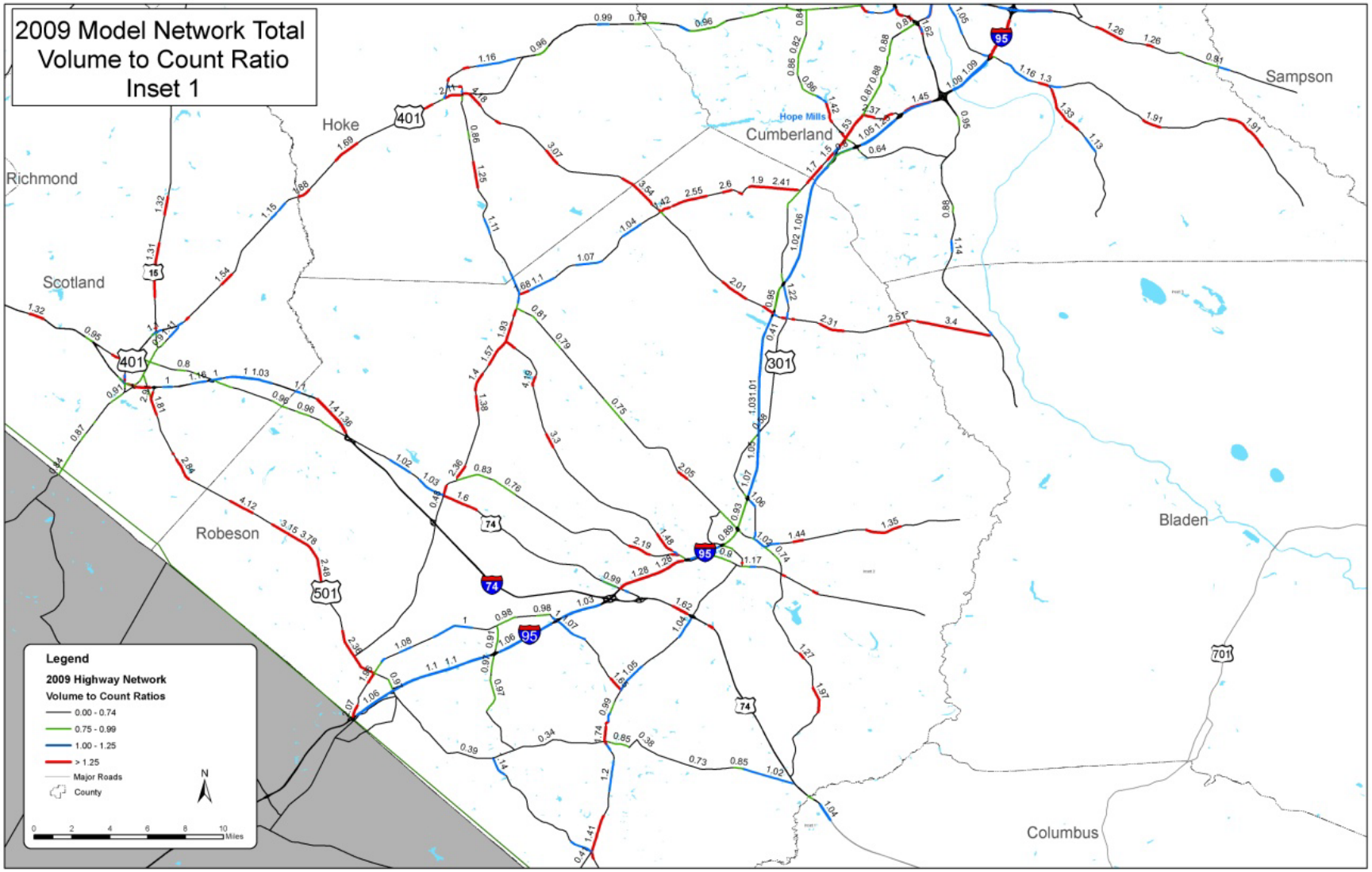


Figure 2.7 Volume-over-Count Ratios Mid-Corridor Segments

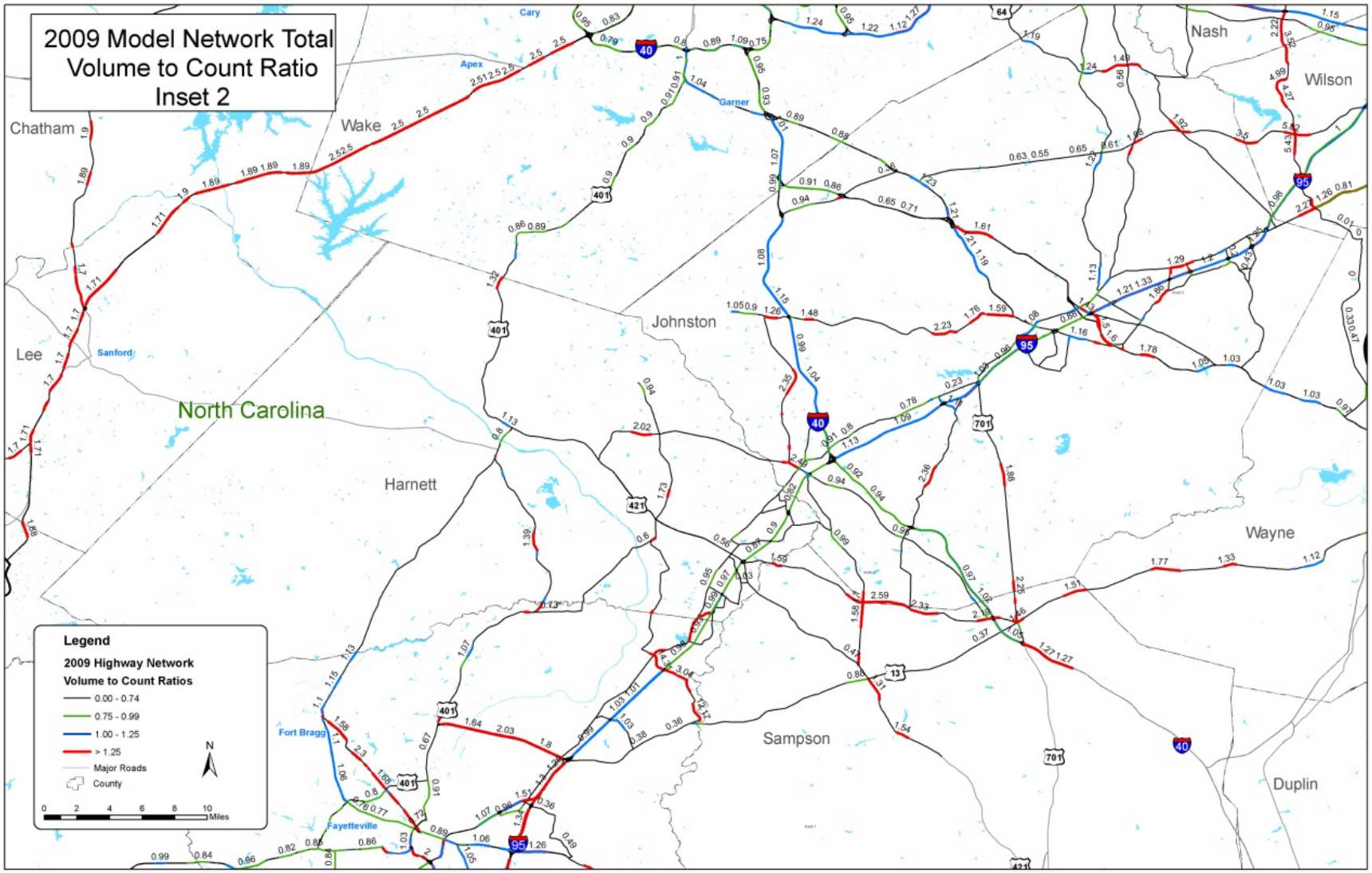
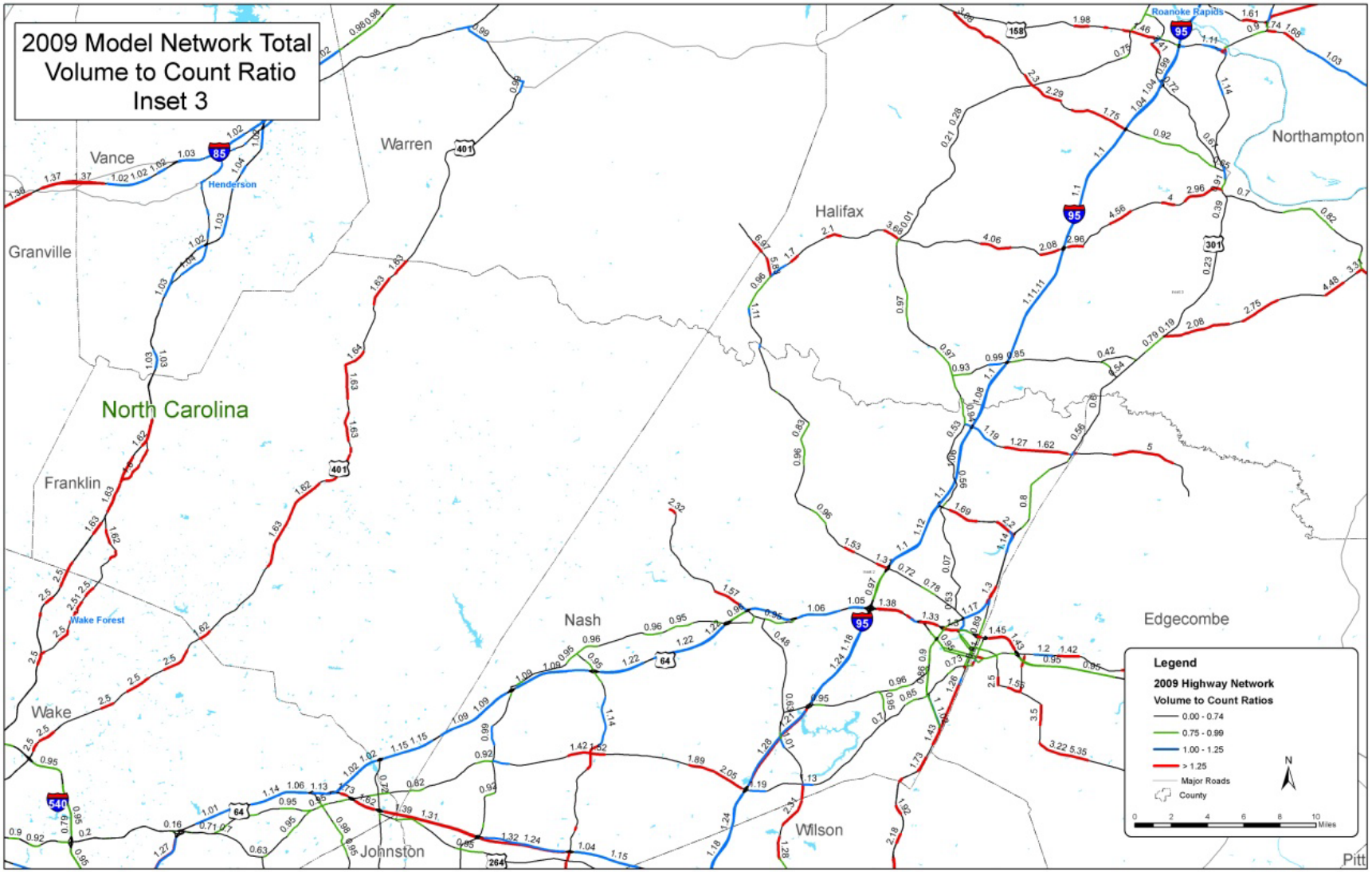


Figure 2.8 Volume-over-Count Ratios Northernmost Corridor Segments



Origin-Destination (OD) Patterns

A select link analysis was performed on the links at the ALPR locations in an attempt to compare OD patterns with license plate survey results. It is surmised that the difference is caused by the operating characteristics of the Origin-Destination Matrix Estimation (ODME) process which focuses on calibrating to counts rather than origin-destination patterns. Additionally, issues such as centroid loading point locations vis-à-vis the ALPR locations could impact origin-destination factors. ODME involves using counts where available to develop trip tables for use in model assignment and analysis. Ideally, the more counts that exist, the better, as there is less interpolation in missing areas. If counts are too few, the resulting interpolation errors may be large. In addition to inevitable ODME methodology issues, the use of assignment preloads further distort the comparison.

Travel Times

Average observed versus modeled travel speeds were compared for specific segments between the 10 ALPR locations depicted earlier in Figure 2.4. The observed speeds were obtained from data collected by the Michael Baker Corporation team as part of the I-95 Corridor Planning and Finance Study. The comparison, as illustrated in Tables 2.6 through 2.9, reveals that the model compares reasonably well to observed data, in both directions.

Table 2.6 Observed Southbound I-95 Travel Times and Speeds

	Distance (Miles)	Speed (MPH)	Travel Time (Minutes)
Station 1 to Station 3	53	73	44
Station 1 to Station 6	115	71	97
Station 1 to Station 8	177	70	152
Station 3 to Station 6	62	70	53
Station 3 to Station 8	125	69	108
Station 6 to Station 8	63	69	55

Table 2.7 Modeled Southbound I-95 Travel Times and Speeds

	Distance (Miles)	Speed (MPH)	Travel Time (Minutes)
Station 1 to Station 3	53	73	44
Station 1 to Station 6	115	71	97
Station 1 to Station 8	177	69	154
Station 3 to Station 6	62	69	54
Station 3 to Station 8	125	68	110
Station 6 to Station 8	63	67	56

Table 2.8 Observed Northbound I-95 Travel Times and Speeds

	Distance (Miles)	Speed (MPH)	Travel Time (Minutes)
Station 1 to Station 3	54	73	45
Station 1 to Station 6	115	71	97
Station 1 to Station 8	176	70	150
Station 3 to Station 6	60	69	53
Station 3 to Station 8	121	69	105
Station 6 to Station 8	61	70	53

Table 2.9 Modeled Northbound I-95 Travel Times and Speeds

	Distance (Miles)	Speed (MPH)	Travel Time (Minutes)
Station 1 to Station 3	54	67	48
Station 1 to Station 6	115	68	101
Station 1 to Station 8	176	70	151
Station 3 to Station 6	60	69	52
Station 3 to Station 8	121	71	102
Station 6 to Station 8	61	72	51

Trip Length Distribution

While it is understood that the CTDM is a generalized ODME without specification by trip purpose, average trip lengths were compared against trip category data from the earlier referenced ICAT model. It was observed that the CTDM weighted average trip lengths for autos and trucks for all trips (both corridor and diversion) were approximately twice the values observed from the ICAT. Tables 2.10 and 2.11 illustrate the resulting average trip lengths for autos and trucks from the CTDM and the ICAT, respectively.

Table 2.10 CTDM Average Trip Length (Miles)

	2009	2040 No Build	2040 No Toll
Weighted Passenger Car	45.10	44.06	44.06
Weighted Heavy Vehicle	74.51	62.92	62.92

Table 2.11 ICAT Average Trip Length (Miles)

	2010	2030
Auto	23.18	23.48
Truck	31.83	32.42

It must be noted that this comparison was performed primarily for completeness. The ICAT model and the CTDM models differ significantly with regard to scale and purpose which may be a factor in the trip length distribution (TLD) variance. The ICAT model covers a region spanning most of the Eastern Seaboard of the country but focused on I-95, whereas the CTDM is focused on North Carolina and parts of immediately adjacent states like Virginia and South Carolina.

