Technical Memorandum 7

Existing
Transportation System Evaluation

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Transportation System Evaluation

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1.0 Introduction

1.1 Corridor Location and Overview

The purpose of the I-24 Multimodal Corridor Study is to examine potential multimodal transportation improvements that would address existing and emerging transportation system issues associated with this strategic corridor through central Tennessee connecting the Clarksville, Nashville and Chattanooga urban areas. The corridor extends from the Kentucky border to where it meets I-75 in Hamilton County, a distance of approximately 185 miles (refer to Figure 1.1).

The analysis of corridor needs will go through a structured process of characterizing existing and projected corridor conditions, describing the purpose and need for corridor improvements, defining a set of performance measures against which to evaluate improvement options, and evaluating potential corridor improvements against these performance measures to develop a set of recommended improvements.

1.2 Purpose of This Document in the Study Process

Evaluation of the existing transportation system will establish a benchmark for the examination of future travel and transportation system operating characteristics. The analysis presented in this document will provide a frame of reference for determining the level of improvement or degradation that would be associated with future conditions and potential improvement scenarios. The transportation system evaluation process will take place at two different levels of analysis:

- Study area level (macroscopic), and
- Corridor level (mesoscopic)

1.2.1 Macroscopic Modeling

This type of travel modeling is mostly characterized by a relatively large model study area. In this study of the I-24 Corridor, macroscopic-scale modeling was used to estimate system-wide performance statistics in an analysis area surrounding the study corridor. System-wide measurements are statistics that not only represent I-24, but conditions on other freeways and thoroughfares that interact with I-24. The macroscopic model analysis area, surrounding the I-24 Corridor is shown in Figure 1.2. A more descriptive explanation of the macroscopic model is provided in the next section.

1.2.2 Mesoscopic Modeling

This type of travel modeling is mostly characterized by a relatively smaller study area, in comparison with macroscopic modeling. In this study, the mesoscopic model's study area is much smaller, in terms of area, than the macroscopic model. Performance measurements from the mesoscopic model emphasize the evaluation of traffic conditions on I-24 itself and its interchanges. As such, the length of the study area is essentially the same as in the macroscopic study area, but the width of the band surrounding I-24 is much smaller. More emphasis is placed on simulating vehicles and the influence on them from traffic control and turn-lane geometry, in comparison with the macroscopic model. The mesoscopic model analysis area for the I-24 Corridor is shown in Figure 1.3. A more descriptive explanation of the mesoscopic model is provided in the next section.

Figure 1.1: Study Corridor Map

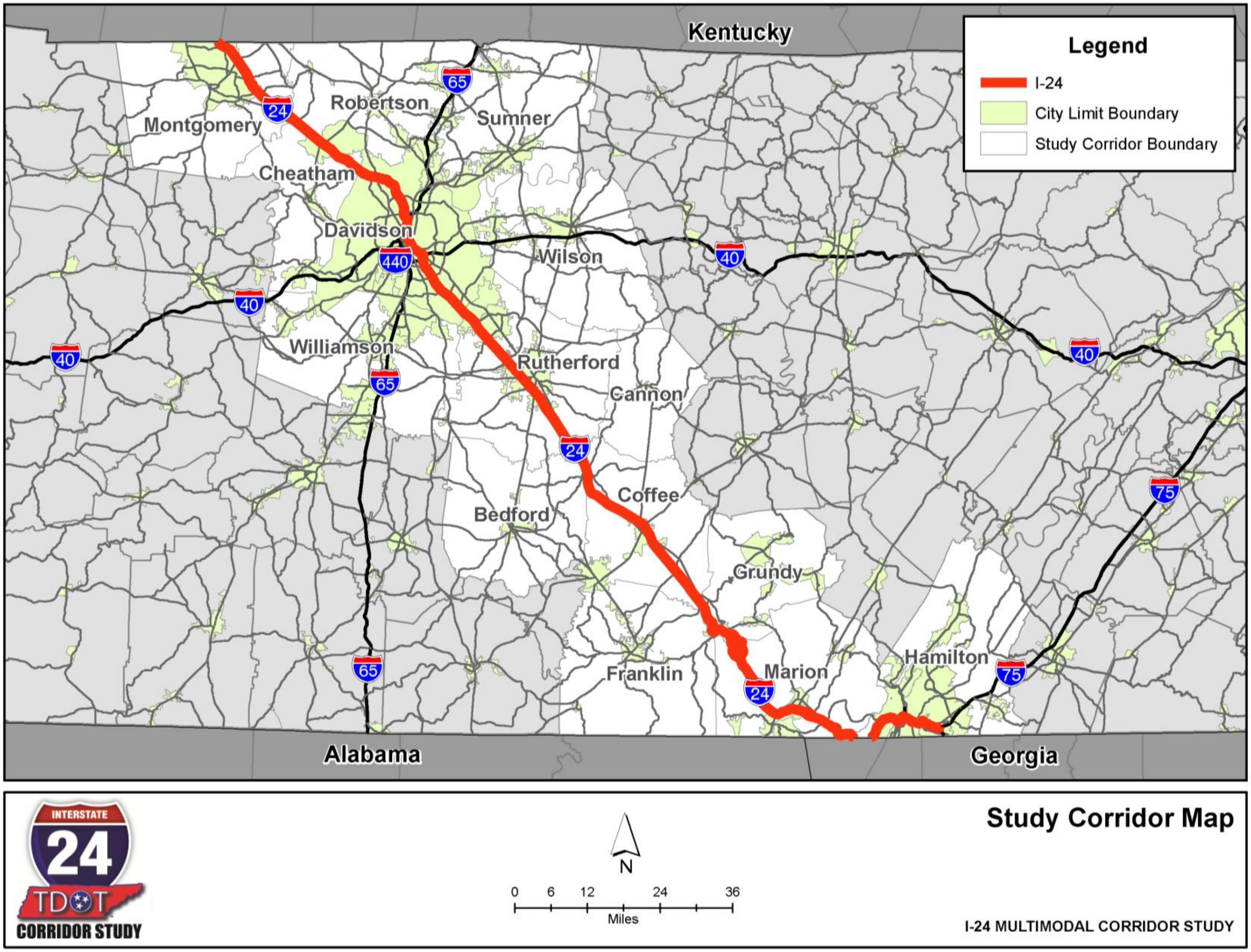


Figure 1.2: Macroscopic Model Analysis Area Map

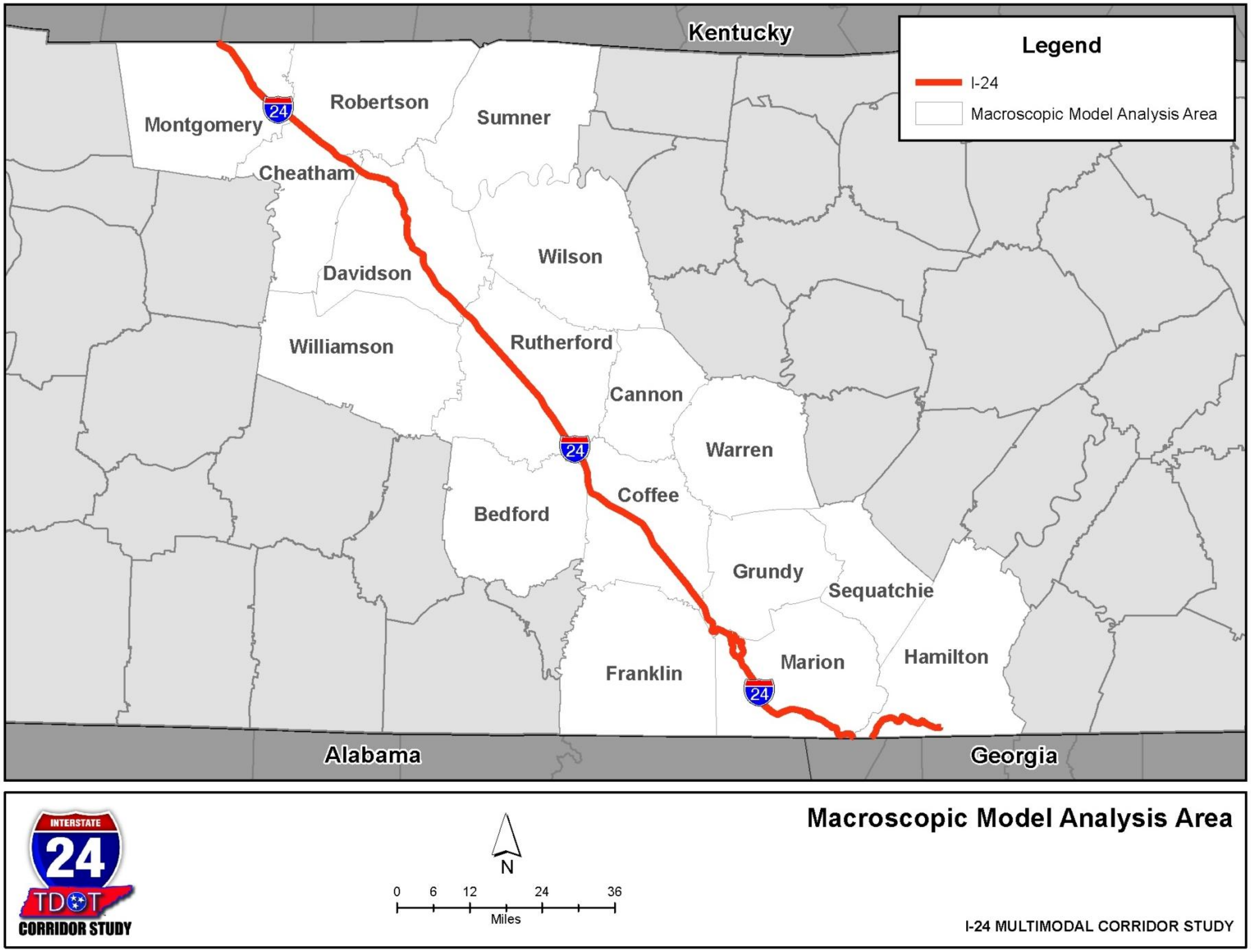
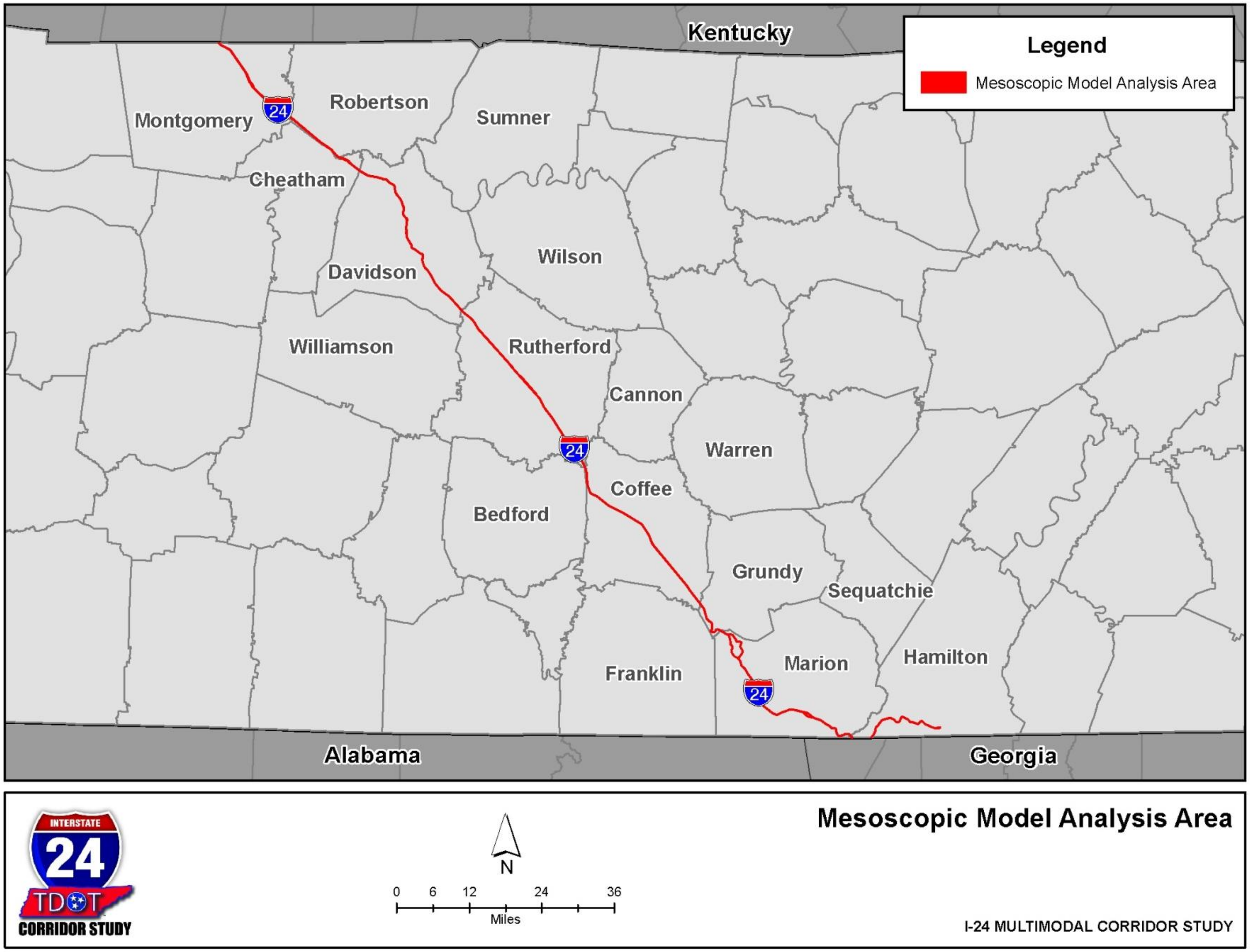