2.5 MODEL FLOW (METHODOLOGY)

The I-95 CTDM uses ODME as the basis for trip table development. Consequently, it does not include a trip generation section where trips are calculated based on defined socioeconomic characteristics. This does pose some limitations in terms of analysis that can be conducted with the model, something that needs to be carefully considered. The trip table was developed based on a travel survey at 10 ALPR locations along I-95 and major facilities connecting to I-95. Existing count data were used to extrapolate and fill in gaps and TransCAD Origin Destination Matrix Estimation software then used to develop a trip table. The locations were shown earlier in Figure 2.4.

Two categories of vehicles were recorded in the survey, Passenger Cars (PC) and Heavy Trucks (HV). It should be noted that the passenger car category included light box trucks, pickup trucks, and SUVs. The trip tables comprised a 71 x 71 matrix corresponding with the number of internal and external zones.

Following development of the overall trip table by vehicle category, the table was then disaggregated into local and intercity trips. This stratification was based on the travel time of the trip. Forty-five minutes was used as the cutoff point with trips shorter considered local and trips longer considered intercity. Through trips or external to external (EE) trips are determined by default based on the respective origin and destination zones. Hence, a trip between two external zones will be considered EE, between an external and an internal IE or EI (internal-external) and between two internal zones internal-internal (II). Note that it is possible to have intercity II and IE/EI trips depending on travel time of the trip. Note that the intercity and local designations apply only to PC trips. Truck trips are simply defined by the nodes they traverse (Internal, External, or Internal-External Trips). The result of this process was eight separate trip tables by vehicle type and trip category. For the PCs, the categories are IE Local, IE Intercity, II Local, II Intercity, and EE. For trucks they are IE, EE, and II.

The next step in the modeling process was to determine the trips that may use diversion facilities based on alternative travel times and toll rates along such routings. The table was then further split into an in-corridor (I-95 and vicinity only) and a diversion table. Once the 16 trip tables were identified, it was then necessary to consider tolling effects for such alternatives.

Four sets of network skims (shortest path estimations – based on travel times in the case of this model) are performed to determine how tolling is handled. They are:

1. A skim of the diversion network using all links, including tolled links;
2. A skim of the diversion network without tolled links;
3. A skim of the in-corridor network using all corridor links, including tolled facilities; and
4. A skim of the in-corridor network without tolled links.

The resulting skims are used to determine how the trip tables are further split based on tolls. For the diversion network, if the travel time on the tolled facility is five or more minutes faster than on the no-toll option, the toll choice routine is used to split up the diversion tables into tolled and nontoll tables; otherwise, all the trips are assumed to use the no-toll option. A similar procedure is used to split the in-corridor trip tables with the exception that the trips are applied to corridor links only. No-toll trips are prohibited from using tolled facilities.

Note that non I-95 toll facilities use travel time as a surrogate for generalized cost which typically takes value of time (VOT) into consideration.

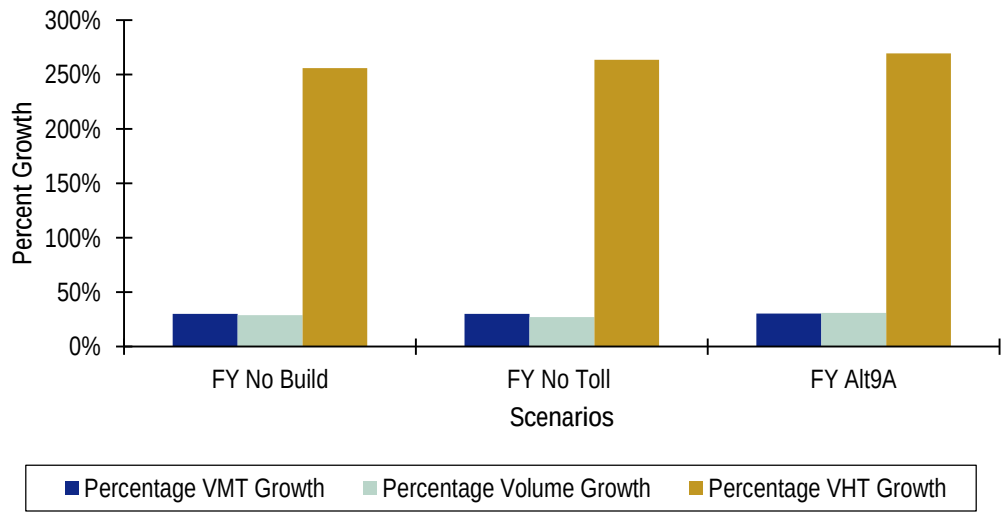
For tolled scenarios, the model utilizes a feedback process where the congested travel times are used as input to the toll diversion calculation and assignment of a subsequent iteration. For the first iteration, free-flow travel times are used to determine the toll diversion. Note that nontolled scenarios do not utilize feedback looping and simply use free-flow time as input to the skims for assignment and toll diversion.

2.6 GROWTH METHODOLOGY

The growth methodology used by the model development team appears reasonable. Growth for local areas is driven by socioeconomic growth, whereas external travel is grown based on traffic trends. The rationale for this approach is that local traffic is more sensitive to population and employment changes compared to through traffic which is affected by other characteristics. In the absence of data related to other explanatory factors, historical trends are reasonable surrogates.

The vehicle-miles traveled for the entire model area grew by approximately 65 percent between 2009 and 2040. The vehicle-hours traveled, however, grew by 256 percent, over the same period (Figure 2.9). This leads to the comparison of VMT and VHT growth projected for the other future year scenarios as well. The notation "FY" in Figure 2.9 refers to future year, which in this case is 2040. The alternatives are described in Section 2.7.

Figure 2.9 Comparison of 2009 Base Year versus 2040 VMT and VHT



Further investigation reveals that travel speeds on several links in the model are very low in comparison to free-flow speeds, which is likely a consequence of extremely high preloaded volumes used in model validation. Once assigned, these volumes exceed capacity, in many cases, by over 100 percent, causing speeds on those links to plummet.

The growth rates at the 10 ALPR survey locations are illustrated in Table 2.12. The segment south of the interchange with I-40 is projected to experience a higher growth rate compared with the segment north of the interchange. I-40 also is projected to experience high growth (60 percent) over the 31-year period. Since the focus was on "model growth," model volumes were used to represent 2009 conditions rather than traffic counts. Table 2.13 illustrates the growth in traffic volumes on certain I-95 sections. The table illustrates that the volumes are not necessarily balanced in each direction, which is likely attributable a large percentage of long trips within the corridor.

Table 2.12 Projected Two-Way Volumes between 2009 and 2040

ALPR Survey Station	ALPR Survey Locations	2009 Modeled	2040 No Build	Percentage Growth
Station 1	I-95 South of Exit 180 (at SR 1201)	33,773	43,098	28%
Station 2	I-95 North of Exit 145 (at SR 1510)	43,154	53,442	24%
Station 3	I-95 North of Exit 121 (at SR 1309)	43,589	58,708	35%
Station 4	I-95 North of Exit 102 (at SR 2141)	43,531	56,669	30%
Station 5	I-95 North of I-40 (at SR 1171)	37,649	62,430	66%
Station 6	I-95 North of Exit 61 (at SR 1813)	47,947	66,199	38%
Station 7	I-95 North of Exit 33 (at SR 1726)	42,595	73,979	74%
Station 8	I-95 North of Exit 2 (at SR 2459)	33,979	49,323	45%
Station 9	I-40 North of Exit 309 (at SR 2700)	71,657	114,365	60%
Station 10	U.S. 64 West of NC 96 (at SR 2368)	51,453	75,907	48 %

Speeds

The base year 2009 model network speeds are quite consistent throughout the I-95 corridor. For example, in 2040, the southbound direction experiences a projected reduction in speeds between ALPR Stations 6 (I-95 North of Exit 61 (at SR 1813)) and 8 (I-95 North of Exit 2 (at SR 2459)). Figures 2.10 and 2.11 illustrate average congested speeds across I-95 in 2009 and 2040. This reduction is consistent with the considerable increase in traffic along I-95 between Stations 6 and 7 as depicted in Table 2.13.

Figure 2.10 Comparison of Base Year (2009) and Future (2040) No-Build Speeds (MPH) Southbound

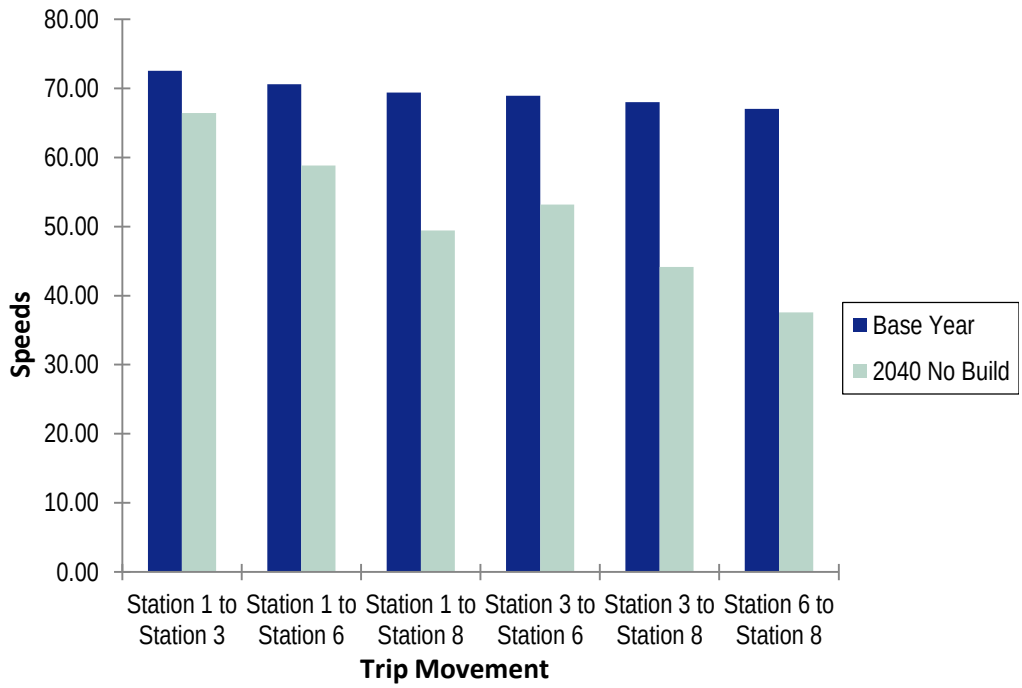


Figure 2.11 Comparison of Base Year (2009) and Future (2040) No-Build Speeds (MPH) Northbound

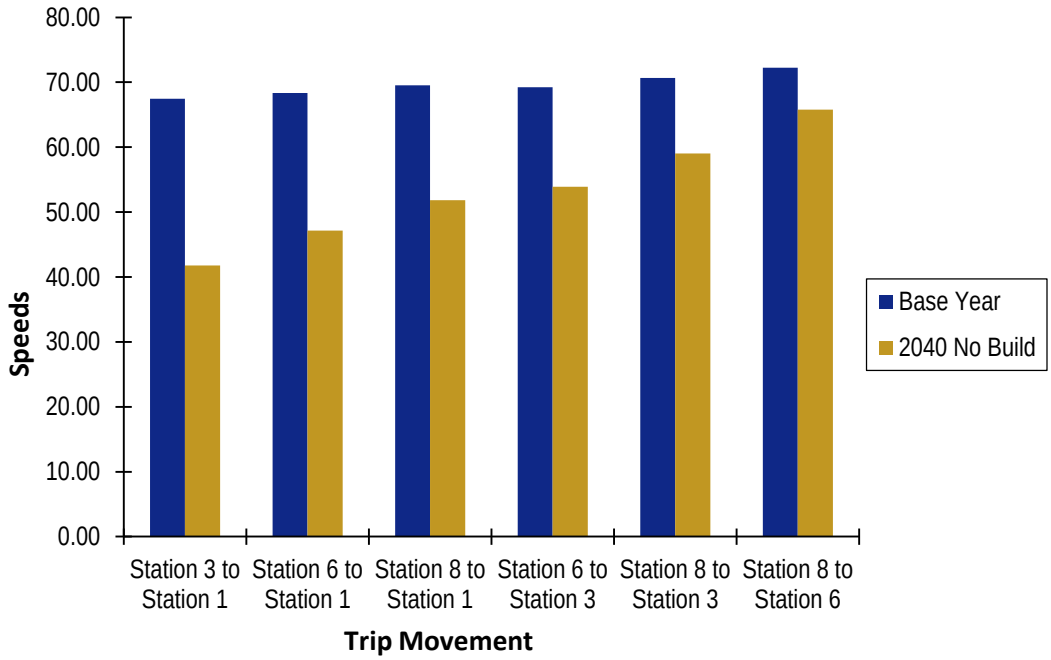


Table 2.13 Daily Volumes by Direction at Select I-95 Locations

	Base Year			Future Year No Build			Growth		
	Northbound	Southbound	Total	Northbound	Southbound	Total	Northbound	Southbound	Total
Station 5	18,474	19,175	37,649	30,788	31,642	62,430	67%	65%	66%
Station 6	24,098	23,849	47,947	33,197	33,002	66,199	38%	38%	38%
Station 7	20,952	21,643	42,595	36,489	37,490	73,979	74%	73%	74%
Station 8	16,999	16,980	33,979	24,476	24,847	49,323	44%	46%	45%

Speeds Due to Preloaded Volumes

It was observed that several roadway links were coded with high preloaded volumes, which, in turn, could cause high volume to capacity ratios. The high volume to capacity ratios cause the speeds to reduce dramatically.

2.7 DIVERSION ANALYSIS

An important criterion used to evaluate the CTDM was sensitivity to tolling. The following scenarios were run using the CTDM.

Alternatives Analyzed

I-95 Project ID Definitions

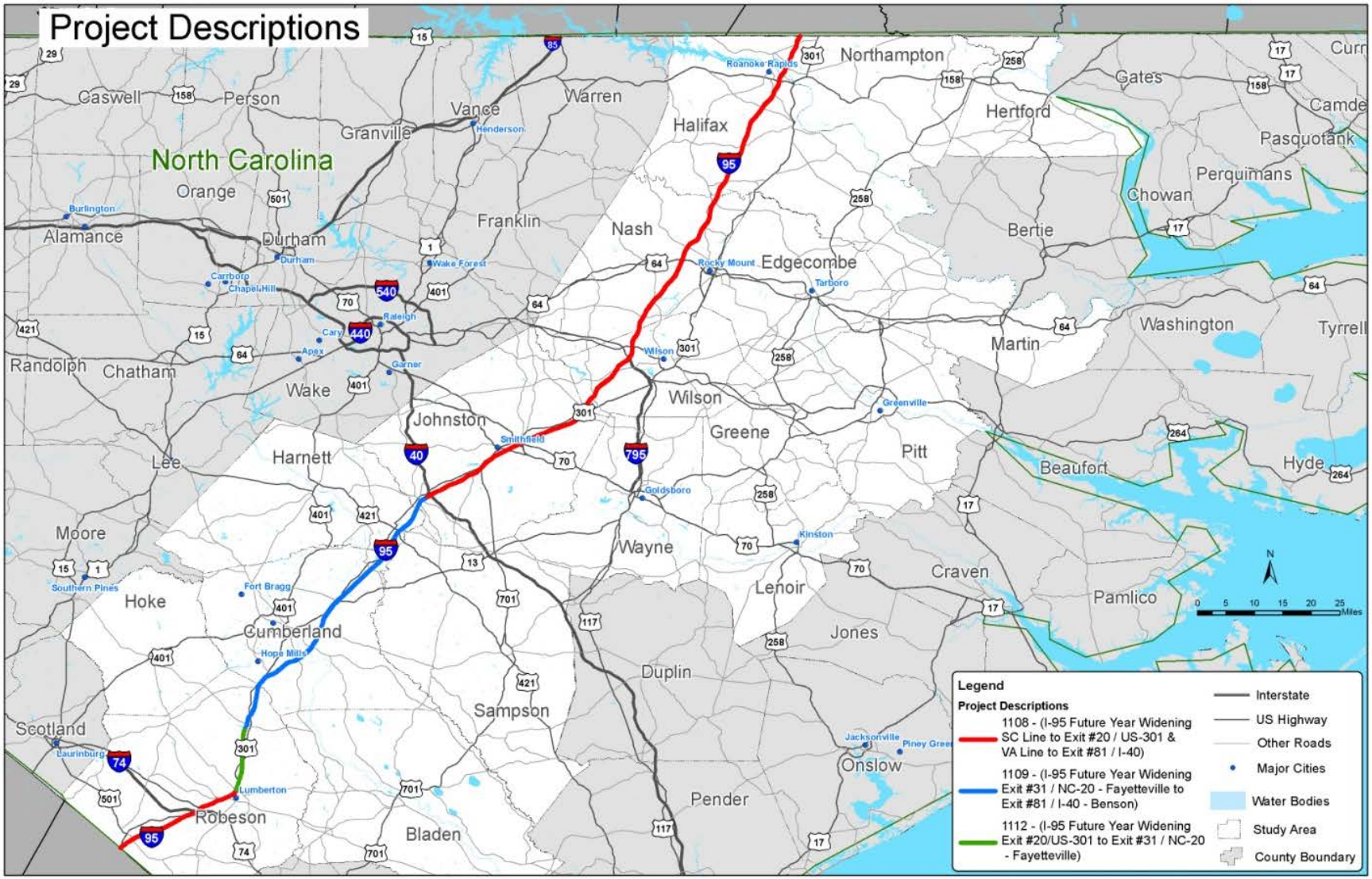
Figure 2.12 depicts the three future I-95 widening projects described below.

- **1108 –** This project represents a one-lane widening from two to three lanes per direction along I-95. The extent of the project is from the South Carolina state line to Exit 20 near Fayetteville and from the Virginia state line southwards to the I-40 intersection.
- **1109 –** This project represents a two-lane widening from two to four lanes per direction along I-95. The project extends from Exit 31 at the NC SR 20 intersection to the I-40 interchange which is the southern extent of Project 1108.
- **1112 –** This project represents a one-lane widening from two to three lanes per direction along I-95. The project is scheduled to be undertaken by 2020, unlike the previous two, which will be completed by 2040. It extends from Exit 20 to Exit 31 at the NC SR 20 intersection which is the southern extent of project ID 1109.

The three projects mentioned above form a continuous extent of improvement along I-95 in North Carolina of at least one lane per direction with two lanes per direction along ID 1109.

1. **2040 No Build –** This scenario includes no capacity enhancing projects along I-95. Specifically, project IDs 1108, 1109, 1112 described above, and which are present in the Tolled scenarios, are absent. There are several build projects in other areas of the network, including areas around Raleigh, among others. Note that tolls are present on non-I-95 facilities, particularly around the Raleigh area.
2. **2040 Build/No Toll –** This scenario includes project IDs 1108 and 1109. As is the case for the No Build, no I-95 tolls are present but tolls are present on non-I-95 facilities.
3. **2040 No Toll/All Projects –** This scenario includes all the I-95 projects (IDs 1108, 1109, and 1112). As is the case for the No Build, no I-95 tolls are present but tolls are present on non-I-95 facilities.
4. **2040 Alternative 9A –** This is a tolled scenario with I-95 tolls of between $2 and $3 at various locations. All the build scenario projects (IDs 1108, 1109, and 1112) are present.
5. **2040 Alternative 12A 3** Like Alt 9A, this is a tolled scenario with I-95 tolls of between $1.00 and $1.50 at various locations. The gantries are spaced closer than in the case of Alt 9A. All the build scenario projects are included.

Figure 2.12 Future I-95 Expansion Projects



Results

There is a logical increase in I-95 volumes between the No Toll/No Build and the No Toll/Build scenario, which includes additional widening on I-95. Both Alternatives 9A and 12A experience a reduction in volume throughout I-95, as depicted in Table 2.14. Alternative 12A appears to experience a larger reduction in volumes on I-95, in spite of a lower toll at each gantry. However, in Alternative 12A, the gantries were spaced closer together (10 miles versus 20 miles in Alternative 9A), likely preventing local trips from using I-95 as a shortcut. It appears that the model is more sensitive to gantry locations than toll values.

Table 2.14 I-95 Demand Projections among Alternatives

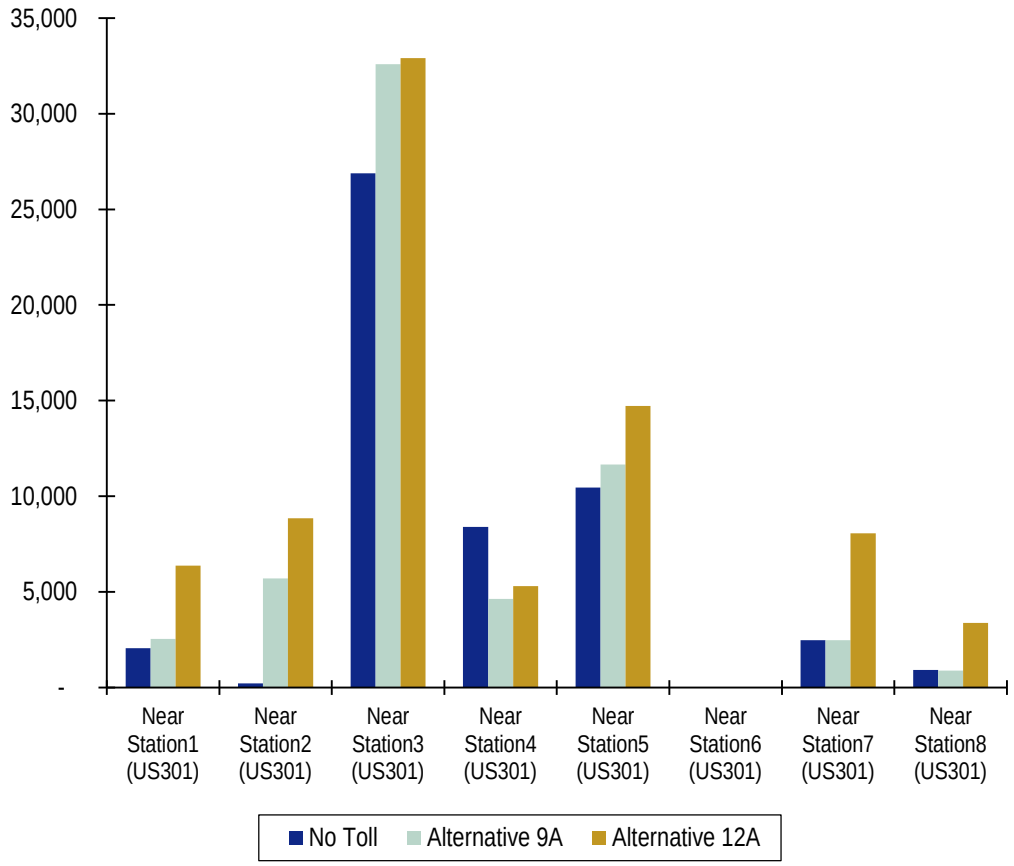
ALPR Survey Stations	ALPR Survey Locations	2040 No Build	2040 No Toll	2040 Alt 9A	2040 Alt 12A
Station 1	I-95 South of Exit 180 (at SR 1201)	43,098	43,098	42,984	39,006
Station 2	I-95 North of Exit 145 (at SR 1510)	53,442	55,176	48,458	37,605
Station 3	I-95 North of Exit 121 (at SR 1309)	58,708	62,623	46,924	43,986
Station 4	I-95 North of Exit 102 (at SR 2141)	56,669	63,923	49,683	32,470
Station 5	I-95 North of I-40 (at SR 1171)	62,430	58,975	43,427	34,215
Station 6	I-95 North of Exit 61 (at SR 1813)	66,199	80,539	58,250	59,818
Station 7	I-95 North of Exit 33 (at SR 1726)	73,979	87,462	79,653	66,911
Station 8	I-95 North of Exit 2 (at SR 2459)	49,323	49,344	34,338	34,478
Station 9	I-40 North of Exit 309 (at SR 2700)	114,365	109,673	111,202	111,942
Station 10	U.S. 64 West of NC 96 (at SR 2368)	75,907	76,460	83,924	83,723

Elasticity

Alternative 9A is a tolled scenario with I-95 tolls of between $2 and $3 at various locations. The alternative includes several Build projects that entail capacity improvements along I-95.

As seen in Table 2.15, traffic is diverted away from I-95 in Alternative 9A, compared to the 2040 No Toll scenario. A good portion is diverted to U.S. 301, as shown in Figure 2.13. The percentage diversion ranges from close to no diversions at the northern most part of the corridor to 30 percent at the southernmost portion. The percentage diversions vary between 22 and 28 percent between Stations 3 and 6. This level of diversion is not uncommon based on other tolling projects that the team has been involved with.

Figure 2.13 Comparison of Daily Two-Way Volumes Along U.S. 301 across Build Alternatives



It is possible that alternative routes, such as U.S. 301, become more attractive south of Rocky Mount, due to a multitude of reasons, including proximity to I-95, and increased capacity, causing a higher percentage of traffic to divert from I-95. Also, between the interchanges with U.S. 264 and I-40, the number of plausible alternative routes increases, with I-795 and U.S. 117 becoming more accessible.

Alternative 12A also is a tolled scenario with I-95 tolls of between $1.00 and $1.50 at various locations, which on average are spaced closer together than is the case for Alternative 9A. All the build scenario projects are present and represent capacity projects along the length of I-95 in North Carolina.

Alternative 12A experiences a similar diversion pattern compared to 9A (Table 2.16). However, the percentage peak diversions are considerably higher and are attributable to the proximity of the gantry locations to each other. As seen in Figure 2.13, the volumes in Alternative 12A are higher on U.S. 301 (for the most part) compared to Alternative 9A, supporting the argument that shorter trips are less likely to use I-95 when the gantry spacing is less.

Table 2.15 Comparison of 2040 No Toll and 2040 Alternative 9A Volumes

ALPR Survey Stations	ALPR Survey Locations	2040 No Toll	2040 Alt 9A	Diff 9A No Toll	Percentage Difference
Station 1	I-95 South of Exit 180 (at SR 1201)	43,098	42,984	(115)	0%
Station 2	I-95 North of Exit 145 (at SR 1510)	55,176	48,458	(6,718)	-12%
Station 3	I-95 North of Exit 121 (at SR 1309)	62,623	46,924	(15,700)	-25%
Station 4	I-95 North of Exit 102 (at SR 2141)	63,923	49,683	(14,239)	-22%
Station 5	I-95 North of I-40 (at SR 1171)	58,975	43,427	(15,548)	-26%
Station 6	I-95 North of Exit 61 (at SR 1813)	80,539	58,250	(22,288)	-28%
Station 7	I-95 North of Exit 33 (at SR 1726)	87,462	79,653	(7,809)	-9%
Station 8	I-95 North of Exit 2 (at SR 2459)	49,344	34,338	(15,006)	-30%
Station 9	I-40 North of Exit 309 (at SR 2700)	109,673	111,202	1,530	1%
Station 10	U.S. 64 West of NC 96 (at SR 2368)	76,460	83,924	7,464	10%

Table 2.16 Comparison of 2040 No Toll and 2040 Alternative 12A Volumes

ALPR Survey Stations	ALPR Survey Locations	2040 No Toll	2040 Alt 12A	Diff 12A No Toll	Percentage Difference
Station 1	I-95 South of Exit 180 (at SR 1201)	43,098	39,006	(4,092)	-9%
Station 2	I-95 North of Exit 145 (at SR 1510)	55,176	37,605	(17,571)	-32%
Station 3	I-95 North of Exit 121 (at SR 1309)	62,623	43,986	(18,637)	-30%
Station 4	I-95 North of Exit 102 (at SR 2141)	63,923	32,470	(31,453)	-49%
Station 5	I-95 North of I-40 (at SR 1171)	58,975	34,215	(24,760)	-42%
Station 6	I-95 North of Exit 61 (at SR 1813)	80,539	59,818	(20,721)	-26%
Station 7	I-95 North of Exit 33 (at SR 1726)	87,462	66,911	(20,551)	-23%
Station 8	I-95 North of Exit 2 (at SR 2459)	49,344	34,478	(14,866)	-30%
Station 9	I-40 North of Exit 309 (at SR 2700)	109,673	111,942	2,269	2%
Station 10	U.S. 64 West of NC 96 (at SR 2368)	76,460	83,723	7,263	9%

2.8 IMPLICATIONS ASSOCIATED WITH USING THE EXISTING MODEL

Our review of the travel demand model indicated that while the model may have been adequate for conducting the I-95 Corridor and Financing Study, for the economic assessment that is being conducted as part of the current study, there are additional model factors that must be considered.

For purposes of the economic analysis, it is critical that several aspects of the model behave as expected. Projected traffic growth is certainly one such aspect that is expected to be within reason, between the base and horizon years. The ability of a model to predict travel growth is dependent on how well and to what level of detail it has been validated, as well as on its sensitivity to change.

The large increase in VHT (seen in Section 2.5) between the base year and future years revealed that speeds on several local roadways reduced significantly in the future No Build compared to the base year. It was established that several roadway links in the model were observed to have extremely low speeds (less than 5 mph in some cases), and consequently high volume to capacity ratios. This applied to links in both the diversion network (used as alternative routes for long-distance travel) and in-corridor (in the vicinity of I-95) roadway links. It was also observed that several links, including ramps to I-95, had background preloads, which constituted 100 percent of the volume on some links. This finding implied that the model was not assigning traffic properly to those links. These issues were further exacerbated in the future year scenarios.

The three areas that are likely to produce model results that fall short of expectations for this study are:

1. Volume preloads used;
2. Insufficient validation – by geography and by mode; and
3. Skimming (shortest path determination) prior to assignment based solely on time.

These three topics are discussed in more detail below.

Volume Preloads

Evaluation of the model included looking at the use of preloaded assignment volumes to improve travel volume validation. It was stated that preloads were used in areas where the count difference with assignment was greater than +/- 0.9 on non-I-95 links. That was confirmed in the analysis.

It was observed that for some links, particularly in the western part of the study area, the preloaded volumes appeared to be extremely high. Preload volume values of 150,000 or greater were observed, which is a total traffic volume found only on the most congested roadways in the country. While these high values are acceptable for the previous traffic and revenue study focused solely on I-95,

they are problematic for conducting the current economic assessment study in which the consultant team will need to be able to reasonably determine the traffic impact on I-95, on diversion corridors, and for geographic regions.

The large preload values and corresponding assignment consequently resulted in large volume-over-capacity values, in some cases exceeding 3.0. This further caused a significant increase in link travel times and decrease in corresponding congested speeds, particularly along I-85 and I-77 in Southwestern North Carolina.

Table 2.17 illustrates a sample of links that have significant preload volumes and correspondingly low congested speeds below 1 mph. A total of 79 such links were observed. Note that there were significantly more links with low congested speeds between 1 and 40 mph that were excluded from this table for brevity.