Figure 1.3: Mesoscopic Model Study Analysis Map



2.0 Tier II Model Development

Tier II modeling in the I-24 Multimodal Corridor Study entailed consolidating the three macro-scale travel demand models into one, single travel demand model. The individual macro-scale models were described in a companion paper titled, *Technical Memorandum 3 – Travel Demand Model Process*. A two-tier modeling process was used for three primary reasons:

- Provide the kind of travel demand information that are required to consider and evaluate transportation improvements targeting inter-city movements of people and freight;
- Provide a consistent, level-playing field to measure and evaluate highway system operating conditions such as average travel speeds and delay; and,
- Maximize the superior database of long distance travel represented in Tennessee's Statewide Model and using the detailed network, zone and trip table information in the MPO models.

Tier II modeling entailed developing two different models; a macroscopic-scale model and a mesoscopic-scale model. The consolidated, macroscopic model was created through a merging process of three macro-scale models: (1) Enhanced Tennessee Statewide Model that includes the Clarksville MPO planning area; (2) Chattanooga MPO model; and (3) Nashville MPO model. The mesoscopic model was developed from the consolidated, macroscopic model by means of a network and trip table extraction process. Model development steps that were performed to create the Tier II models to study I-24 are illustrated in a task diagram layout in Figure 2.1.

2.1 Macroscopic Consolidated Model

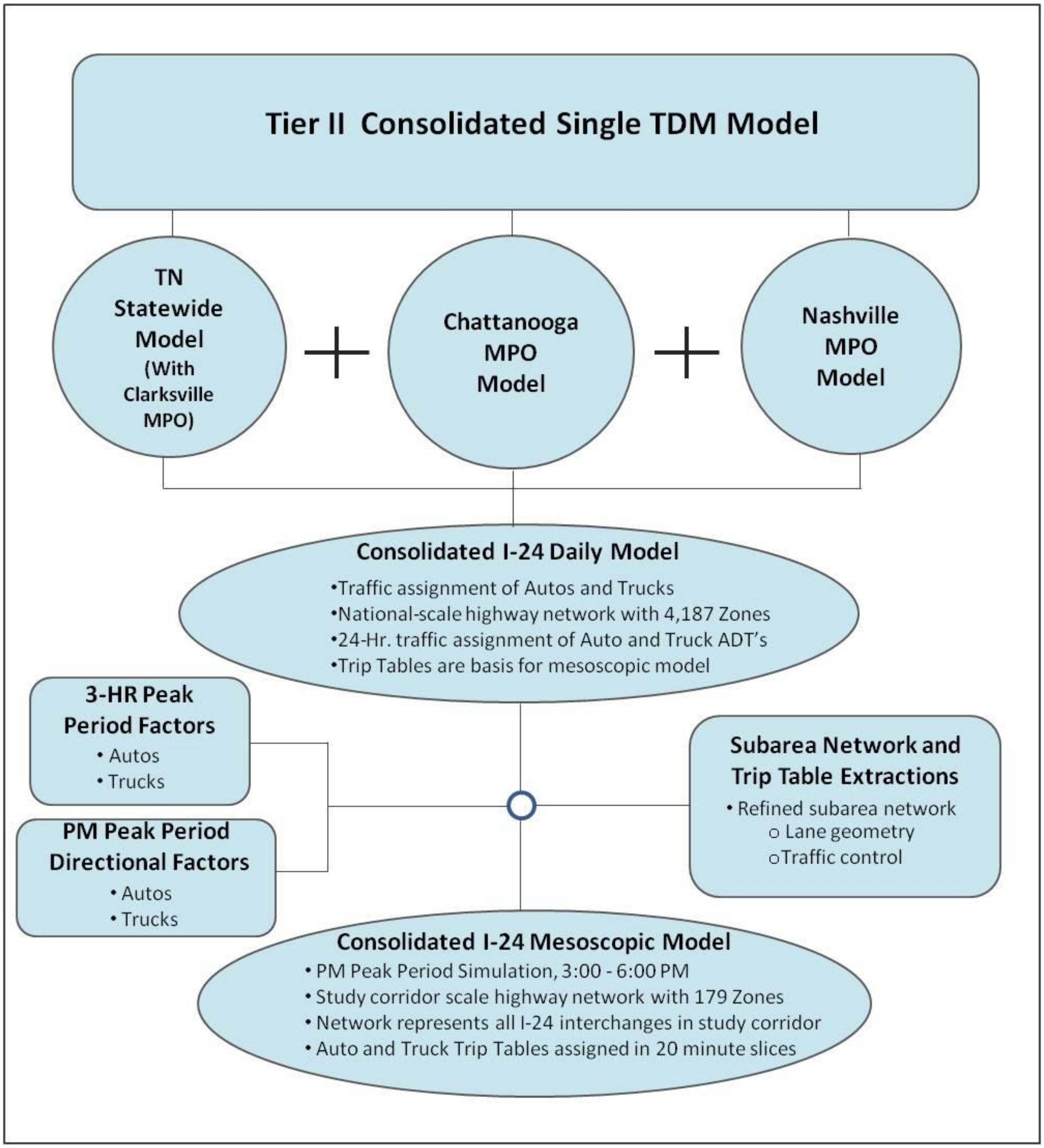
Three steps were used to merge the macroscopic models into a consolidated I-24 daily trip model. There were tasks related to merging the highway networks as well as the trip tables. The final step was that of validation. The study team did not perform a full calibration of the consolidated I-24 daily trip model, but did make minor adjustments to the auto and truck trip tables. Each of the model development steps is described in more detail later in this section.

2.1.1 Network

The spatial merge of the networks and zones was a simple GIS merge process. Subareas of the Statewide Model network overlaying the Nashville and Chattanooga MPO model areas were removed from the Statewide Model network and replaced by their MPO counterparts. The most difficult part of the network merge was indentifying the highway line file and endpoint file attributes from each macro-model that would go into the consolidated I-24 Corridor model and then populating those attributes.

Application of the consolidated, daily I-24 Corridor model was to be done using the automated TransCAD model script employed in the Statewide Model. To accommodate the calculation of

Figure 2.1: Tier II Modeling Procedure



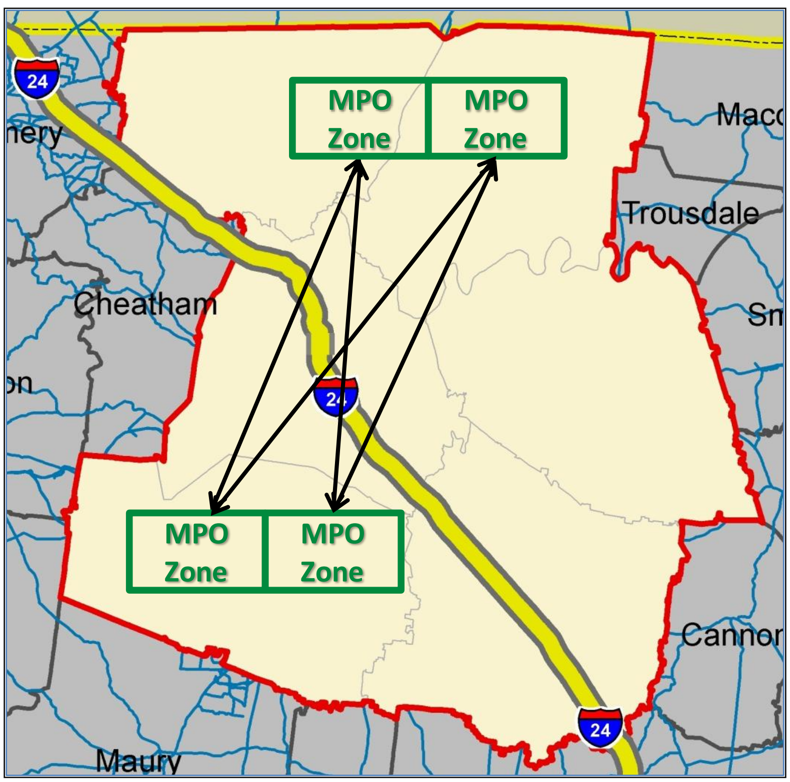
link attribute variables needed to run traffic assignment, MPO model link attributes were updated to reflect functional class, number of lanes, area type and terrain type that are used in the Statewide Model.