Table 2.17 Sample of Model Links with Significant Preload Volumes

Link ID	Link Travel Time (Minutes)	Congested Speed (MPH)		Preload Volume		Volume/ Capacity Ratio	Daily Capacity	
		AB	BA	AB	BA		AB	BA
18346	34.08	0.74		150,800	0	2.36	63,850	0
20566	33.12	0.74		150,800	0	2.36	63,850	0
20249	212.96	0.18		136,700	0	2.98	45,850	0
20251	188.26	0.18		136,700	0	2.98	45,850	0
20262	319.17	0.18		136,700	0	2.98	45,850	0
20263	59.97	0.18		136,700	0	2.98	45,850	0
20130	18.97	0.71		136,200	0	2.38	57,250	0
20131	19.08	0.71		136,200	0	2.38	57,250	0
20247	243.67	0.23		130,000	0	2.84	45,850	0

The resulting preload volumes and their effects on speeds indicate that the analysis of diversion or lack thereof from I-95 to other parallel corridors will require careful consideration. The low speeds on I-85/I-77 may, for example, discourage more diversion than the model suggests and may warrant special post processing. When included in the calculation of volume/count ratios, the preloads have a tendency of masking assignment error on certain links.

Validation

Focus on I-95

As discussed in Section 2.3, the model validates reasonably well on I-95. However, it was observed that the model did not validate as well on potential alternative routes, such as U.S. 301. Accurate count data and operating conditions on alternative routes are important for determining the economic impact of

alternatives on distinct geographies across the State. The model was found to lack the required fidelity to an even higher extent away from the immediate vicinity of I-95. It is important for the model to produce volumes that are comparable to observed counts on routes that could potentially serve as alternative routes as well, to ensure that the diversion analysis is realistic. The validation criteria, however, can be relaxed the farther away the roadway is from the focus area.

By Total AADT

For the purposes of this study, auto and truck volumes are expected to represent realistic flow conditions. The model validation by vehicle type is currently limited to I-95.

Skimming (Determining Shortest Paths) Based on Time Alone

The CTDM uses skims prior to toll choice and assignment that are based on time alone. For no-toll scenarios and the first feedback iteration of tolled scenarios, free-flow travel time is used. Subsequent feedback iterations utilize congested travel time. The toll choice routine utilizes values of time by trip type to stratify trips into toll willing and nontoll willing trips. Commonly, however, toll analysis makes use of generalized cost approaches where values of time, as well as vehicle operating cost (VOC) are considered in addition to the travel time or distance. This is an important consideration as it limits the ability to model the tradeoff between free but higher-cost routings and toll routings that, except for tolls are lower-cost routings.

In addition, there are other limitations of the model, in the context of an economic assessment study, that are listed below:

- Insufficient validation along the western portion of network – I-85 and I-77, for example, which may stem from a lack of "loading points" near I-85.
- Absence of VOC when determining route choice.
- Inability to account for induced demand or trips that decide not to travel as a result of tolling on I-95.
- Western areas of the model network, such as I-85, do not show any change between 2009 and 2040. This may be a consequence of the absence of diversions in the untolled base year scenario and a lack of "loading points."

2.9 RECOMMENDATIONS/OPTIONAL APPROACHES

To address the areas that warranted refining for purposes of the NC I-95 Economic Assessment, CS recommended the following courses of action, discussed with NCDOT, and it was agreed to:

1. Added further detail to the model network and zone structure;
2. Carried out an updated origin-destination matrix estimation (ODME) to include more count locations on I-95, U.S. 301, and other potential alternate routes. Attempted to reduce the use of preloads to the extent possible;
3. Traffic counts were used from all available data sources, including NCDOT counts, data gathered during the previous stage of this study, and available models, such as the ICAT.
4. Improved validation by mode where data was available; and
5. Used skims that considered the value of time and vehicle operating cost before feeding into route choice and assignment procedures.

3.0 Model Refinement

3.1 BACKGROUND

NCDOT decided it was important to refine the CTDM, as a result of the recommendations that CS made from their evaluation of the model. This section describes the methodology that was adopted to enhance the model and validation and sensitivity analyses resulting from the refinement. Section 4.0 discusses the application of the enhanced model to evaluate the impact of project alternatives.

3.2 METHODOLOGY

Network and Zone Refinement

Master Network Setup

The CTDM network is set up in a master format that includes all possible scenario links for all years. CS retained the master network format for the purposes of the analysis. The master network developed by CS represents a combination of CTDM master network links and Integrated Corridor Analysis Tool (ICAT) network links. ICAT refers to the Integrated Corridor Analysis Tool (ICAT) developed for the I-95 Corridor Coalition to evaluate traffic trends broadly along the Eastern Seaboard of the country. Determination of the specific link set used in the CS network was based whether the link was deemed "In-Corridor" in the CTDM network or not. The exception to this occurred on links in the Raleigh/Durham/High Point Triangle area where CTDM links were retained. CTDM In corridor are those links roughly proximate to I-95 where the diversions are considered local. Figure 3.1 illustrates the CTDM network superimposed on the ICAT network whereas Figure 3.2 shows the full extent of the ICAT network.

Figure 3.1 CTDM Network overlaying ICAT Links

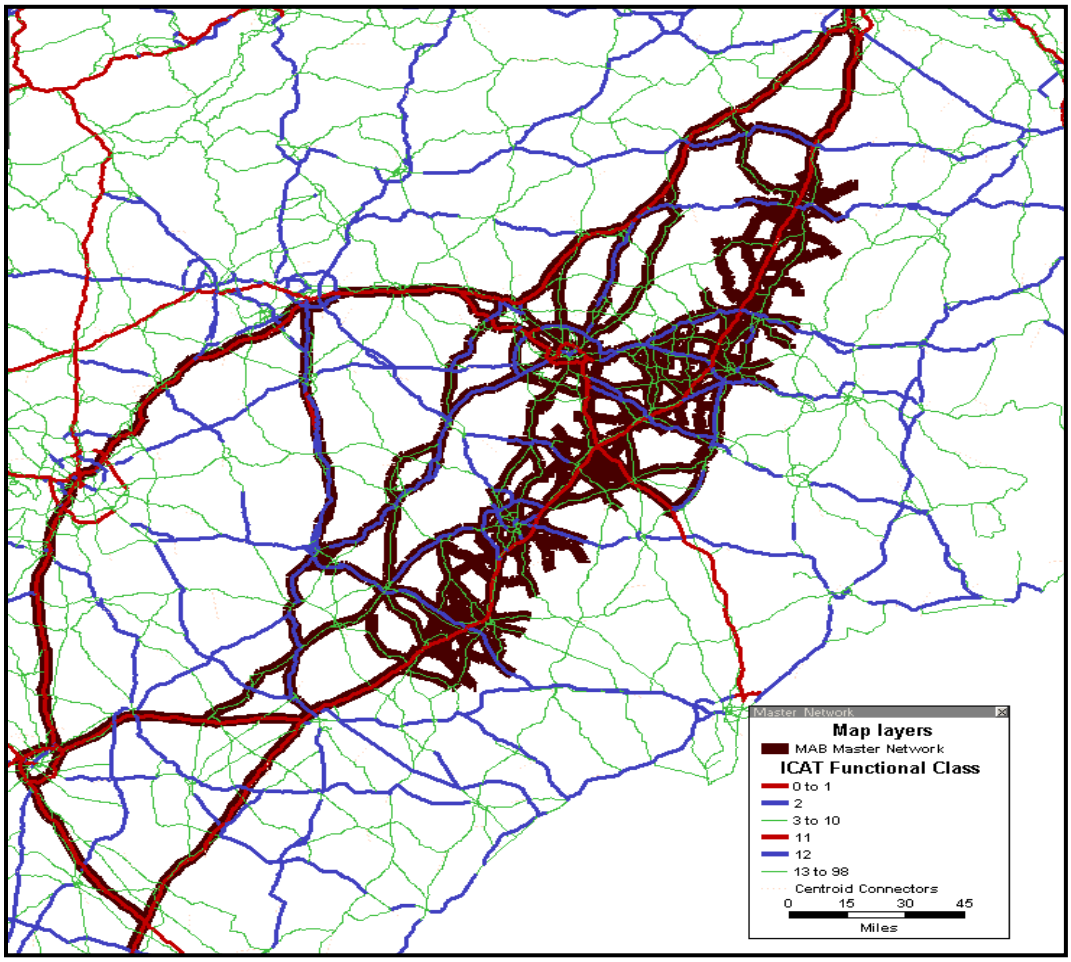
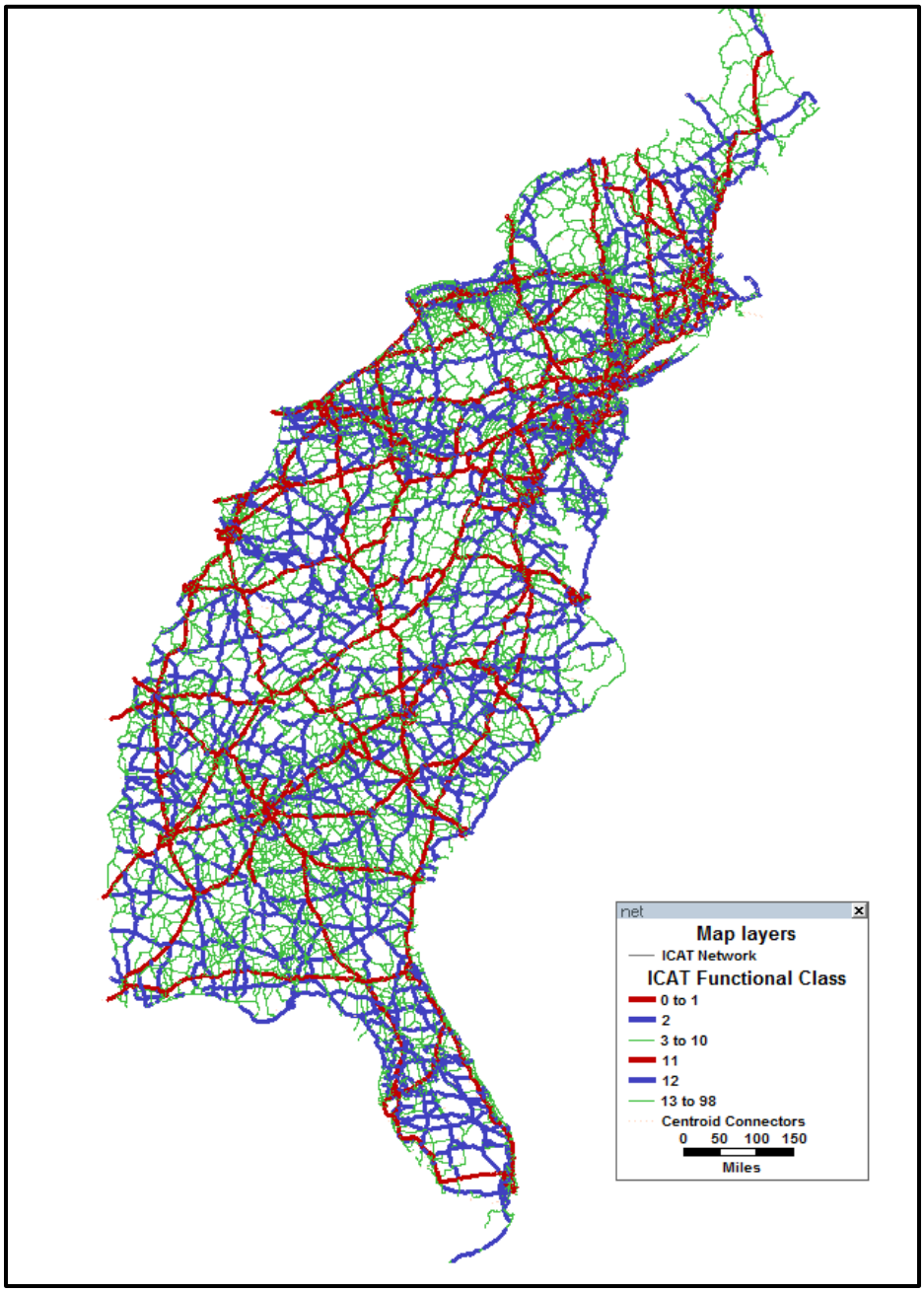


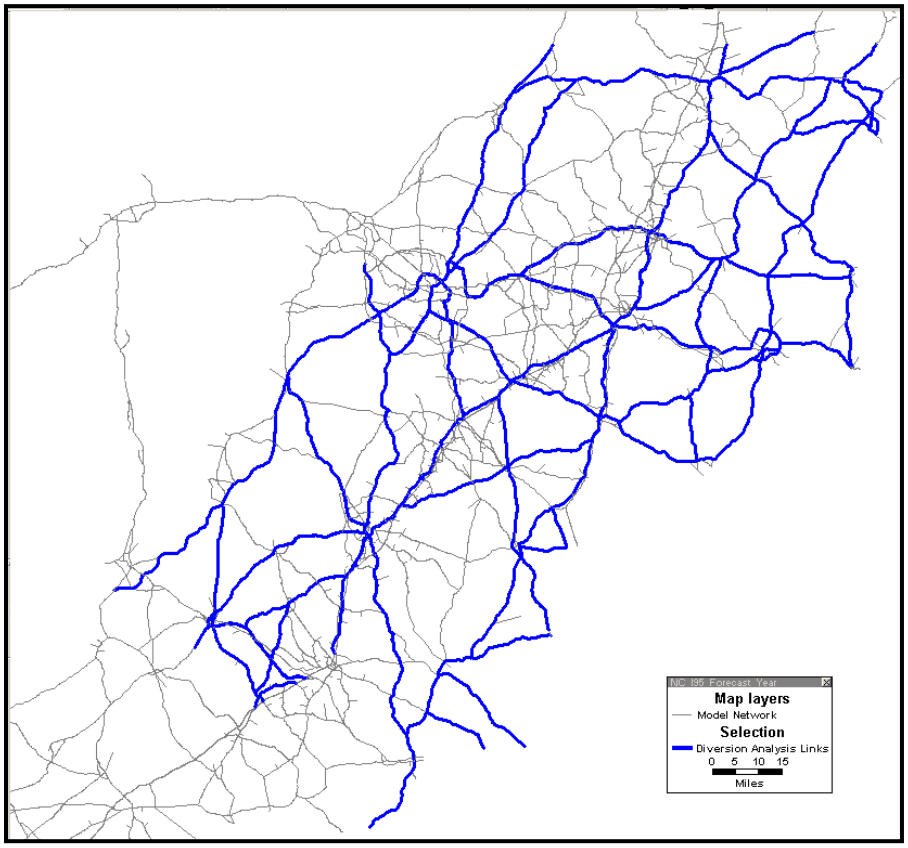
Figure 3.2 Full Extent of ICAT Network from Florida to Maine



Given the large size of the ICAT network, for the purposes of the study it was necessary to extract the portion of the ICAT network that corresponds to the general study area extent roughly represented by the CTDM network. Additionally, it was necessary to include additional links from the ICAT network for the purposes of diversion analysis, mostly to the east of I-95. Figure 3.3 illustrates the roadways, colored blue, that were evaluated for diversions. The initial ICAT

subarea extraction process produced 307 initial centroid zones (traffic entry and exit points). The network was then further refined to be more granular such that the final number of zones amounted to 532.

Figure 3.3 Diversion Analysis Links



Once the ICAT subarea including diversion links was created, the CTDM and extracted ICAT links were combined. This involved performing a join of the two networks using the TransCAD Merge Geography tool. The resulting merged network consisted of all the links in both networks. Note that following the join, additional links were coded that represented diversion links that were not present in either the CTDM or ICAT networks. In many cases, these links represent new roadway alignments that have been either built since the base year of the CTDM, or are planned to be built. Figure 3.4 is a comparison of the final zone placement compared with centroid nodes used in the CTDM network. Figure 3.5 illustrates a section of the merged network where the I-95 intersects with I-40 clearly identifying the links sourced from the and the ICAT networks respectively.

Figure 3.4 CS and CTDM Zone Centroid Comparison

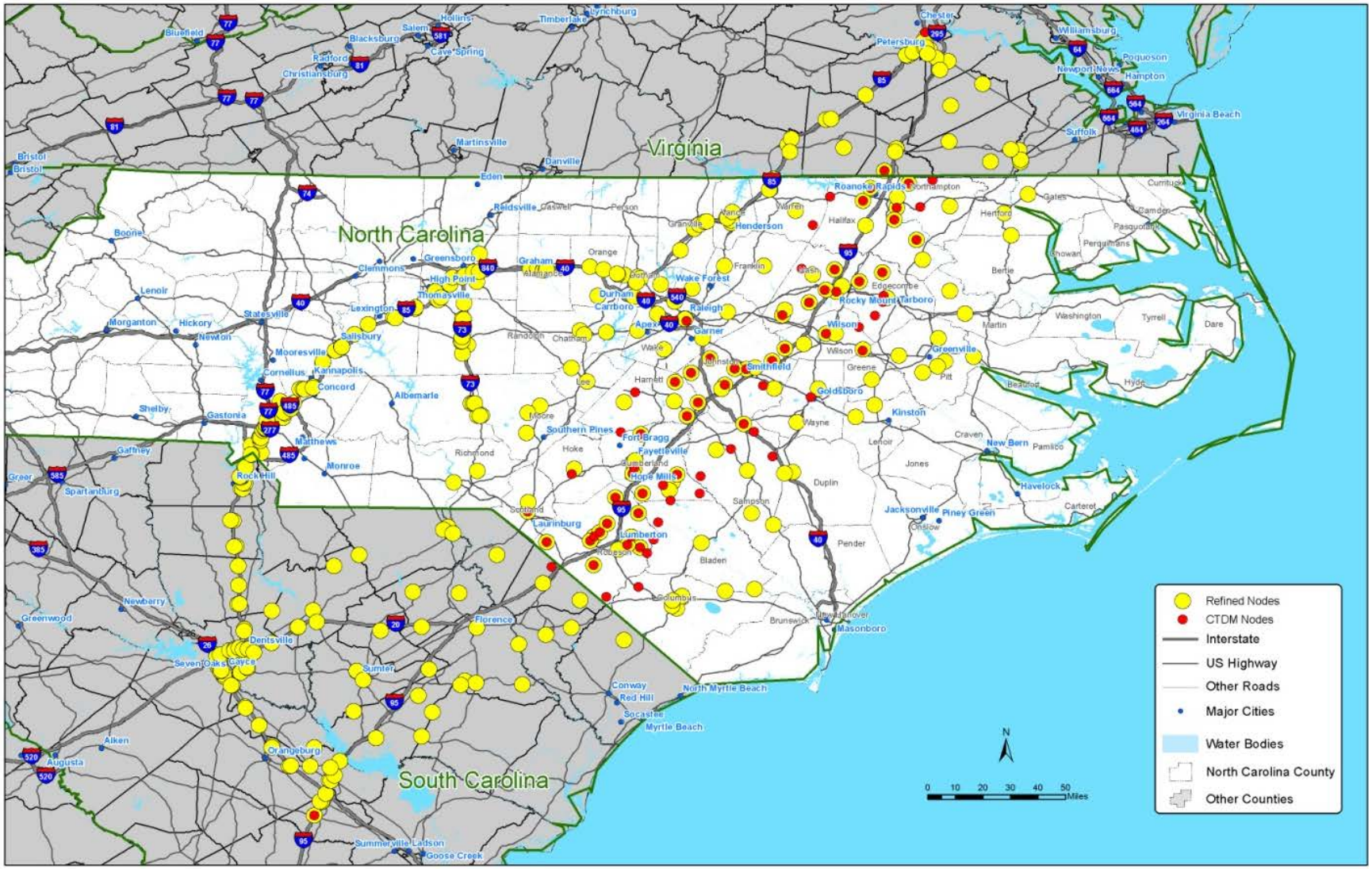
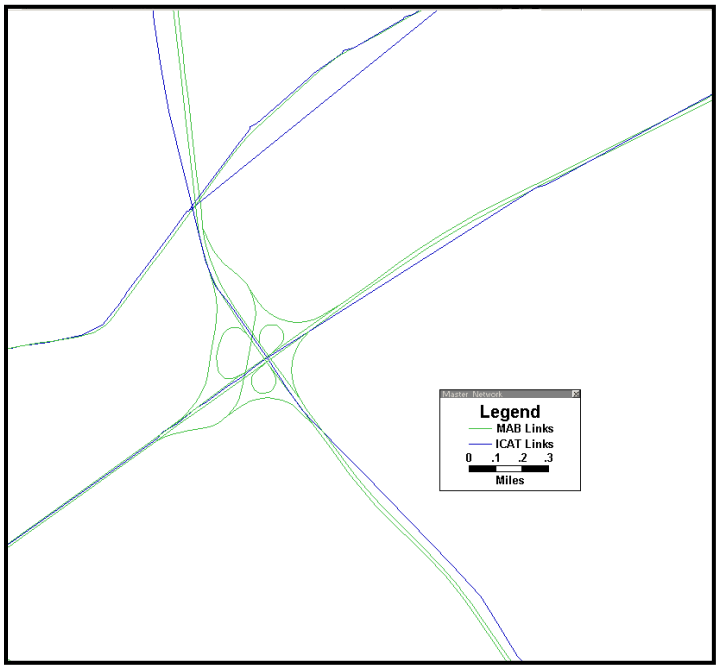


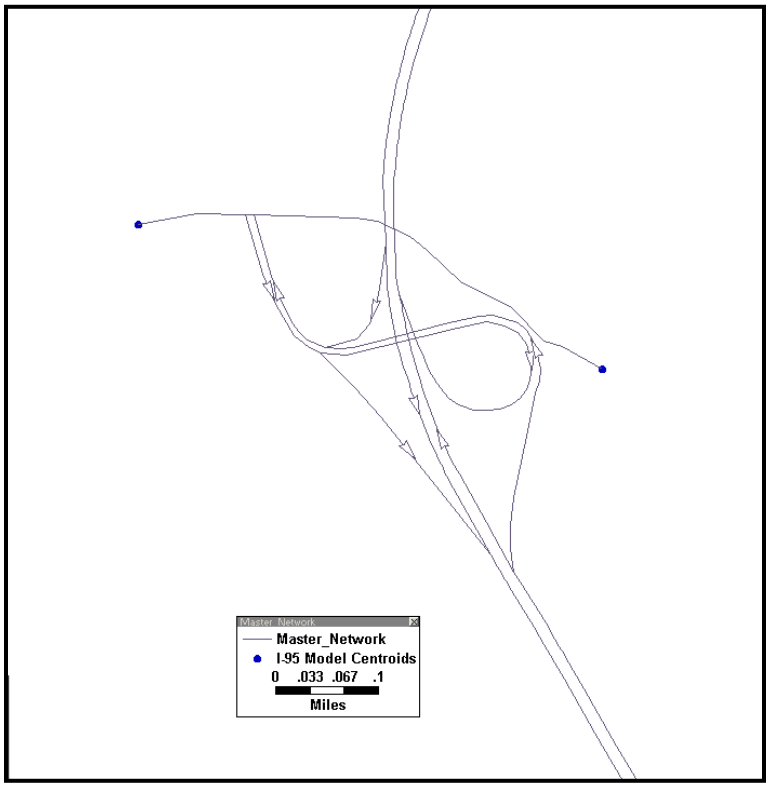
Figure 3.5 Merged Network Link Source Comparison



With the networks joined, it was then necessary to remove duplicate links appropriate to the network segment. CTDM links outside the In-Corridor area and the Triangle region were flagged and similarly, ICAT links inside the CTDM In-Corridor and Triangle area were also flagged. These links were then removed by exporting the network minus the flagged links. It then became necessary to clean up the overlapping areas where CTDM sourced and ICAT sourced links intersect. This involved ensuring that dual line coded links from CTDM converged onto the correct ICAT sourced nodes, ensuring that one-way directionality was properly accounted for and ensuring that there were no missing connecting links. Note that the ICAT network does not contain dual line coding for controlled access facilities and also does not include ramps.

In areas where new centroid nodes were added representing roads connecting to interchanges (for dual line coded facilities), new interchange ramps were required to be coded. This was mainly a concern along I-95, U.S. 264, U.S. 70, I-40, and several of the Triangle region controlled access roadways. Figure 3.6 gives an example.

Figure 3.6 Newly Coded Ramp Along I-95



It was also important to ensure that the CTDM project ID information was properly transferred to all links, including ICAT sourced links that contained no such project attributes. This was accomplished by the use of spatial join techniques and extensive manual editing of the network in areas that contain projects. An attribute in the model called Project ID that identifies the links that are associated with a specific forecast year project. For each Project ID, there are a series of other attributes that identify roadway characteristics. Among these are:

1. Number of lanes;
2. Link direction;
3. Road name;
4. Area type;
5. Functional class;
6. Facility type;
7. Signal density;
8. Divided or undivided;
9. Posted speed; and
10. Project year.

Figure 3.7 illustrates the attributes as depicted in TransCAD used to define the specific projects.

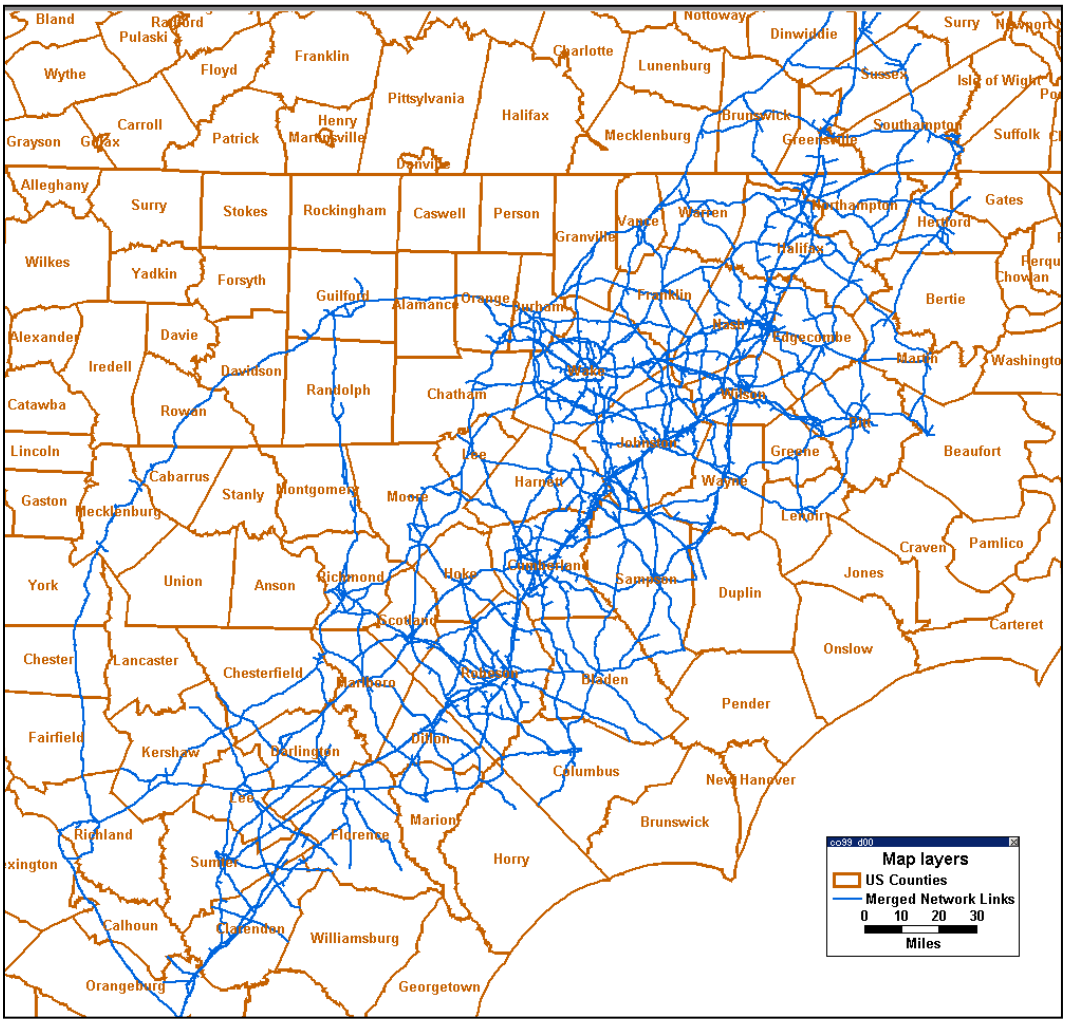
Figure 3.7 Network Project-Specific Attributes

P1_ID	P1_Dir	P1_ROAD_NAME	P1_AREA_TYPE	P1_FAC_TYPE	P1_FUNC_CLASS	P1_AB_Lanes	P1_BA_Lanes	IVIDED_CODE	ted_Speed	P1_BA_Posted_Speed	P1_Signal_per_Mile	P1_
--	--		--			--	--	--	--	--	--	
--	--		--			--	--	--	--	--	--	
1040	0	NC-42	2	3	3	2	2	3	55	55	0	
1040	0	NC-42	2	3	3	2	2	3	55	55	0	
1107	1	I-795	2	1	1	2	0	1	70	0	0	
1107	1	I-795	2	1	1	2	0	1	70	0	0	
1107	1	I-795	2	1	1	2	0	1	70	0	0	
1107	1	I-795	2	1	1	2	0	1	70	0	0	
1107	1	I-795	2	1	1	2	0	1	70	0	0	

County Code

Among the summarization results tabulated, vehicle activity statistics such as VMT and VHT are included. This necessitated ensuring that the coded county ID attributes were consistent irrespective of network source (CTDM or ICAT) To ensure such consistency, the national county database file was used to spatially join the state/county Federal Information Processing Standard (FIPS) code to newly merged network. This process overwrote the existing FIPS value in the merged network where such values existed and ensured that newly coded links had an associated county FIPS code. Figure 3.8 depicts the North Carolina counties taken from the TransCAD software database with the merged network overlaid.

Figure 3.8 U.S. Counties and Merged Master Network



Project Year Network Development

For a specific scenario, an associated project file that contains a list of the projects included is read via a lookup process. If the project is to be included, the corresponding project link attributes described above are copied to a scenario-specific network. The project list file contains the extension ***.lst*** and is a simple ASCII text file. It is found in the Master network folder path.

During development of the scenario-specific network, the capacities were calculated for specific combinations of capacity type, area types, lanes, signal density, and the other attributes listed above via a capacity lookup table process. The capacity table, like the scenario list file described earlier is located in the Master network folder and called ***capacity_table.bin***. Figure 3.9 illustrates some of the Capacity table attributes, including FUNC_CLASS, AB_LANES, BA_LANES etc.