2.1.2 Trip Tables

Auto and truck trips for the new consolidated trip table came from all three macro-models. To facilitate a seamless travel demand model, long distance trips from the Statewide Model were used. These trips also replaced external-to-external (E-E) and internal-external (I-E) trips from the MPO models. Statewide Model trips internal to the Nashville and Chattanooga MPO regions were removed from the Statewide Model prior to consolidating trips with the MPO models. In the consolidated model, these kinds of trips were replaced by their counterparts from the MPO model trip tables. This cut, paste and merge of modeled trips produced a seamless, full-coverage auto and truck trip tables of 24-hour, daily travel patterns in the I-24 Corridor's model analysis area.

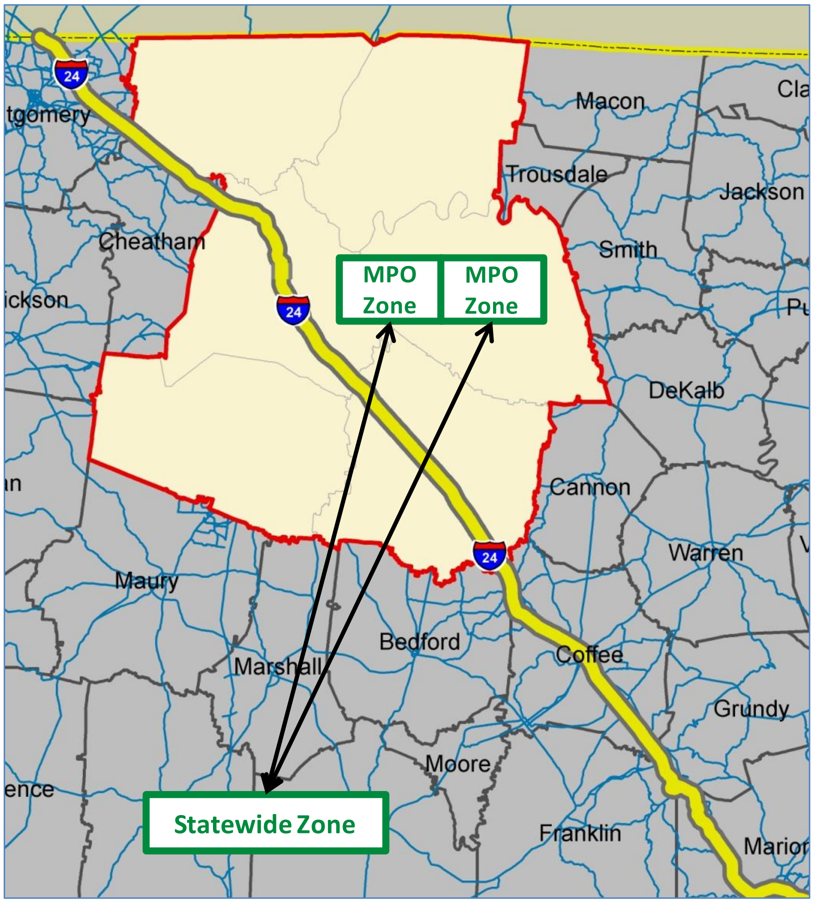
A map image, Figure 2.2, illustrates how trips that were internal to the MPOs were cut, pasted and merged during the trip table development process. For illustration purposes, the Nashville MPO region is depicted. Inside the six-county Nashville MPO region, zones and trips from the Statewide Model were removed. They were replaced by the Nashville MPO's zone system and internal-to-internal (I-I) auto and truck trip tables. The same process was used to represent auto and truck travel inside the Chattanooga MPO region.

Figure 2.2: Consolidating Trip Tables (I-I NashvilleTrips)



An image illustrating how MPO model's external trips were removed and replaced by their counterparts from the Statewide Model is shown in Figure 2.3. Both external-to-external (E-E) and internal-to-external (I-E) trips inside the MPO models were removed. The example in the figure corresponds to MPO model I-E trips. Since the MPO model zone systems are more refined than those in the Statewide model, trip interchange volumes from the Statewide Model were disaggregated into two or more zones at the trip interchange end located inside an MPO boundary.

Figure 2.3: Consolidating Trip Tables (I-E NashvilleTrips)

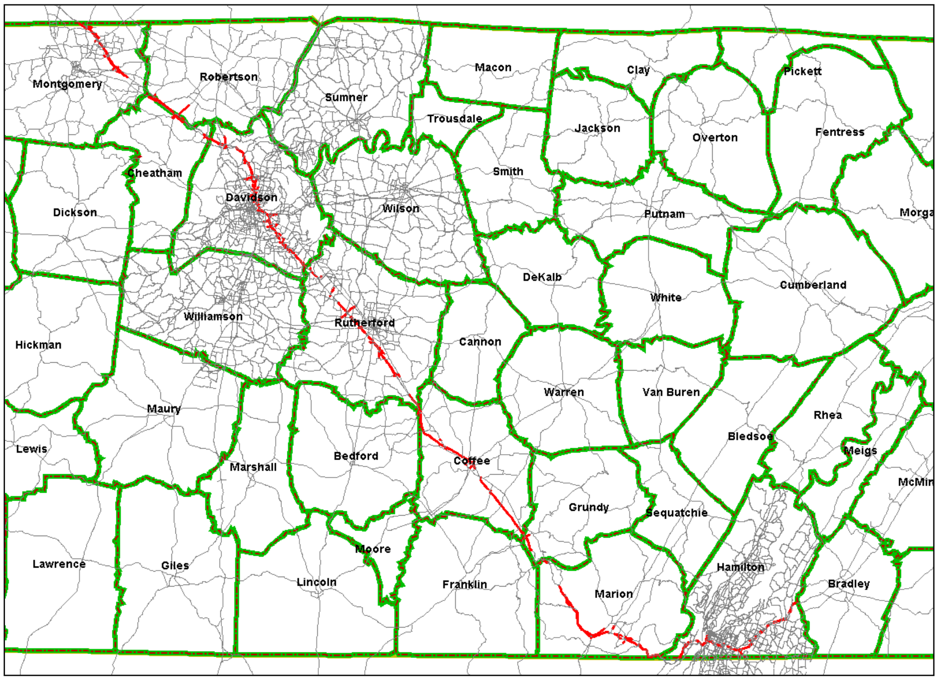


2.1.3 Validation

Initial base year 2010 traffic assignments of autos and trucks in the Tier II, consolidated model were not as close to the three separate traffic assignments output by the Tier I macro-scale models. In light of the findings of the initial validation check, the model development team needed to make refinements to the Tier II consolidated model auto and truck trip tables and conduct a new set of validation checks.

Using the TransCAD trip table estimator tool, the base year 2010 auto and truck trip tables were modified so that that the modeled traffic assignment volumes better matched 2011 TDOT traffic counts. A sample of 347 highway network links with 2011 traffic counts was used to make the adjustments. The sample of links is highlighted in bright red color in Figure 2.4. The sample predominantly includes I-24 links and links on cross-streets interchanging with I-24. Spatially, the sample stretches all the way from Chattanooga to Clarksville.

Figure 2.4: Traffic Count Link Sample for Matrix Estimator Application



A root mean square error (RMSE) test was performed to test how well modeled traffic assignments matched TDOT's 2011 counts. The relative RMSE results are listed below.

- Interstate Links – 12.0%
- Non-Interstate Links – 23.9%
- Overall Sample of Links – 15.8%

These percentages mean that there was an overall 15.8% deviation between modeled daily volumes and TDOT's traffic counts in the 347 link sample. The deviation on I-24 and other freeways interchanging with I-24 was smaller than for non-freeway cross streets interchanging with I-24.

Passenger car and truck trip tables before and after the trip table estimator adjustment were compared to evaluate the impact of the refinement on the trip length frequency distribution. Table 2.1 shows modeled average trip lengths before and after the refinement.

Table 2.1: Modeled Average Trip Lengths Before and After Refinement

Trip Length Distribution Statistics (in miles)	Passenger Car		Truck	
	After Refinement	Before Refinement	After Refinement	Before Refinement
Average	12.3	12.4	32.5	34.0
Standard Deviation	11.8	11.9	29.0	28.2

The overall trip length distribution produced a slight reduction in average trip lengths. The share of auto and truck trips before and after the refinement are displayed in Figures 2.5 and 2.6, respectively, using 10 minute time intervals.

Figure 2.5: Passenger Car Trip Length Distributions

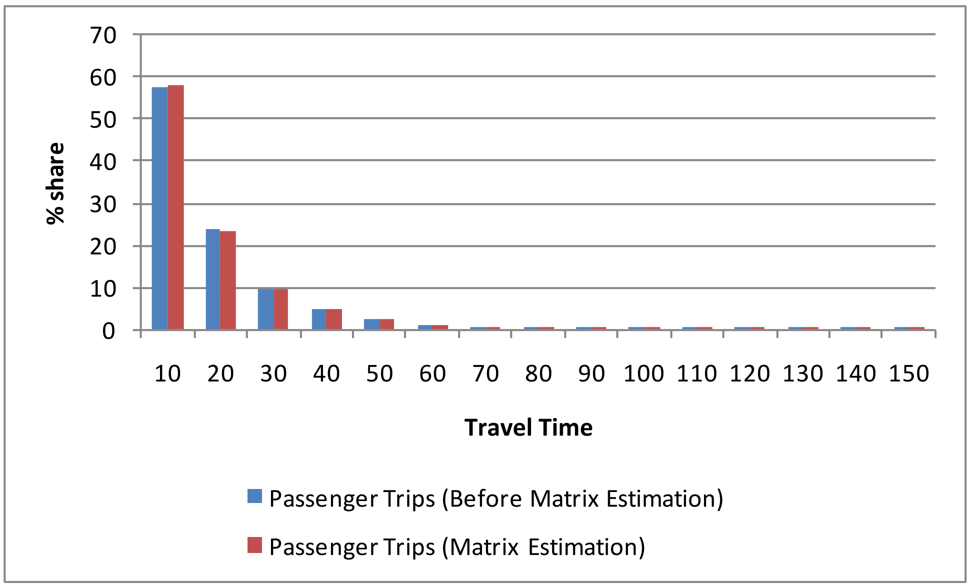
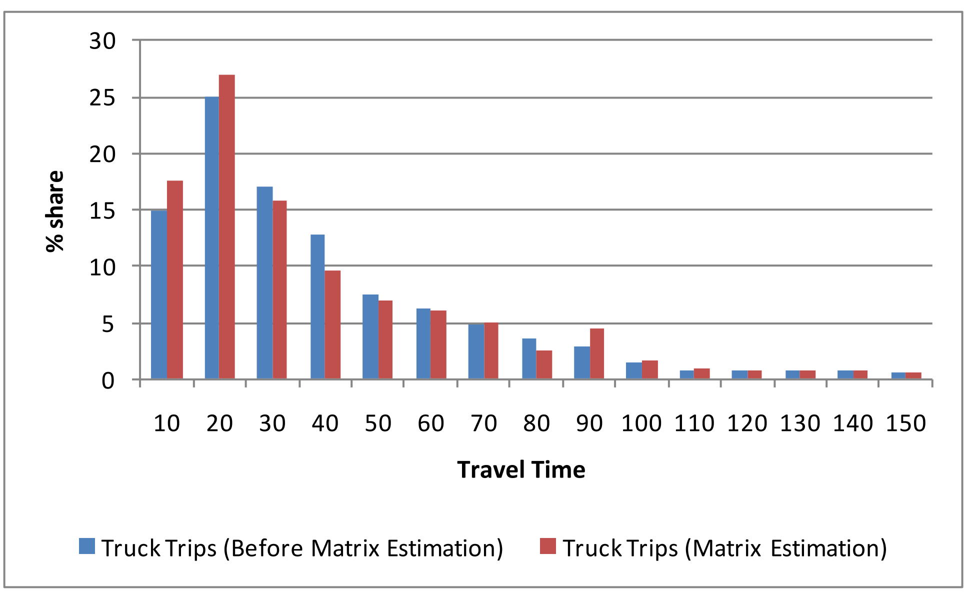


Figure 2.6: Truck Trip Length Distributions



Modeled Daily Vehicle Miles of Travel (DVMT) versus 2011 traffic count-based DVMT is presented in Table 2.2. A total of 380 highway network links scattered throughout the corridor's model analysis area comprised the sample. It compares the vehicle-miles-traveled, based on modeled volumes, against the vehicle-mile-traveled computed from TDOT's 2011 counts using the sample of 380 links.

Table 2.2: Modeled DVMT Versus Counted DVMT

Area Type	Facility Type	Model-Based DVMT	Count-Based DVMT	Percent Difference
Rural	Interstates	2,885,634	2,731,789	6%
	Expressway	187,992	179,955	4%
	Principal Arterials	23,550	23,942	-2%
	Minor Arterials	151,792	137,508	10%
	Collectors	17,358	21,647	-20%
Urban	Interstates	4,460,537	4,301,577	4%
	Expressway	33,451	32,911	2%
	Principal Arterials	127,304	135,601	-6%
	Minor Arterials	206,968	197,683	5%
	Collectors	30,143	30,928	-3%
Total		8,124,729	7,793,541	4%

Based on this sample, modeled DVMT was 4% higher overall in comparison with counted DVMT. Modeled DVMT on Urban Interstate facilities was 4% higher than the counted DVMT and it was 6% higher on Rural Interstate facilities. Modeled DVMT on rural collectors was 20% lower than counted DVMT indicating that the Interstate System may be attracting more traffic from parallel collectors than what observed traffic would suggest.

2.1.4 Application

One of the key advantages of building a consolidated, I-24 Travel Demand Model is being able to identify long distance travel movements. Using the Tier I models, most of these kinds of trips inside the I-24 model analysis area do not exist. Daily bandwidths from the 2010 trip tables highlighting long distance trips are presented in Figures 2.7 and 2.8 for autos and trucks, respectively.

As seen in Figure 2.7, the thickest district-district bandwidth lines for autos connect District 3 with Chattanooga and District 2 with Nashville. District 3 includes Chattanooga's southern suburbs in Georgia plus eastern Tennessee outside of the I-24 model analysis area. The District 2 to Nashville movement includes some commuter trips from proximate cities like Dickson and Columbia, but also from more distant places in western Tennessee like Jackson and Memphis.

Figure 2.7: Bandwidth Volumes of Modeled Long Distance Auto Trips

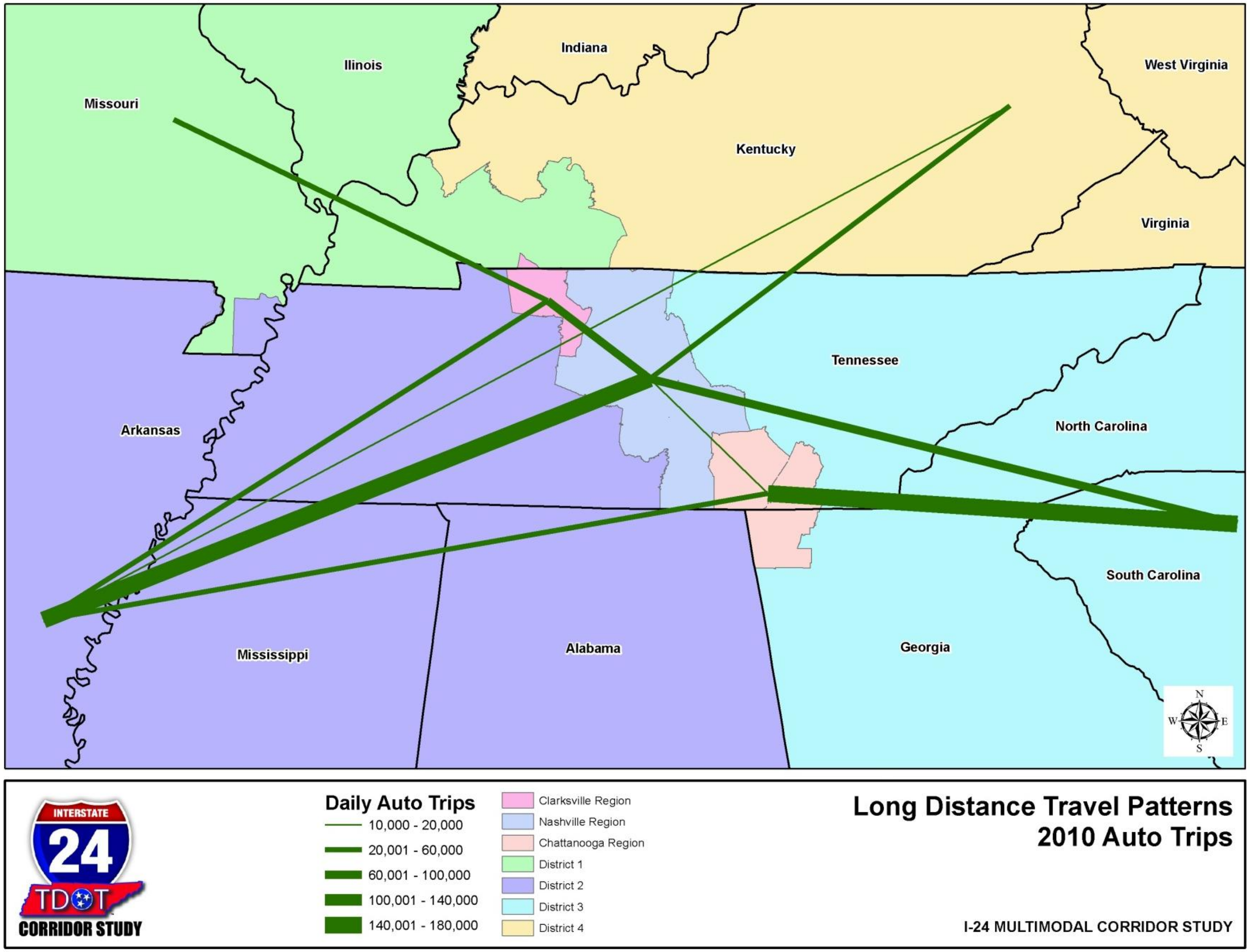
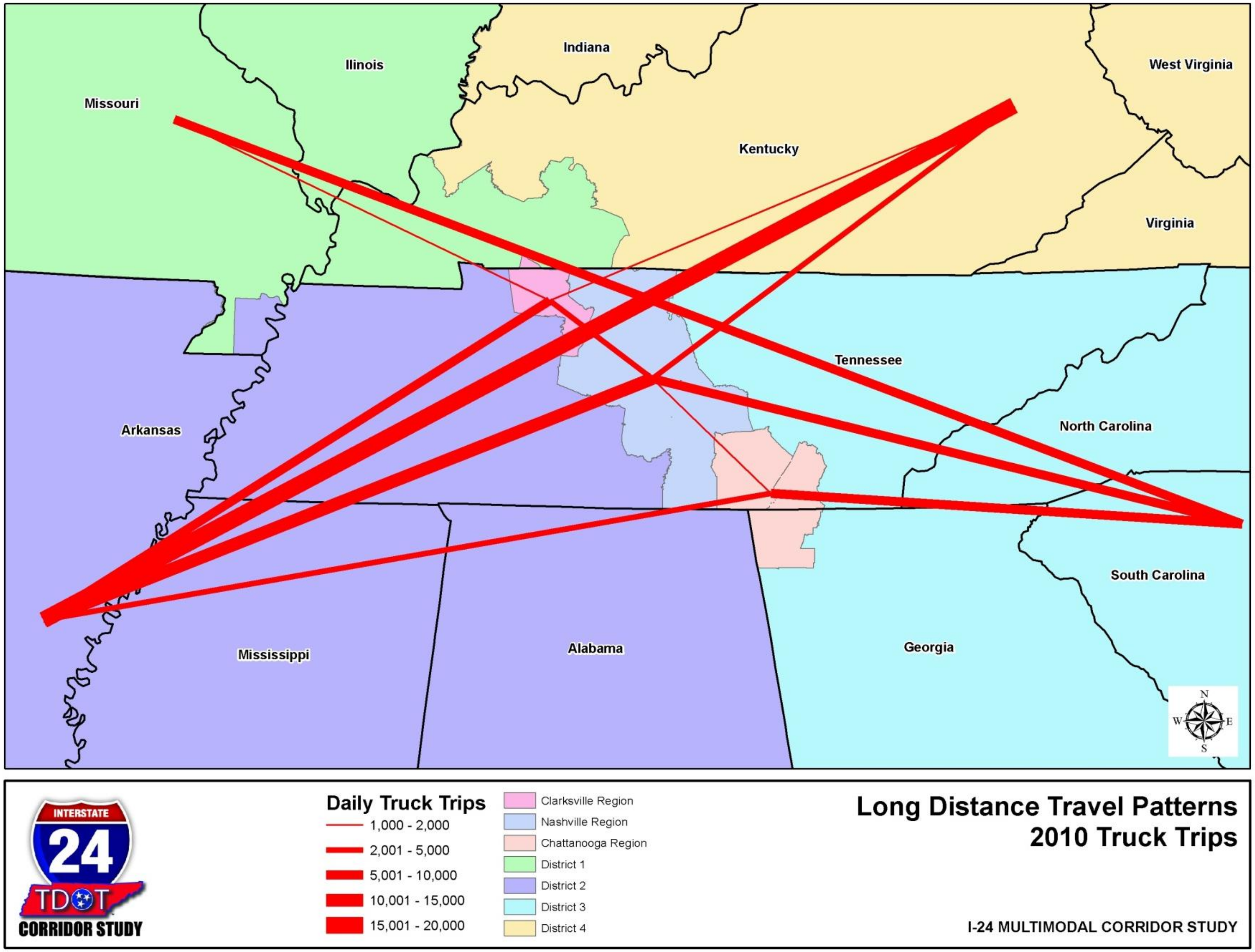


Figure 2.8: Bandwidth Volumes of Modeled Long Distance Truck Trips



The only auto district-district movement, inside the model study area, with a relatively high volume is the Clarksville to Nashville origin-destination pair.