Figure 3.9 Capacity Table Lookup File

Dir	AREA_TYPE	FUNC_CLASS	AB_LANES	BA_LANES	DIVIDED_CODE	AB_POSTED_	BA_POSTED_	Speed	SIGNAL_PER	ROAD_NAME	CAPACITY	FACIL_TYPE
1	1	1	0	2	1	0	65	65	0	I-95	36350	I-95
1	1	1	0	2	1	0	70	70	0	I-95	37050	I-95
1	2	1	0	2	1	0	65	65	0	I-95	38850	I-95
1	1	1	2	0	1	65	0	65	0	I-95	36350	I-95
1	1	1	2	0	1	70	0	70	0	I-95	37050	I-95
1	2	1	2	0	1	65	0	65	0	I-95	38850	I-95
1	2	1	2	0	1	70	0	70	0	I-95	39700	I-95
1	1	1	3	0	1	65	0	65	0	I-95	54450	I-95
1	1	1	4	0	1	70	0	70	0	I-95	74250	I-95
1	1	1	4	0	1	65	0	65	0	I-95	73650	I-95

Free-flow speeds are calculated using the posted speeds on the links. Adjustments are made based on a combination of roadway type (full or controlled access), urban or rural split, and density. Depending on the specific combination, adjustments may be either up, down or no change to the posted speeds.

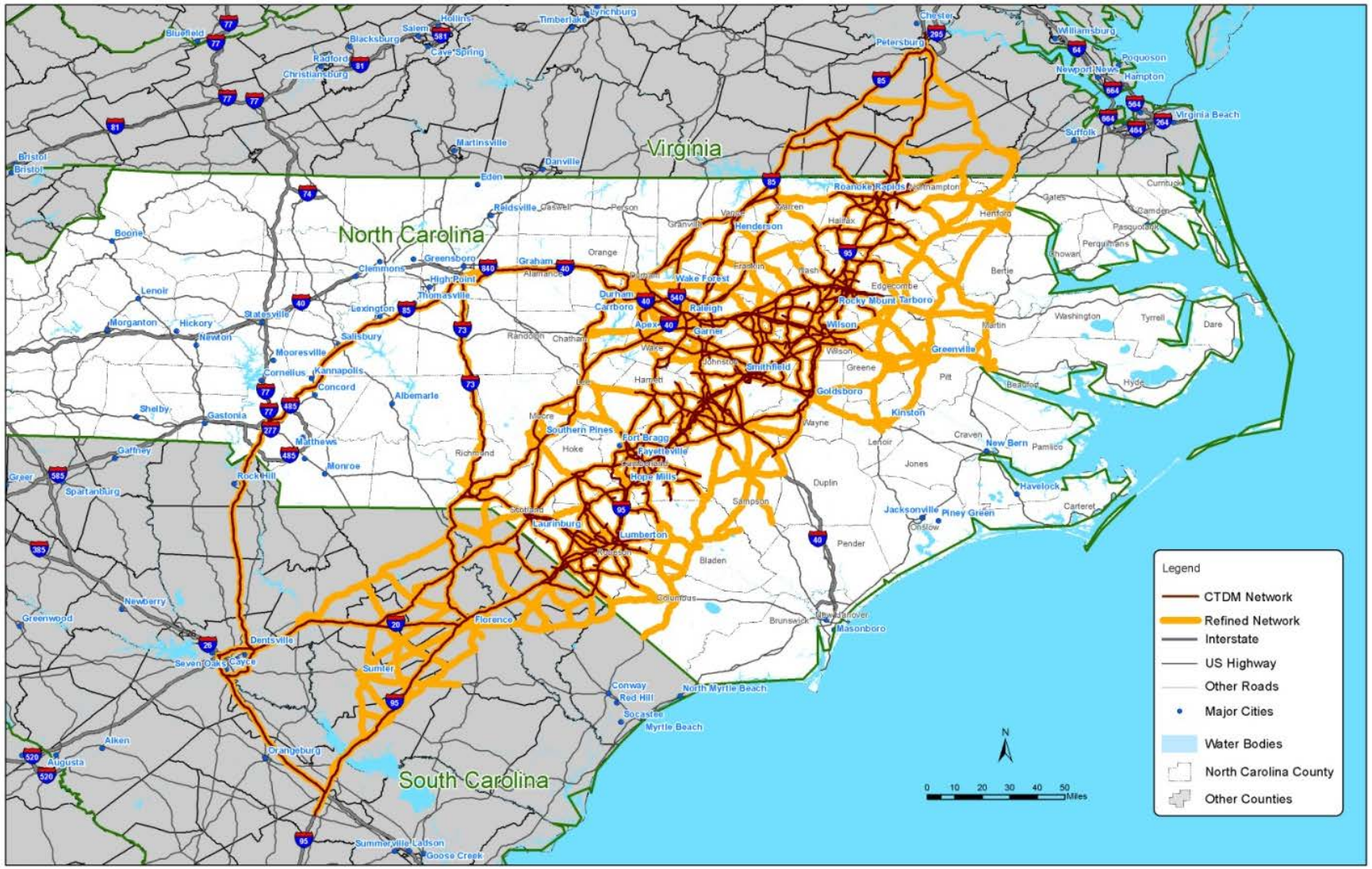
Final Adjustments

Prior to assignment of the scenario-specific networks, a final capacity adjustment was made where standard lane capacities per road type were used to calculate the overall link capacities. For example, Interstates, the capacity value used was 2,000 vehicles per hour per lane which when multiplied by total number of lanes and a daily factor (K-factor) of 10 gives the final daily capacity. Arterial roads used a starting capacity of 1,200 vehicles per lane.

Auto and truck toll fields were also populated and used to calculate the final vehicle operating cost as part of the generalized cost implementation in the MMA (Multimodal, Multiclass assignment). The auto toll fields are called AB_AUTO_TOLL and BA_AUTO_TOLL. The truck toll fields are called AB_TRK_TOLL and BA_TRK_TOLL. Similarly, auto and truck VOC (vehicle operating cost) fields were used as the actual toll impedance in the MMA routine. Note that a scenario was run that utilized a stratified toll rate, with the full-cost toll applied to through I-95 trips and a half-cost toll applied to more local trips. For this scenario, a separate network was developed off the regular toll network but with additional VOC and toll attributes to demarcate the separate toll and assignment classes. For both tolled cases, the average spacing between gantries was set at 10 miles. An initial run was also performed with tolls set at 20-mile spacing (explained further in Section 4.0).

Figure 3.10 gives an overview of the final refined network in comparison with the original network obtained from CTDM.

Figure 3.10 Refined Network Compared to Initial Network



Data Identification and Geocoding

The primary source of traffic count data was average annual daily traffic volumes (AADTs) provided by NCDOT. The NCDOT Traffic Survey Group provided the data in electronic format as an ArcMap shapefile.

AADT represents the total traffic volume in both directions on a roadway on an average day under typical traffic conditions. NCDOT collects 48-hour traffic count data using their more than 40,000 Portable Traffic Count (PTC) Stations for Interstates, U.S. roads, North Carolina roads, and state roads. The traffic count data is then adjusted using seasonal factors to produce AADT estimates. NCDOT's AADT data are produced in several different forms, including maps, tables, and ArcGIS shapefiles. The most recent AADT data available is from 2011.

I-95 OD Patterns (ALPR Survey)

The ALPR survey results were used to adjust the generated ODME trip patterns. Given that the ALPR survey represented actual flows, it provided a basis for calibrating the ODME. To perform the adjustment, it was necessary to first develop a select link trip table representing flows between each of the ALPR locations (a select link trip table represents an origin-destination trip table contribution trips to the selected link alone). This was undertaken by creating a select link query file that specifically obtained the unique flows between each pair of ALPR locations. Note that the ALPR locations do not correspond to the zone centroid loading points, hence, a straightforward select link output table does not represent ALPR to ALPR flows.

The adjustment was performed by reading in the survey trip table data and determining the auto and truck flows between each pair. The model select link survey results by auto and truck are compared for those specific pairs to the survey trips, using matrix manipulation techniques. The model matrix numbers were adjusted to match the surveyed trips for the specific ALPR pair. This procedure was performed automatically following ODME preparation script.

Origin-Destination Matrix Estimation (ODME)

Base Year Trip Table Development

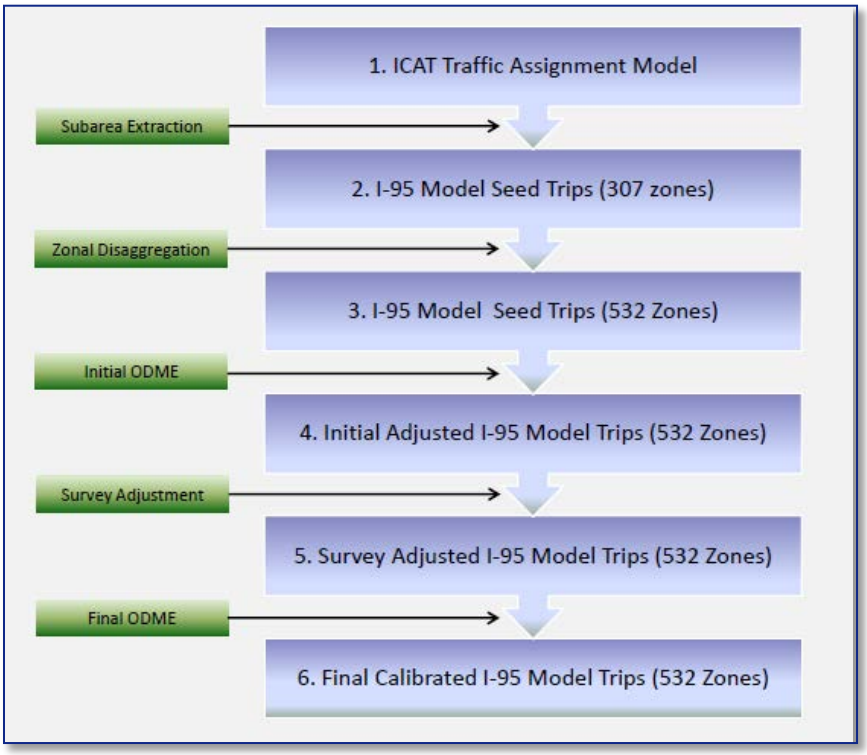
Currently there is no validated travel demand model that encompasses the I-95 study area. There is, however, the Integrated Corridor Analysis Tool (ICAT) that encompasses all of the I-95 study area. ICAT was developed for the I-95 Corridor Coalition and provided estimates of regional travel demand in the study corridor. These estimates, combined with observed traffic data, (traffic counts) and more detailed highway network information from the CTDM, form the basis for a forecasting model capable of estimating future travel demand in the study corridor that is sensitive to changes in the transportation infrastructure, to changes in land use forecasts, and to changes associated with roadway pricing.

Base Year Model

Figure 3.11 provides an overview of the process used to develop the base year trip tables for the forecasting tool for the analysis of travel characteristics within the I-95 corridor in North Carolina. The following briefly describes each of the steps:

1. ICAT Assignment Model – Underlying base and future trip patterns are based on the vehicle assignments from the ICAT model.
2. Subarea extraction is performed consistent with the I-95 forecasting tool to produce base and future year auto and truck trip tables.
3. ICAT-based subarea trip tables (307 zones) are disaggregated to a more granular zone system (532 zones). These disaggregated trip tables serve as the seed matrices for the matrix calibration process that follows.
4. Origin Destination Matrix Estimation (ODME) is performed to calibrate the base year auto and truck trip tables to the observed counts throughout the model area.
5. Base year trip tables are further adjusted to include information from the ALPR OD Survey.
6. A second ODME is performed to refine the survey adjusted trip tables to better match the observed counts.

Figure 3.11 Base Year Trip Table Development Process



Base Year Trip Table Calibration

The ODME procedure within TransCAD was used to calibrate the demands within the I-95 Corridor. It is an iterative process that fluctuates between the traffic assignment and matrix estimation stages and the main objective is to refine the initial OD vehicle matrices from the seed trip tables to better match the observed data. The procedure is based on the Maximum Likelihood technique, which attempts to estimate a trip table that maximizes the probability of all input datasets.

The input datasets include an initial estimate of the OD matrices, (seed matrices) as described above and traffic count data. The procedure is Multimodal and Multiclass (MMA) and the MMA OD Matrix Estimator is based on TransCAD's MMA assignment procedure. The MMA assignment routine is a generalized cost assignment that assigns trips by individual mode or user class to the network simultaneously. Each mode or class can have different congestion impacts, different volume delay function parameters, different values of time, and different sets of excluded facilities and types of tolls. The advantage of using the MMA Assignment for OD Matrix Estimation is that rather than producing just one overall trip OD matrix, the MMA ODME can generate estimated trip matrices for each mode or class.

The determination as to what vehicle trip tables to estimate using ODME was based on the study objectives and the availability of the count data. A successful implementation of the multimodal approach requires multimodal count data. A review of the count data revealed that the classification scheme that yielded the most data points was to break the counts into two groups: truck and nontruck or auto. The nontruck group included all vehicle types not classified as a truck in the counts.

Cost Parameters

Vehicle operating costs (VOC) were assumed to be:

- Autos = $0.23 per mile; and
- Trucks = $0.76 per mile.

Value of time (VOT) parameters were assumed to be:

- Autos = $16.08 per hour; and
- Trucks = $24.72 per hour.

OD Validation Results

For this study, common measures of travel demand assignment validation as recognized by FHWA were used to compare the assigned volumes to observed traffic counts. These include the percent deviation between the counts and assigned volumes and the percent Root Mean Square Error (RMSE) of these deviations.

Table 3.1 compares estimated traffic flows to observed counts for the entire study area stratified by functional class. This comparison indicates how well the model is replicating traffic flows on the different types of roadways. Overall the estimated flows are within 1 percent of the observed counts with a percent RMSE less than 15 percent. For the I-95 roadway, the model matches volumes to a much greater degree of accuracy. The percent RMSE is under 6 percent for I-95 links.

In comparison, the CTDM calibrated within 9 percent of the observed counts with a percent RMSE of 38.1, network-wide.[2] For the I-95 roadway, the percent RMSE was 15.1 percent and percent deviation from counts 5.6 percent.

Table 3.1 Assigned Volumes Stratified by Vehicle Type and Geographic Area

	Average Count	Average Flow	Number	Percent Dev	Percent RMSE
Autos					
Other	8,815	8,909	31	1.1%	5.9%
I-95	14,288	14,193	121	-0.7%	6.0%
U.S. 301	2,656	2,754	102	3.7%	31.8%
Other Freeways	16,510	16,481	185	-0.2%	15.8%
Major Roads – In Corridor	2,170	2,185	484	0.7%	30.3%
Major Roads – Out of Corridor	2,143	2,192	454	2.3%	42.5%
Auto Total	5,338	5,357	1,377	0.3%	22.7%
Trucks					
Other	796	770	31	-3.2%	9.9%
I-95	2,842	2,834	121	-0.3%	11.1%
U.S. 301	184	189	102	2.7%	26.7%
Other Freeways	1,333	1,331	185	-0.1%	17.2%
Major Roads – In Corridor	140	142	484	0.9%	31.4%
Major Roads – Out of Corridor	181	191	454	5.7%	43.9%
Truck Total	569	572	1,377	0.5%	24.1%
All Vehicles					
Other	9,611	9,679	31	0.7%	5.8%
I-95	17,131	17,027	121	-0.6%	5.6%
U.S. 301	2,841	2,943	102	3.6%	31.0%
Other Freeways	17,843	17,812	185	-0.2%	15.2%
Major Roads – In Corridor	2,310	2,327	484	0.7%	29.4%
Major Roads – Out of Corridor	2,323	2,383	454	2.6%	41.8%
Grand Total	5,907	5,929	1,377	0.4%	21.5%

[2] Memo 2: *Overview of I-95 CTDM and Calibration/Validation*, November 2, 2012.

In addition to the summary statistics presented in Table 3.1, the modeled volumes were compared against counts along I-95 and U.S. 301, in Tables 3.2 and 3.3. I-95 volumes were compared at the eight ALPR locations along I-95. As indicated in Table 3.2, the maximum deviation from counts was 12 percent, with the majority of volumes within 7 percent of the counts. Of the eight U.S. 301 locations where modeled volumes were compared with counts, six were within 10 percent of the counts and two were within 30 percent.