As seen in Figure 2.8, the thickest bandwidth line for long distance truck trips connects District 2 and District 4. If this particular line was drawn using the road system, it would pass through the center of Nashville. District 2 represents western Tennessee, including the Memphis region, and states located west and southwest of the corridor study area. District 4 represents most of Kentucky, Virginia and other states positioned north and northeast of Tennessee.

2.2 Mesoscopic Model

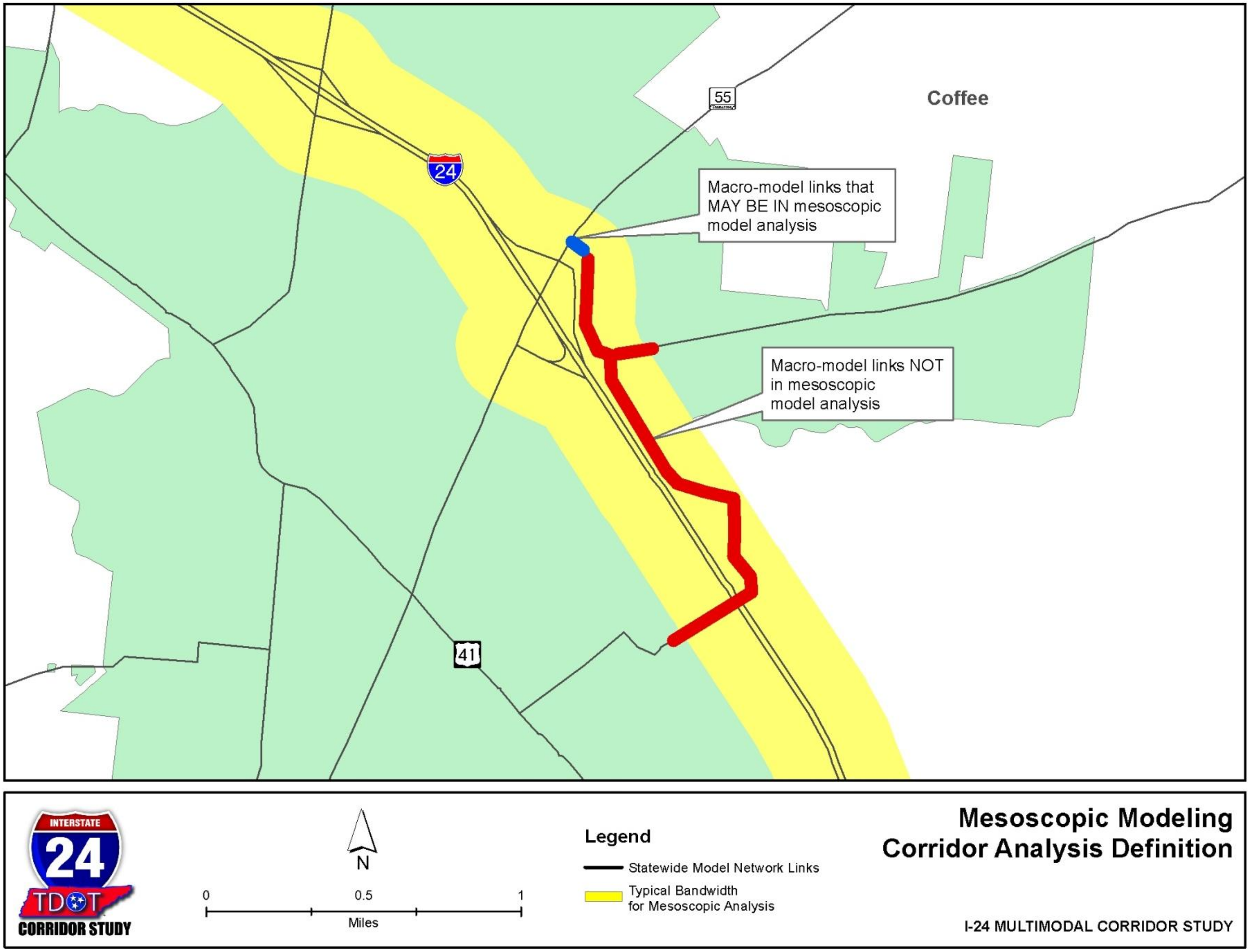
Operational performance measures on I-24, itself, were calculated using a mesoscopic-scale modeling process. TransModeler (TM), another product in Caliper Corporation's family of traffic analysis software, simulates the movements of all vehicles modeled through a network for a defined model time period and for defined time intervals within the model period. TM computes simulation segment and node characteristics during a given time interval to determine how a particular vehicle should progress in its path at one of three levels of fidelity (detail): Macro, Meso or Micro. Operational performance on sections of I-24 will be analyzed using the Meso-level of fidelity in its segments and nodes.

A bandwidth map depicting network links selected to be in the meso-scale simulation analysis is presented in Figure 2.9 for a section of I-24 skirting Manchester in Coffee County. Roads located inside the yellow corridor band but that are not explicitly legs of intersections formed by the ramp termini, like the blue and rust colored lines, were evaluated separately by the model team to determine if they would be in the mesoscopic model's simulation network.

The steps required to implement mesoscopic modeling in the I-24 Multimodal Corridor Study are listed below:

1. Define a subarea network for mesoscopic analysis along the entire 185 mile length of the I-24 Corridor (as depicted by Figure 2.7) and run the Tier II model to extract a 24-hour trip table for the subarea;
2. Import the corridor subarea network into TM as the simulation network, setting all freeway, ramp and interchanging cross-streets to the mesoscopic fidelity-level and all other links and nodes as macro fidelity;
3. Apply time-of-day (TOD) factors to the corridor's subarea trip tables to produce three-hour PM peak period auto and truck trip tables. The TOD factors will be consistent with peak hour factors in TDOT's traffic database as well as travel demand model TOD factors used in the Chattanooga MPO and Nashville MPO models;
4. Select a 3 hour peak period to model based on the 3 sequential hours with the most trips, most likely the PM peak period from 3:00 to 6:00, and create peak period trip table matrices for autos and trucks;

Figure 2.9: I-24 Corridor Band for Defining Limits of the Mesoscopic Model Network



5. Import the period trip tables to TM and define traffic distribution curves for the peak period to create trip table matrices by time segment (20 minute segments);
6. Initially, using all default settings and parameters suitable for the meso-level of TM fidelity, setup and run a dynamic traffic assignment (DTA) for the 3-hour PM peak period;
7. Evaluate results and make adjustments as needed. The modeling team will make decisions about making refinements to add more detailed information to the network or to possibly scale-back the mesoscopic model size depending on the outcome of testing the entire I-24 Corridor for a 3-hour PM peak period;
8. Validation: The study team has access to estimated, as opposed to observed, peak hour volumes on all sections of I-24 from TDOT's traffic database. There are also available counts for most of the interchange ramps. The study team will make comparisons of mesoscopic model flow results in the corridor to the available count data and make adjustments to the model as appropriate;
9. Summarize selected output performance measures for the corridor; such as: level-of-service, average travel speed and queuing length.

2.2.1 Network

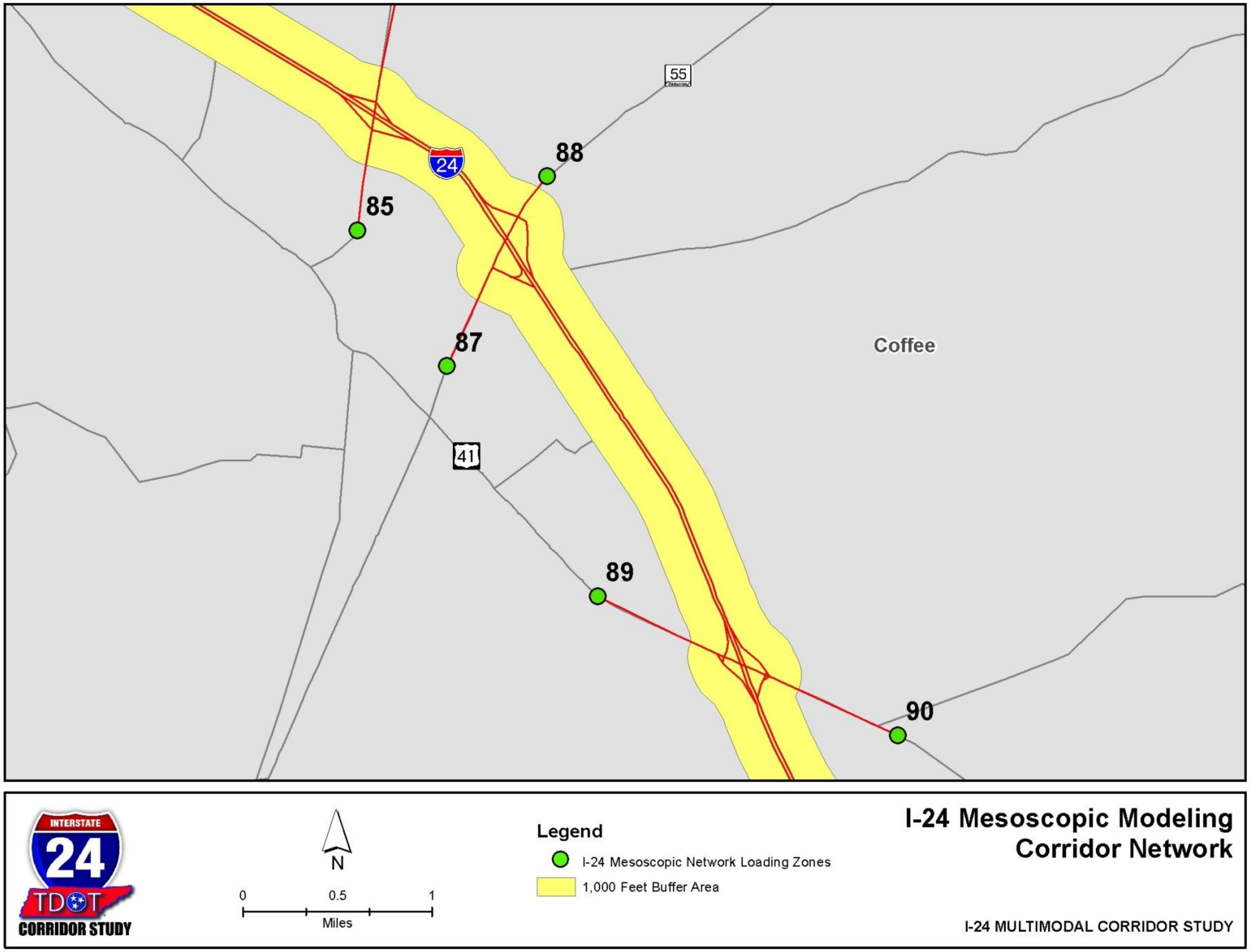
Mesoscopic simulation in TransModeler (TM) is different from a traditional planning model's traffic assignment. The TM simulation network was created by importing a TransCAD (TC) line network but requires some additional user input to make this happen. A portion of the TransCAD highway line file that was imported to TM is displayed in Figure 2.10. A selection set of links representing I-24 and its interchanges, those colored red, were extracted from the consolidated Tier II macro-model along with daily auto and truck trip tables. The extracted subarea network was subsequently imported into TransModeler.

During the TransCAD link import process, correspondence information between the functional class system in the input network and TM Road Class system was provided; which included the classification of centroid connectors. On import, TM created a classification lookup table to maintain the correspondence between what is in the TransCAD network for defined road functional classes and the internal TM Road Class system.

A selection set of endpoints, also referred to as centroid nodes, were created from the input network and this selection set was used on import to define the centroids and centroid connectors in the simulation network. Lastly, the modeling fidelity to be used in the simulation, meso-scale, was defined in the node table.

On import, TM builds a simulation network from the TransCAD link and node layers. The simulation network includes the original link and node layers from the TransCAD network but also includes additional layers for Segments, Lanes, Link Connectors, Centroids, Centroid Connectors, Sensors, Signals and Vehicles. The segment table creates an association between

Figure 2.10: I-24 Corridor TransCAD Highway Line File Imported to TransModeler



links and nodes. A segment in TM is a little different than a segment in a TransCAD network. In TM, a link is always made up of one or more segments. If the nodes at opposite ends of a link have the same fidelity setting, then on import, TM will create one segment associated with the link in the segment table and give it the same fidelity setting as the nodes. If the nodes have differing fidelity settings, then TM creates two segments in the segment table (essentially a split of the link but in the link table the link remains whole) each having the fidelity of the node to which it is connected. The segment table then includes both a segment ID and the link ID to which it is associated. Having associated segments on a link provides the capability to code attributes that may changes along the link without having to split the link. In addition to the fidelity, the number of lanes is also a segment level attribute. In the simulation network a link stores the number of segments on the link, each segment stores the number of lanes on the segment and each lane stores a number of lane level attributes like lane position, lane change restrictions, presence of parking alone the lane, allowed movements at the destination end of the lane, etc.. Nodes in the simulation network represent intersections and therefore each node is associated with a set of lane connectors than represent the possible movements for the link segments that connect at the node. Intersection control is also associated with the node layer.

When importing a TransCAD planning network into a simulation network there is no information for the additional data layers required by the simulation model so these are populated with defaults. This implies that all segments inherit the number of lanes from their parent link and that lane connectors are created at all nodes such that all possible turning movements are allowed. In a simulation model, the accuracy of the configuration and control at intersections is critical to accurately representing the capacity of the allowed movements which directly affect the estimated delay. Planning networks often make simplifications of the roadway geometry which have little to no effect in a planning model but can have significant impacts on movement delay in a simulation model. One of the main simplifications in the I-24 subarea network is at the intersections of on and off ramps at the arterials. Many of these locations have dedicated, uncontrolled right run lanes from the off ramp onto the arterial or from the arterial onto the on ramp effectively by-passing the intersection required for the left turning movements. In the planning network many of these locations are coded as simple four leg intersections which when converted to an intersection model significantly underestimate the capacity of the available movements. Prior to importing the subarea network into TM an extensive review of all intersections and ramp merges along the entire corridor was performed comparing the network coding to actual imagery for the intersections and the network edited and adjusted as appropriate.

2.2.2 Intersections

For mesoscopic and macroscopic modeling in TM, detailed intersection models can be coded but are not required. In the absence of control information at the intersections, TM will apply simple priority based stop models based on the relative priority of the intersecting road classes. Since the imported planning network contains no control information, the resulting imported network initially contains no control information and, therefore, the default priority stop models would be applied for all intersections. In order to get the simulation of I-24 to perform well, it was necessary to re-code intersections around interchanges. In TransModeler, the following kinds of intersection refinements were made to the network: lane geometry at and around intersections; adding simple timing algorithms representing traffic signal controllers; and, applying 'Stop' or 'Yield' control as actual conditions warranted. After importing the planning network into the simulation network in TM, another review of all intersections in the corridor was conducted comparing all intersection locations to actual imagery and coding intersection lane connectors based on visual inspection. All intersections with signal controls present were noted and simple signal controls with default timing plans were added. Ideally, actual signal controller and timing data for intersections should be used to more accurately reflect the computed delay for the signalized movements. However this detailed level of data was not available for this project. Since the focus of the operational analysis was on the mainline freeway segments, it was felt that using a default set of controls and timings at signalized intersections would be a good approximation. Some initial testing indicated that in most cases the intersection models performed well. There were a few intersections where the cycle lengths were increased slightly from the original default values to improve the performance of the intersection under high demand conditions.

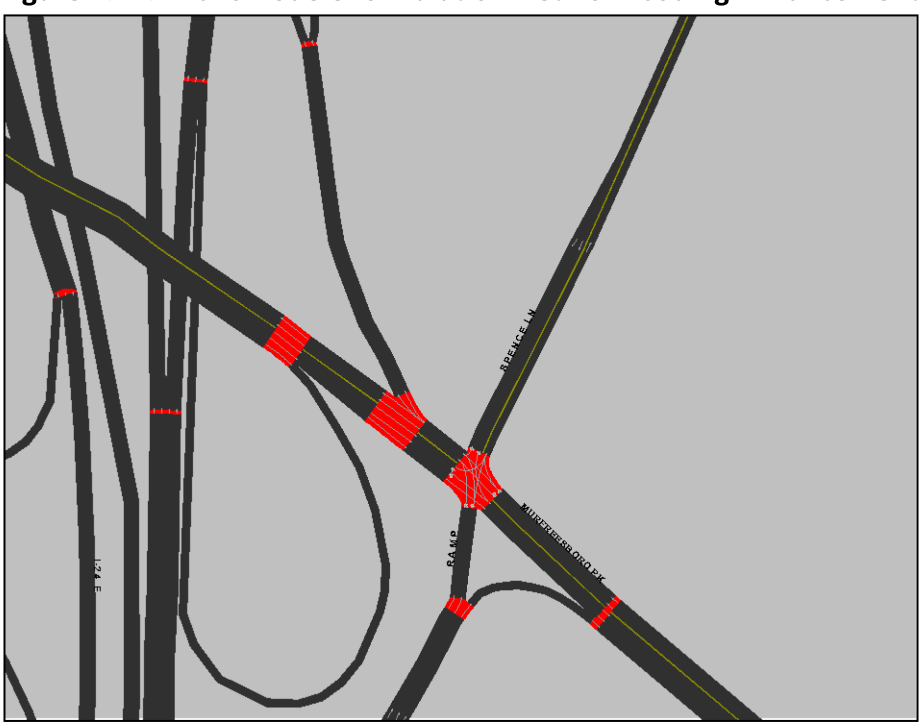
An illustration of I-24 and its interchanges, east of downtown Nashville, as they appear in TransModeler, are displayed in Figure 2.11. Roadway links are expanded to represent the number lanes on the associated segments and shown in black. Nodes are expanded to represent intersections and are shown in red. Centroids and centroid connectors are shown in green.

Figure 2.12 displays a closer view of an intersection at the westbound I-24 on and off ramps at Murfreesboro Pike and the intersection with Spence Lane. This view shows the kinds of typical additional level of detail that was coded into the simulation network to adequately model the intersection behaviors. Changes in the number of lanes on segments into and out of intersections were made to accurately reflect number of lanes available at the intersections. Lane connectors were corrected from the original defaults to represent the allowed movements at the intersections and controls were added where appropriate: in this case at the intersection of Murfreesboro Pike, Spence Lane and the I-24 ramp.

Figure 2.11: I-24 Corridor TransModeler Network Illustration

Source: Caliper Corporation's TransModeler

Figure 2.12: TransModeler Simulation Network Coding Enhancements



Source: Caliper Corporation's TransModeler

2.2.3 Trip Demand

TM uses what it refers to as a Trip Data Table to represent demand. This is not equivalent to a trip table in the TransCAD model context. A TM Trip Data Table is created from one or more traditional trip tables but also requires paths and time period information. The Trip Data Table consists of a table containing vehicle IDs with associated attributes; such as: Trip Origin, Trip Destination, Network Path and Departure Time. TM provides a number of methods for defining demand in the simulation, one of which is reading in traditional TransCAD trip tables. When linking in OD based trip matrices as input, TM creates the vehicle ID based Trip Data Table by creating a vehicle for each trip in the matrix, assigning its origin and destination zones from the input matrix cell, assigns it path from the path file from the available set of paths between the origin and destination and finally gives it a departure time based on the model period. If a set of paths are not available at the time the input demand is linked (which is usually the case when setting up a new project) then paths will be built automatically so that paths can be assigned to the vehicles in the Trip Data Table. TM has several options for how paths are built (deterministic, stochastic or probabilistic) and how departure times are determined (deterministic, uniform or random) for the input demand. For this project stochastic path building was used and uniform distribution of trips within each time interval was used.

Initially, the modeling team extracted a 24-hour trip table for the subarea network used in the mesoscopic model from the Tier II model. Time-of-day factors, by subarea network zone, were developed and applied to the 24-hour trip table to produce three hour PM peak period trip tables for autos and trucks. Within the PM peak period, vehicle movements are simulated for a defined time interval and trip tables or trip flow rates are defined for each time interval. A 20-minute time interval was used resulting in 9 modeled time intervals across the 3-hour model period. A bandwidth map showing hourly flows from a 3-hour trip assignment of autos and trucks to the extracted subarea network, in the TransCAD platform, is displayed in Figure 2.13. The directional flow of traffic is evident from different line thicknesses on I-24 and ramps at the SR-55 interchange.