In comparison, The CTDM model validation had six of the eight I-95 locations validating within 15 percent, with two locations within 25 percent (Table 2.4). A similar comparison of modeled volumes on U.S. 301 using the CTDM revealed that while four locations validated within 20 percent, there were others that were off by 77 to 126 percent (Table 2.5).

Table 3.2 Daily Two-Way I-95 Traffic Volumes

Locations	Daily Two-Way Count	Modeled Volume	Percentage Difference
Station 1	41,252	40,259	-2%
Station 2	42,096	39,156	-7%
Station 3	44,706	39,764	-11%
Station 4	32,932	37,019	12%
Station 5	43,434	44,098	2%
Station 6	45,668	48,109	5%
Station 7	45,352	46,147	2%
Station 8	31,950	28,645	-10%

Table 3.3 Daily Two-Way U.S. 301 Traffic Volumes

	Daily Two-Way Count	Modeled Volume	Percentage Difference
North of NC 186 (Northampton)	628	651	4%
North of NC 33 (Nash)	2,370	1,731	-27%
South of NC 97 (Nash)	1,392	981	-29%
North of NC 39 (Johnston)	1,740	1,722	-1%
South of U.S. 701 (Johnston)	2,080	1,863	-10%
South of I-295 (Cumberland)	1,662	1,519	-9%
North of NC 71 (Cumberland)	3,508	3,349	-5%
North of U.S. 501 (Robeson)	1,384	1,352	-2%

3.3 FUTURE YEAR FORECASTS

This section describes the approach that was used to estimate future year traffic volumes within the refined I-95 Corridor Model and lists the set of assumptions made with regard to inputs for these forecasts.

Growth Assumptions

Future year growth for each vehicle type, autos, and trucks was estimated within the ICAT regional model based on forecasted land use. To capture this growth, the ICAT model was applied to produce future year traffic forecasts and the trips within the corridor were extracted from this assignment and disaggregated to the 532 zone system that underlies the I-95 Corridor Model consistent with the base year subarea extraction. Growth factors were then calculated for each of the 532 zones based on the difference between the raw base and future year subarea trip tables. These growth factors were applied to the calibrated base year trip table to produce the future year trips.

The projected growth in traffic on I-95, between the base year 2011 and the two horizon years, 2020 and 2040 are illustrated in Table 3.4. The growth by 2020 ranges between 10 and 16 years, and by 2040 ranges between 34 and 50 percent.

Table 3.4 I-95 Traffic Growth

Location	Base Year Volume (2011)	2020 No Build Volume	2040 No Build Volume	2020 Growth (versus Base Year)	2040 Growth (versus Base Year)
Station 1	40,259	45,007	59,879	12%	49%
Station 2	39,156	43,919	58,820	12%	50%
Station 3	39,764	44,695	55,697	12%	40%
Station 4	37,019	42,998	52,883	16%	43%
Station 5	44,098	49,162	61,285	11%	39%
Station 6	48,109	55,408	67,227	15%	40%
Station 7	46,147	51,093	62,017	11%	34%
Station 8	28,645	31,597	38,418	10%	34%

Although validation typically implies replicating base year results, the effort also included ensuring that traffic growth and diversion rates would be within acceptable limits. As discussed in Section 4.0, the model was applied to several future year scenarios, including alternatives with tolls.

4.0 Analysis and Findings

After completing validation and ensuring that the results were within industry-accepted standards, the model was applied to several project alternatives listed below.

The alternatives modeled were:

- 2011 Base year.
- 2020 and 2040 scenarios:
  - No Build (Business as Usual) (includes committed projects);
  - No Toll Build (includes committed projects and applicable I-95 projects as described in Section 2.7);
  - Tolls with 10-Mile Gantry Spacing; and
  - Tolls with Mitigation – 10-Mile Gantry Spacing and 50 percent toll discount for "internal" or nonthrough traffic.

Table 4.1 lists the toll amounts used for each scenario at each gantry.

Table 4.1 Toll Rates Used

Toll	10-Mile Spacing (No Mitigation)		10-Mile Spacing with Mitigation (Through Trip Tolls)		10-Mile Spacing with Mitigation (Local Trip Tolls)	
Gantry	Auto Toll $	Truck Toll $	Auto Toll $	Truck Toll $	Auto Toll $	Truck Toll $
1	1.02	2.86	1.02	2.86	0.51	1.43
2	1.02	2.86	1.02	2.86	0.51	1.43
3	1.02	2.86	1.02	2.86	0.51	1.43
4	1.02	2.86	1.02	2.86	0.51	1.43
5	1.02	2.86	1.02	2.86	0.51	1.43
6	1.02	2.86	1.02	2.86	0.51	1.43
7	1.02	2.86	1.02	2.86	0.51	1.43
8	1.02	2.86	1.02	2.86	0.51	1.43
9	1.02	2.86	1.02	2.86	0.51	1.43
10	1.02	2.86	1.02	2.86	0.51	1.43
11	1.87	5.24	1.87	5.24	0.94	2.62
12	1.87	5.24	1.87	5.24	0.94	2.62
13	1.87	5.24	1.87	5.24	0.94	2.62
14	1.87	5.24	1.87	5.24	0.94	2.62
15	1.87	5.24	1.87	5.24	0.94	2.62
16	1.87	5.24	1.87	5.24	0.94	2.62
17	1.87	5.24	1.87	5.24	0.94	2.62
18	1.02	2.86	1.02	2.86	0.51	1.43

4.1 ANALYSIS RESULTS

This section presents the results comparing the aforementioned alternatives. A comparison of VMT and VHT across alternatives, compared against the base year (2011), is presented in Table 4.1. The table presents results aggregated for all I-95 sections as well as a primary study area which is approximately 10 miles on either side of I-95. As expected, both miles and hours traveled in the No Build and No Toll Build alternatives increase relative to the base year. Also consistent with expectations, the impact of tolled scenarios is higher on I-95 than it is on the primary study area, given that traffic is diverted away from I-95 when tolled, predominantly to roadways in the immediate vicinity of I-95. The scenario with toll mitigation is also impacted less by tolls, compared with the regular toll scenario, given the lower tolls that "local" users would pay. It is likely that toll impacts could reduce further into the future, given users' familiarity with tolls along the facility, and the likely positive impact that widening the remainder of I-95 could have.

Tables 4.2 and 4.3 show projected volumes along I-95 for the 2020 and 2040 alternatives, respectively. The locations represent the ALPR survey station locations that have been described earlier in the report. Growth in traffic along I-95 between the base year (2011) and 2020 (10 to 16 percent), and the base year and 2040 (34-50 percent), which translates to a growth rate of between 1 and 1.6 percent per year, which appears reasonable.

When compared against their respective No Builds, widening I-95 without tolls in 2040 is projected to attract a higher percentage of vehicles than in 2020. This is likely attributable to larger growth in traffic volumes and additional I-95 improvements in 2040 (reflected by the higher 2040 No Toll Build percentages).

On the other hand, the impact of tolls on I-95 diversions, is projected to be marginally lower in 2040 when compared to 2020 (reflected by lower diversion percentages in 2040). This trend is likely the effect of a proposed increase in I-95 capacity in 2040, more congestion on diversion routes due to traffic growth, and users' familiarity with tolls, a phenomenon that is not captured by the model .

Tolls on I-95 cause diversions to roadways in the vicinity of I-95 and others, depending on the magnitude of the toll incurred, accessibility and availability of diversion routes. Toll gantries were assumed to be present on the mainline but not the ramps, consistent with the proposed Environmental Assessment design. This toll structure would enable vehicles, both autos and trucks, to skirt the toll plazas on I-95, only to get back onto I-95, as depicted by the green blobs (local diversions)in Figures 4.1 and 4.2.

The two figures illustrate projected toll diversion rates throughout the corridor, for different scenarios. Figure 4.1 represents diversion percentages based on toll rates suggested in the Environmental Assessment phase of the study, also referred to as the original tolled scenario, and Figure 4.2 represents a "mitigation" alternative, assuming that "local" or non-through trips would pay 50 percent of the original tolls, while through users of I-95 would pay the full toll.

In 2040, projected diversions varied between 14 and 49 percent throughout the corridor under the original tolled scenario (Figure 4.1). The magnitude of diversions under the mitigation alternative was significantly less, 4 to 32 percent. This drop in percentage of projected diversions is attributable to the decrease in tolls for local trips, which make up the majority of trips on I-95. It is worth noting that tolls increased significantly south of the intersection of I-95 and I-40, causing larger diversions on that stretch as compared to the northern segment of I-95, north of the intersection with I-40.

Travel Time Comparisons

A comparison was done of travel times between select ALPR stations roughly located at the north, middle, and southern ends of the corridor. Generally, it is observed that increased capacity, represented by the No Toll scenarios reduce travel time compared to No Build conditions. Tolling further reduces the travel times between links most likely owing to reduced congestion owing to diverted traffic. It is apparent that the effect of capacity is much more significant in 2040 than is the case for 2020 for most movements. Another observation is that the mitigation scenario described as 2040 Separate Toll (Separate, lower toll for internal trips) has an effect somewhere between that of the No Toll scenarios and the Full Toll rate scenario. It is believed that these results are consistent with expected traffic behavior and should be sufficient for further post analysis work.

Table 4.2 Comparison of VMT and VHT across Alternatives

			VMT	VMT Growth over 2011	VHT	VHT Growth over 2011
I-95	2011	Base Run	12,719,313		178,878	
	2020	No Build	14,105,844	10.9%	201,679	12.7%
		Build – No Toll	14,146,904	11.2%	199,169	11.3%
		Build – with Toll	10,875,696	-14.5%	151,558	-15.3%
		Build – Toll with Mitigation	12,738,379	0.1%	178,537	-0.2%
	2040	No Build	17,494,231	37.5%	269,840	50.9%
		Build – No Toll	17,846,811	40.3%	255,270	42.7%
		Build – with Toll	13,843,438	8.8%	195,786	9.5%
		Build – Toll with Mitigation	15,871,366	24.8%	225,947	26.3%
Primary (10-Mile Envelope around I-95)	2011	Base Run	22,579,509		373,854	
	2020	No Build	24,924,202	10.4%	415,746	11.2%
		Build – No Toll	24,951,867	10.5%	412,986	10.5%
		Build – with Toll	23,421,445	3.7%	413,385	10.6%
		Build – Toll with Mitigation	24,428,157	8.2%	414,914	11.0%
	2040	No Build	30,514,633	35.1%	537,119	43.7%
		Build – No Toll	30,740,158	36.1%	519,533	39.0%
		Build – with Toll	28,638,496	26.8%	517,694	38.5%
		Build – Toll with Mitigation	29,881,576	32.3%	521,066	39.4%

Table 4.3 Comparison of 2020 Volumes across Alternatives

Location	Year 2020 No Build volume	Year 2020 No Build Growth (versus Base Year)	Year 2020 No Toll Build Volume	Year 2020 No Toll Build Impact (versus No Build)	Year 2020 Toll Volume	Year 2020 Toll Impact (versus No Toll Build)	Year 2020 Toll with Mitigation Volume	Year 2020 Toll with Mitigation Impact (versus No Toll Build)
Station 1	45,007	12%	44,995	0.0%	38,418	-15%	43,302	-4%
Station 2	43,919	12%	43,908	0.0%	31,211	-29%	40,123	-9%
Station 3	44,695	12%	44,725	0.1%	32,459	-27%	40,806	-9%
Station 4	42,998	16%	43,127	0.3%	20,045	-54%	27,534	-36%
Station 5	49,162	11%	49,360	0.4%	38,654	-22%	45,692	-7%
Station 6	55,408	15%	56,237	1.5%	44,937	-20%	50,831	-10%
Station 7	51,093	11%	51,211	0.2%	23,513	-54%	34,970	-32%
Station 8	31,597	10%	31,638	0.1%	17,556	-45%	27,885	-12%

Table 4.4 Comparison of 2040 Volumes across Alternatives

Location	Year 2040 No Build Volume	Year 2040 No Build Growth (versus Base Year)	Year 2040 No Toll Build Volume	Year 2040 No Toll Build Impact (versus No Build)	Year 2040 Toll Volume	Year 2040 Toll Impact (versus No Toll Build)	Year 2040 Toll with Mitigation Volume	Year 2040 Toll with Mitigation Impact (versus No Toll Build)
Station 1	59,879	49%	60,480	1%	52,110	-14%	57,242	-4%
Station 2	58,820	50%	59,392	1%	47,711	-20%	55,115	-6%
Station 3	55,697	40%	57,827	4%	42,791	-26%	50,757	-9%
Station 4	52,883	43%	54,719	3%	27,766	-49%	36,166	-32%
Station 5	61,285	39%	64,712	6%	42,867	-34%	56,264	-8%
Station 6	67,227	40%	71,157	6%	55,109	-23%	63,764	-5%
Station 7	62,017	34%	63,137	2%	33,085	-48%	42,771	-31%
Station 8	38,418	34%	38,651	1%	20,949	-46%	28,988	-25%

Figure 4.1 Comparison of 2040 Toll versus No Toll Build Scenario Volumes

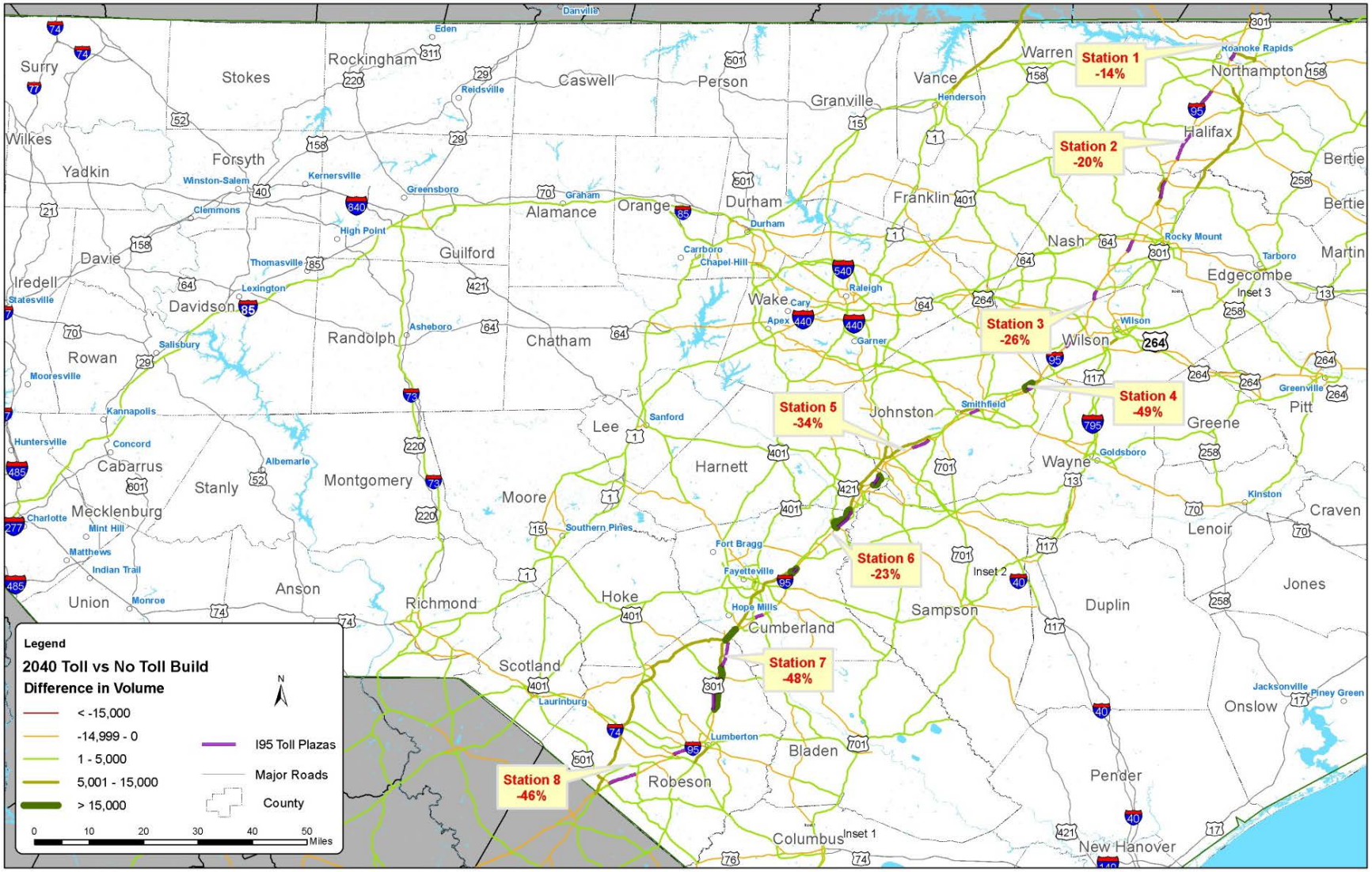


Figure 4.2 Comparison of 2040 Toll with Mitigation versus No Toll Build Scenario Volumes