Typical hourly distributions of auto traffic volumes rise gradually through a PM peak period while truck volumes gradually decline through the PM Peak period. In light of these standard patterns, the three highest volume auto trip tables are represented in the 20-minute trip tables for the 1-hour period between 5:00 and 6:00 PM. The three highest volume truck trip tables are represented by the 20 minute periods between 3:00 and 4:00 PM. The distribution of the final PM peak period trip tables by time interval extracted from the Tier II model and used in the mesoscopic model of the corridor is shown in Table 2.3.

Figure 2.13: Assignment of Extracted Trips to Extracted Subarea Network (in TransCAD platform)

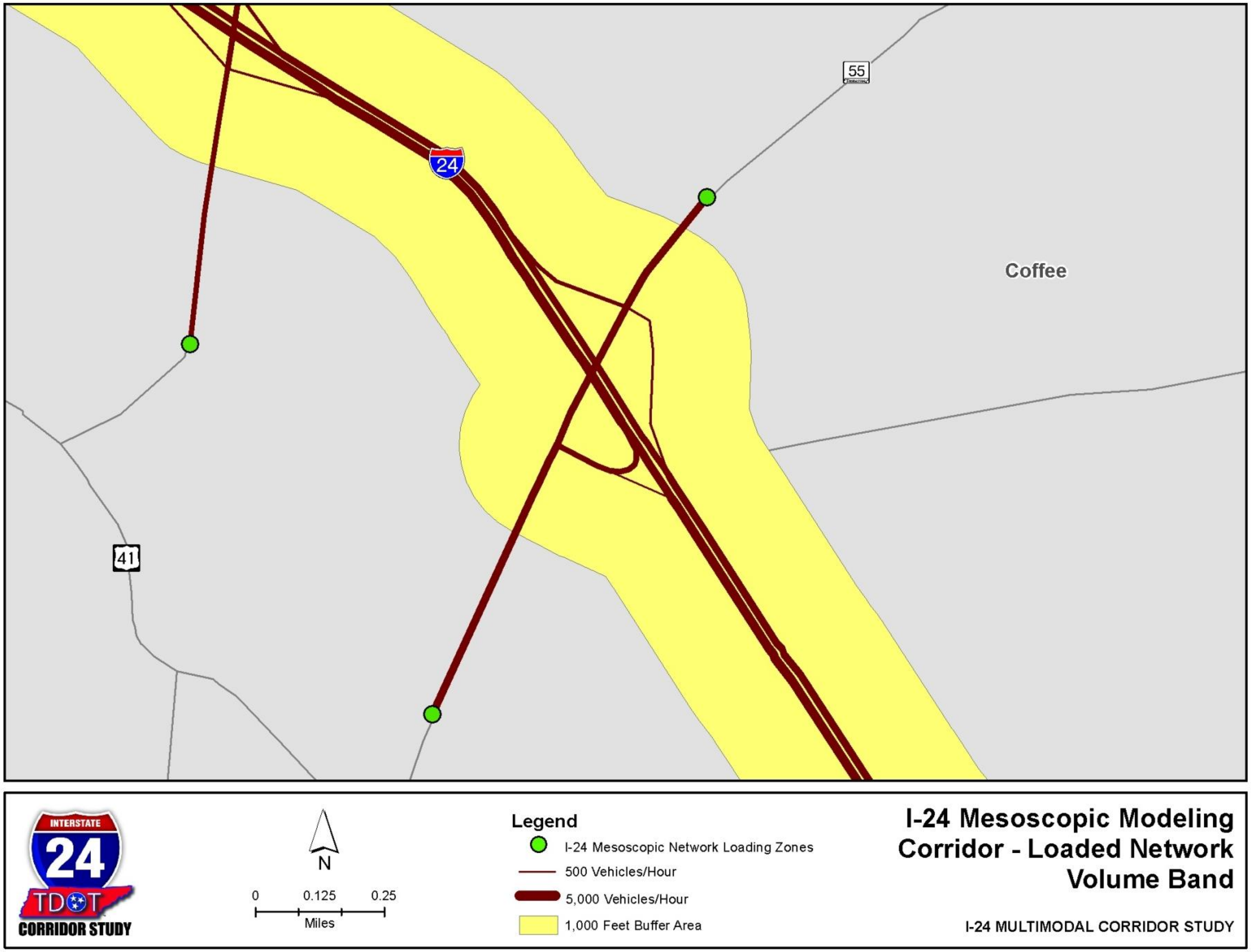


Table 2.3: Distribution of Mesoscopic Model PM Peak Period Trips by Simulation Time Interval

PM Time Interval	Auto Trips	Truck Trips
3:20	36,292	2,318
3:40	36,292	2,318
4:00	36,292	2,501
4:20	39,930	2,501
4:40	39,930	2,318
5:00	43,571	2,318
5:20	47,214	1,724
5:50	43,571	1,724
6:00	39,930	1,563
Total	363,022	19,285

2.2.4 Simulation

TM is a path based simulation model which means that paths are built and/or are available at the beginning of the simulation. During a simulation, vehicles are progressed along their assigned path model-segment by model-segment. The model fidelity associated with each segment determines what methods are used to model the delay (travel times) associated with traversing a segment: macroscopic, mesoscopic or microscopic. These delay methods are fully documented in the TM software documentation. In addition, when moving from one segment to another requires traversing a node, an additional component of delay associated with the intersection must be computed and simulated. The computation of the intersection movement delay is performed based on what type of intersection control has been coded and the current demand at the intersection. Where no control information has been provided, default saturation flow based priority stop models are applied.

When a simulation is run, TransModeler can either simulate the movement of vehicles based on the trips and paths that already exist in the TM Trip Data Table or the modeler can generate a new set of paths to the Trip Data Table based on a new or updated set of path costs. When setting up a new simulation project, a set of paths will be generated when defining the input demand. The user can specify an initial set of link and turning movement travel times to use for this set of paths, use a set of paths from a prior run of the simulation or use free flow times based on the internal link speed table by functional class.

In order to produce a reasonable set of travel times upon which to base the vehicle simulation, it is necessary to run the simulation iteratively feeding back a simulated set of travel times upon which to base a new set of paths. TM provides tools for running the simulation model iteratively and this methodology is referred to as Dynamic Traffic Assignment. The user can specify to run an assignment as opposed to running a single simulation and define the maximum number of assignment iterations to run as well as a desired level of convergence based on a relative gap measure. When running in assignment mode, TM runs multiple runs of the simulation model with the output link and movement times by time segment from one iteration automatically fed back and used for path building for the next iteration until the maximum number of iterations or convergence criteria is met. For this study the dynamic assignment was run for a total of 5 iterations which achieved a relative gap statistic of < 0.001.

3.0 Tier II Macroscopic Model Performance Measures

Performance measures from the macroscopic model that will be used to evaluate the performance of alternative transportation improvement strategies in the I-24 Corridor are presented in this section. The performance measure statistics presented herein provide a set of baseline statistics from which proposed improvement scenarios can be compared and evaluated in a subsequent phase of the study. Performance statistics are presented for two macroscopic model scenarios in this section: (1) Base Year 2010; and, (2) Future Year 2040 Baseline (forecasted 2040 travel demand assigned to the existing highway network).

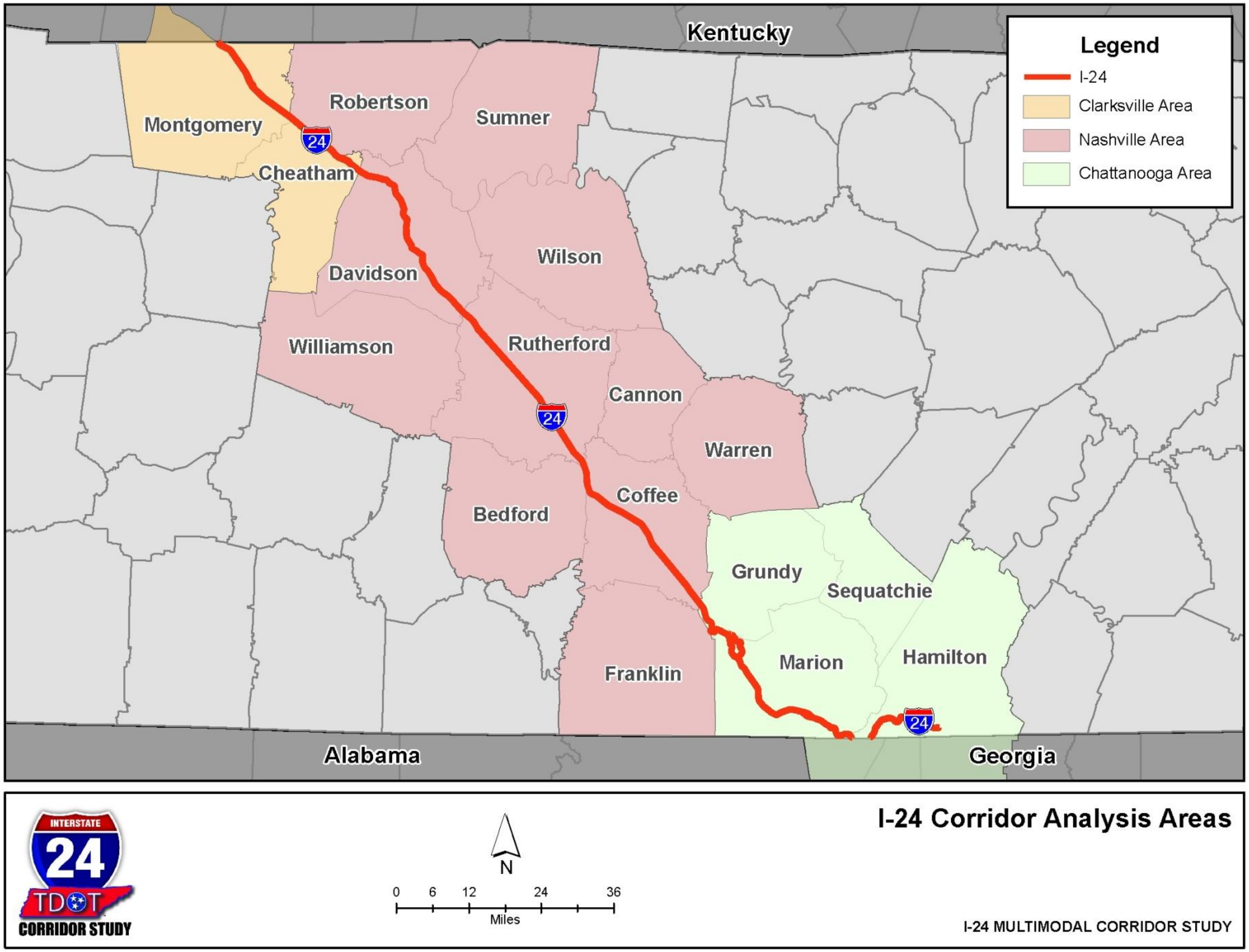
System-level performance measures are presented in this section, while performance measures pertaining to operating conditions on I-24 are reported in the next section. A list of the performance measures that are estimated from applying the I-24 Corridor macroscopic modeling procedure are listed below.