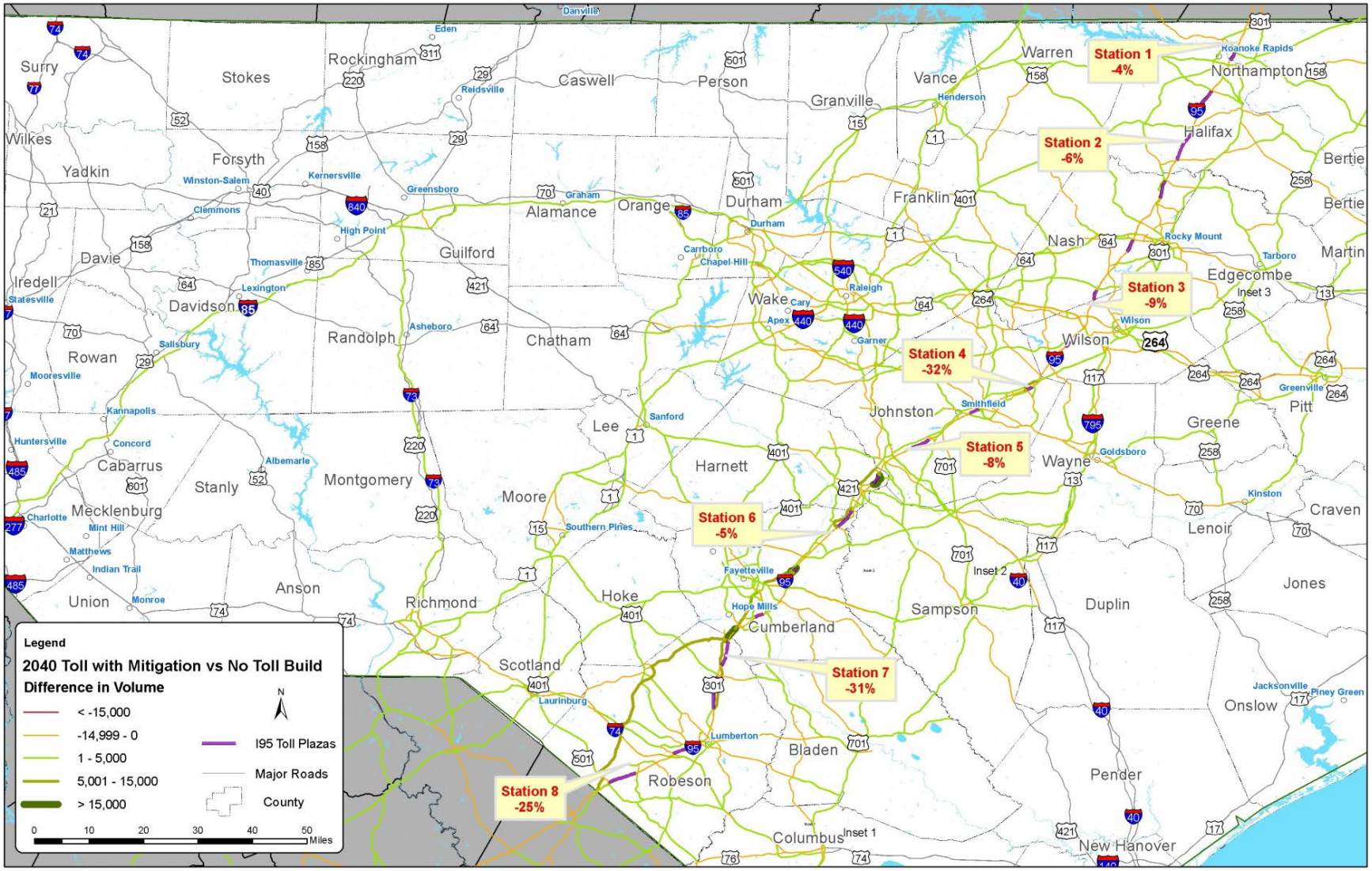


Table 4.5 Comparison of Southbound Travel Times from Select ALPR Stations across Scenarios

Travel South	From Node	To Node	Base Year	2020 No Build	2020 No Toll	2020 Toll	2040 No Build	2040 No Toll	2040 Toll	2040 Separate Toll
Station 1 to Station 3	1605	1564	44.66	45.41	44.32	44.32	50.04	44.74	44.20	44.46
Station 1 to Station 6	1605	1476	118.57	120.80	117.77	117.77	125.94	118.12	117.43	117.56
Station 1 to Station 8	1605	1575	168.74	172.75	166.73	166.73	181.51	167.44	166.41	166.58
Station 3 to Station 6	1564	1476	60.12	61.86	59.56	59.56	66.77	59.57	59.27	59.18
Station 3 to Station 8	1564	1575	110.29	113.80	108.52	108.52	122.34	108.88	108.24	108.20
Station 6 to Station 8	1476	1575	62.67	64.59	61.88	61.88	69.06	61.68	61.88	61.41

Table 4.6 Comparison of Northbound Travel Times from Select ALPR Stations across Scenarios

Travel North	From Node	To Node	Base Year	2020 No Build	2020 No Toll	2020 Toll	2040 No Build	2040 No Toll	2040 Toll	2040 Separate Toll
Station 3 to Station 1	1605	1564	62.80	63.41	62.49	62.49	68.33	61.84	62.18	61.76
Station 6 to Station 1	1605	1476	110.86	111.91	109.48	109.48	121.59	109.36	109.01	108.91
Station 8 to Station 1	1605	1575	169.28	170.63	167.52	167.52	183.60	167.79	167.10	167.15
Station 6 to Station 3	1564	1476	60.14	60.83	59.91	59.91	66.07	59.47	59.43	59.27
Station 8 to Station 3	1564	1575	118.56	119.54	117.95	117.95	128.08	117.90	117.52	117.51
Station 8 to Station 6	1476	1575	44.71	45.14	44.15	44.15	49.35	44.67	44.17	44.38

A. Appendix

This appendix contains three tables:

- Table A.1 – Summary Auto VMT and VHT across Alternatives;
- Table A.2 – Summary Truck VMT and VHT across Alternatives; and
- Table A.3 – Auto and Truck VMT and VHT by Facility Type for the 10-Mile Buffer around I-95.

Table A.1 Summary Auto VMT and VHT across Alternatives

			VMT	VMT Growth over 2011	VHT	VHT Growth over 2011
I-95	2011	Base Run	10,553,904		148,502	
	2020	No Build	11,674,033	10.6%	167,052	12.5%
		Build – No Toll	11,710,145	11.0%	164,979	11.1%
		Build – with Toll	9,384,948	-11.1%	130,926	-11.8%
		Build – Toll with Mitigation	10,851,985	2.8%	152,210	2.5%
	2040	No Build	14,548,050	37.8%	224,717	51.3%
		Build – No Toll	14,865,409	40.9%	212,875	43.3%
		Build – with Toll	12,082,896	14.5%	171,015	15.2%
		Build – Toll with Mitigation	13,703,174	29.8%	195,199	31.4%
Primary (10-Mile Envelope around I-95)	2011	Base	19,597,466		328,078	
	2020	No Build	21,597,213	10.2%	364,185	11.0%
		Build – No Toll	21,620,686	10.3%	361,873	10.3%
		Build – with Toll	20,436,336	4.3%	361,086	10.1%
		Build – Toll with Mitigation	21,264,719	8.5%	363,137	10.7%
	2040	No Build	26,480,400	35.1%	470,475	43.4%
		Build – No Toll	26,682,086	36.2%	455,873	39.0%
		Build – with Toll	25,096,892	28.1%	453,724	38.3%
		Build – Toll with Mitigation	26,111,675	33.2%	457,013	39.3%

Table A.2 Summary Truck VMT and VHT across Alternatives

			VMT	VMT Growth over 2011	VHT	VHT Growth over 2011
I-95	2011	Base Run 2	2,165,408		30,376	
	2020	No Build	2,431,811	12.3%	34,627	14.0%
		Build – No Toll	2,436,760	12.5%	34,190	12.6%
		Build – with Toll	1,490,748	-31.2%	20,632	-32.1%
		Build – Toll with Mitigation	1,886,395	-12.9%	26,327	-13.3%
	2040	No Build	2,946,181	36.1%	45,123	48.5%
		Build – No Toll	2,981,401	37.7%	42,395	39.6%
		Build – with Toll	1,760,543	-18.7%	24,771	-18.5%
		Build – Toll with Mitigation	2,168,192	0.1%	30,748	1.2%
Primary (10-Mile Envelope around I-95)	2011	Base	2,982,042		45,776	
	2020	No Build	3,326,988	11.6%	51,561	12.6%
		Build – No Toll	3,331,181	11.7%	51,113	11.7%
		Build – with Toll	2,985,109	0.1%	52,299	14.3%
		Build – Toll with Mitigation	3,163,438	6.1%	51,777	13.1%
	2040	No Build	4,034,233	35.3%	66,644	45.6%
		Build – No Toll	4,058,072	36.1%	63,661	39.1%
		Build – with Toll	3,541,605	18.8%	63,970	39.7%
		Build – Toll with Mitigation	3,769,901	26.4%	64,052	39.9%

Table A.3 Auto and Truck VMT and VHT by Facility Type for the 10-Mile Buffer around I-95

Base Year							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	12,780,098	180,428	2,436,457	34,267	15,216,555	214,695
II	Arterial	3,022,336	70,585	197,136	4,481	3,219,472	75,066
III	Collector	3,505,142	68,604	321,408	6,254	3,826,550	74,859
IV	Ramp	289,890	8,461	27,041	774	316,931	9,235
	Sum	19,597,466	328,078	2,982,042	45,776	22,579,509	373,854
	QAQC	19,597,466	328,078	2,982,042	45,776	22,579,509	373,854
2020 No Build							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	14,183,005	203,258	2,728,643	38,901	16,911,649	242,159
II	Arterial	3,304,378	77,564	217,926	4,976	3,522,304	82,540
III	Collector	3,799,251	74,075	351,278	6,820	4,150,528	80,895
IV	Ramp	310,579	9,288	29,141	864	339,720	10,152
	Sum	21,597,213	364,185	3,326,988	51,561	24,924,202	415,746
	QAQC	21,597,213	364,185	3,326,988	51,561	24,924,202	415,746
2020 No Toll							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	14,225,142	201,265	2,733,072	38,454	16,958,215	239,719
II	Arterial	3,297,872	77,369	217,205	4,959	3,515,077	82,328
III	Collector	3,785,712	73,813	351,729	6,827	4,137,440	80,640
IV	Ramp	311,959	9,427	29,176	873	341,135	10,300
	Sum	21,620,686	361,873	3,331,181	51,113	24,951,867	412,986
	QAQC	21,620,686	361,873	3,331,181	51,113	24,951,867	412,986

2020 Toll 10 mi							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	11,910,843	167,617	1,817,063	25,444	13,727,906	193,061
II	Arterial	3,584,237	88,536	376,295	9,408	3,960,531	97,945
III	Collector	4,634,105	95,656	756,567	16,378	5,390,672	112,034
IV	Ramp	307,151	9,277	35,184	1,069	342,335	10,346
	Sum	20,436,336	361,086	2,985,109	52,299	23,421,445	413,385
	QAQC	20,436,336	361,086	2,985,109	52,299	23,421,445	413,385
2020 Toll with Mitigation							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	13,381,938	188,875	2,218,525	31,207	15,600,463	220,082
II	Arterial	3,460,950	83,594	318,969	7,537	3,779,919	91,131
III	Collector	4,110,838	81,155	589,945	11,965	4,700,783	93,120
IV	Ramp	310,993	9,513	35,999	1,067	346,992	10,581
	Sum	21,264,719	363,137	3,163,438	51,777	24,428,157	414,914
	QAQC	21,264,719	363,137	3,163,438	51,777	24,428,157	414,914
2040 No Build							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	17,533,582	268,007	3,300,462	50,226	20,834,045	318,233
II	Arterial	3,947,493	96,397	265,361	6,283	4,212,854	102,680
III	Collector	4,626,805	90,636	433,731	8,496	5,060,535	99,132
IV	Ramp	372,520	15,435	34,679	1,639	407,199	17,074
	Sum	26,480,400	470,475	4,034,233	66,644	30,514,633	537,119
	QAQC	26,480,400	470,475	4,034,233	66,644	30,514,633	537,119

2040 No Toll Within a 10-Mile Buffer around I-95							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	17,873,917	256,530	3,336,223	47,508	21,210,140	304,038
II	Arterial	3,907,825	95,104	258,664	6,100	4,166,489	101,204
III	Collector	4,522,489	88,592	427,753	8,381	4,950,242	96,973
IV	Ramp	377,854	15,646	35,432	1,671	413,287	17,318
	Sum	26,682,086	455,873	4,058,072	63,661	30,740,158	519,533
	QAQC	26,682,086	455,873	4,058,072	63,661	30,740,158	519,533
2040 Toll 10 mi							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	15,113,202	215,317	2,156,570	30,627	17,269,772	245,945
II	Arterial	4,166,729	109,071	438,182	11,687	4,604,911	120,758
III	Collector	5,442,194	113,066	904,476	19,752	6,346,671	132,817
IV	Ramp	374,766	16,270	42,377	1,904	417,143	18,174
	Sum	25,096,892	453,724	3,541,605	63,970	28,638,496	517,694
	QAQC	25,096,892	453,724	3,541,605	63,970	28,638,496	517,694
2040 Toll with Mitigation							
CLASS	Name	AUTO_VMT	AUTO_VHT	TRK_VMT	TRK_VHT	Total_VMT	Total_VHT
I	Freeway	16,727,747	239,268	2,586,609	36,894	19,314,355	276,162
II	Arterial	4,062,626	103,404	375,794	9,577	4,438,420	112,981
III	Collector	4,942,241	98,232	764,883	15,690	5,707,123	113,922
IV	Ramp	379,062	16,109	42,616	1,891	421,678	18,001
	Sum	26,111,675	457,013	3,769,901	64,052	29,881,576	521,066
	QAQC	26,111,675	457,013	3,769,901	64,052	29,881,576	521,066