Number	Macroscopic Model Performance Measure	Variable Name
1	Daily Vehicle Miles of Travel (Total Vehicles)	DVMT
2	Daily Vehicle Miles of Travel per capita	DVMT/Person
3	Daily Vehicle Hours of Travel (Total Vehicles)	DVHT
4	Daily Vehicle Hours of Travel per capita	DVHT/Person
5	Daily Vehicle Hours of Delay	DVHD
6	Daily Vehicle Hours of Delay per 1,000 Vehicle Miles of Travel	DVHD/1000 VMT
7	Average Travel Speed in Miles Per Hour	MPH
8	Daily Truck Miles of Travel	Truck DVMT
9	Daily Truck Hours of Travel	Truck DVHT
10	Daily Truck Hours of Delay	Truck DVHD
11	Daily Truck Hours of Delay per 1,000 Truck Miles of Travel	Truck DVHD/1000 Truck VMT
12	Daily Operating Cost	DOC
13	Daily Travel Time Cost	DTTC
14	Distribution of Freight Moving In, Out and Thru the study area by mode (truck, rail and barge) in units of annual tons	Freight Distribution

Most of these performance statistics are tabulated by the three corridor areas used to disaggregate system-level model data by model subarea. Moreover, they are cross-tabulated for three functional classes of road facilities: (1) Interstates; (2) Arterials; and, (3) Collectors. The distribution of freight by mode is not broken down by corridor area. The boundary of each corridor analysis area is highlighted in Figure 3.0.

Baseline statistics produced by the Tier II consolidated I-24 Corridor macroscopic model are presented in this section for each of the performance measures listed above.

Figure 3.0: I-24 Corridor Analysis Areas



3.1 Daily Vehicle Miles of Travel (DVMT)

Total DVMT increased 75% corridor-wide from 2010 to 2040. The biggest jump occurs in the Clarksville area (99%) followed by the Nashville area (81%) and Chattanooga area (52%). In terms of absolute change, the highest increase occurs in the Nashville area which also has the highest concentration of freeways and roadway centerline miles.

Table 3.1: Estimated 2010 and 2040 DVMT by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Total DVMT (1,000's) 2010	2040	Percent Change
Clarksville	Interstates	1,065	2,295	115%
	Arterials	2,548	4,758	87%
	Collectors	644	1,416	120%
	Subtotal	4,256	8,469	99%
Nashville	Interstates	23,414	38,674	65%
	Arterials	19,970	34,502	73%
	Collectors	8,594	20,669	141%
	Subtotal	51,978	93,845	81%
Chattanooga	Interstates	7,988	12,111	52%
	Arterials	6,729	10,164	51%
	Collectors	2,147	3,291	53%
	Subtotal	16,864	25,567	52%
Corridor-wide Total		73,098	127,881	75%

Figure 3.1 presents a visual of 2010-2040 DVMT change by corridor area. While the Clarksville area exhibits the highest percent growth, the majority of increased DVMT occurs in the Nashville area.

3.2 Daily Vehicle Miles of Travel per Capita (DVMT/Person)

DVMT per capita figures in Table 3.2 are an attempt to transform the data in Table 3.1 to be more meaningful by relating to corridor area and corridor-wide population numbers. The total corridor-wide percent change after normalizing for population is 16% over the 30-year period. This is equivalent to 0.5% annual growth. This lower growth rate, in relation to growth shown in Table 3.1, is the marginal growth that would be attributable to normal population growth which is forecast at 1.2% annually in the corridor area.

Figure 3.1: Estimated 2010 and 2040 DVMT by Corridor Area (in 1000's)

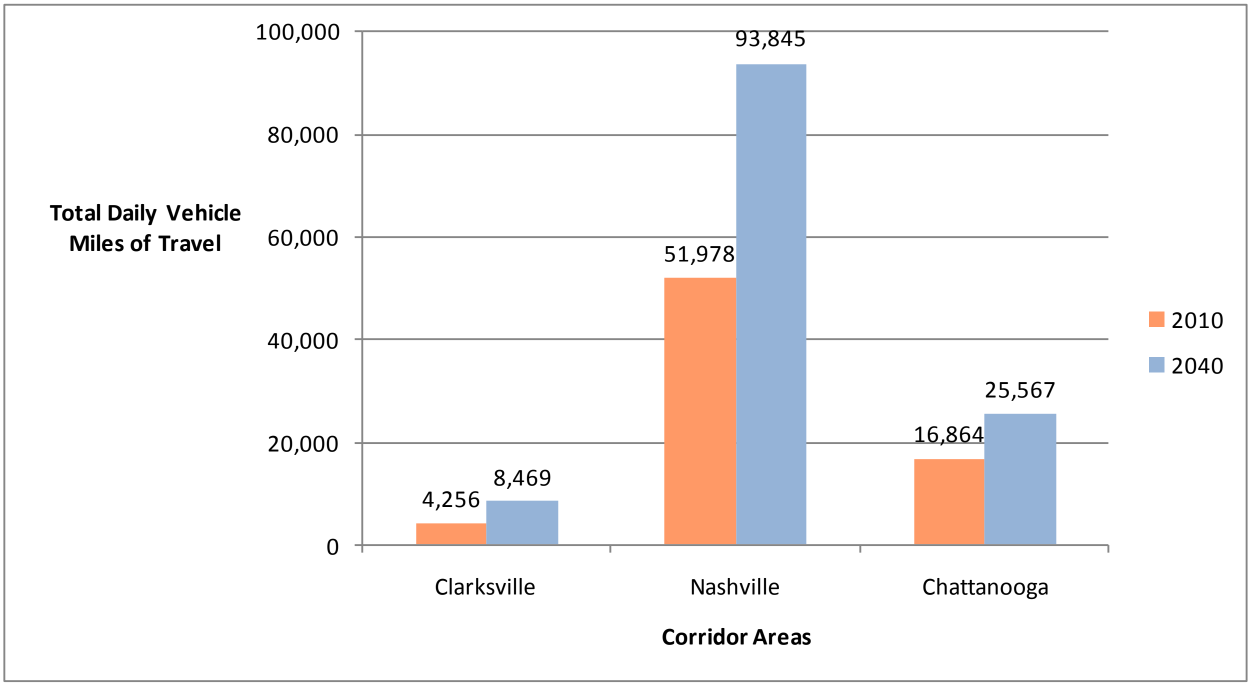
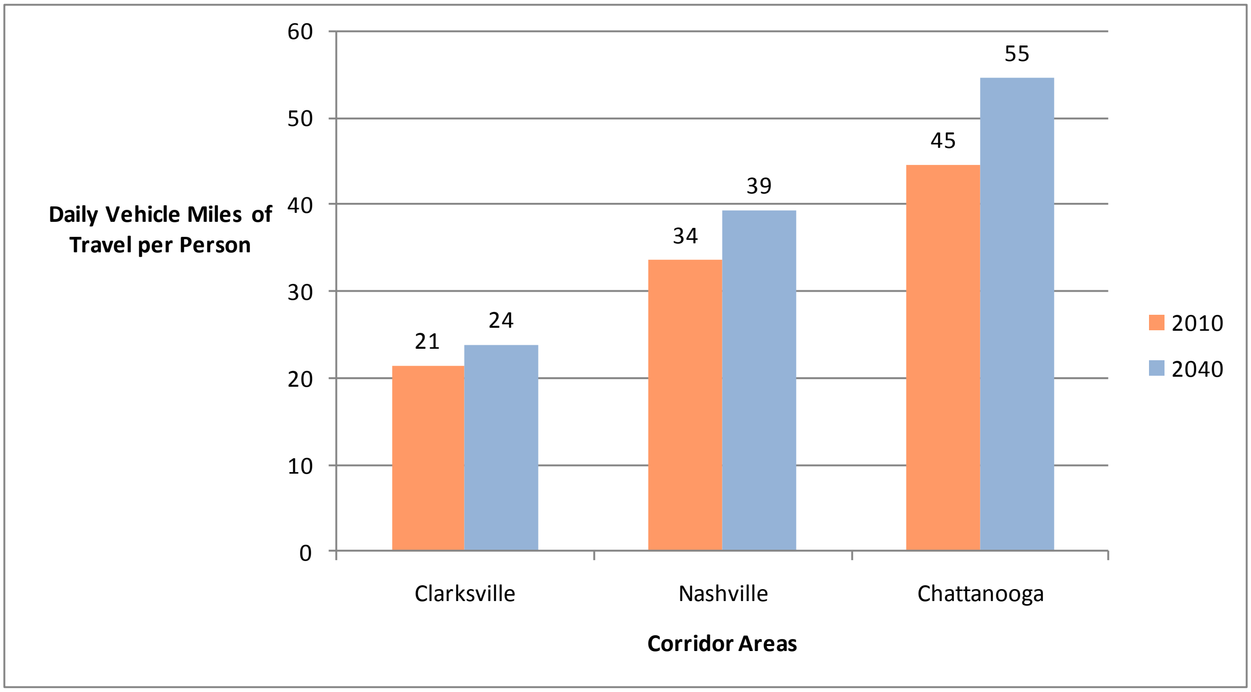


Table 3.2: Estimated 2010 and 2040 DVMT per Person by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	DVMT per Person		
		2010	2040	Percent Change
Clarksville	Interstates	5	6	21%
	Arterials	13	13	4%
	Collectors	3	4	23%
	Subtotal	21	24	11%
Nashville	Interstates	15	16	7%
	Arterials	13	14	12%
	Collectors	6	9	56%
	Subtotal	34	39	17%
Chattanooga	Interstates	21	26	22%
	Arterials	18	22	22%
	Collectors	6	7	24%
	Subtotal	45	55	22%
Corridor-wide Total		34	40	16%

Figure 3.2 visually depicts DVMT/Person across corridor areas. The Chattanooga area has the highest DVMT/Person growth among the three corridor areas. In terms of population growth, the Nashville area has the highest project population growth (49%) in the model analysis area. The Chattanooga area's population growth forecast (24%) was the lowest of the three corridor areas.

Figure 3.2: Estimated 2010 and 2040 DVMT per Person by Corridor Area



3.3 Daily Vehicle Hours of Travel (DVHT)

Modeled daily vehicle hours of travel (DVHT) for the 2010 and 2040 baseline conditions are reported in Table 3.3. DVHT measures the total amount of time that autos and trucks are traveling on the road system on a typical weekday. In understanding these highway system performance measures, it is critical to recognize that the baseline 2040 highway network contains no new roads or additional capacity than what is represented in the base year 2010 highway network. In contrast, future year 2040 travel demand was forecasted for the I-24 model study area using projected population, employment and future year land use plan maps.

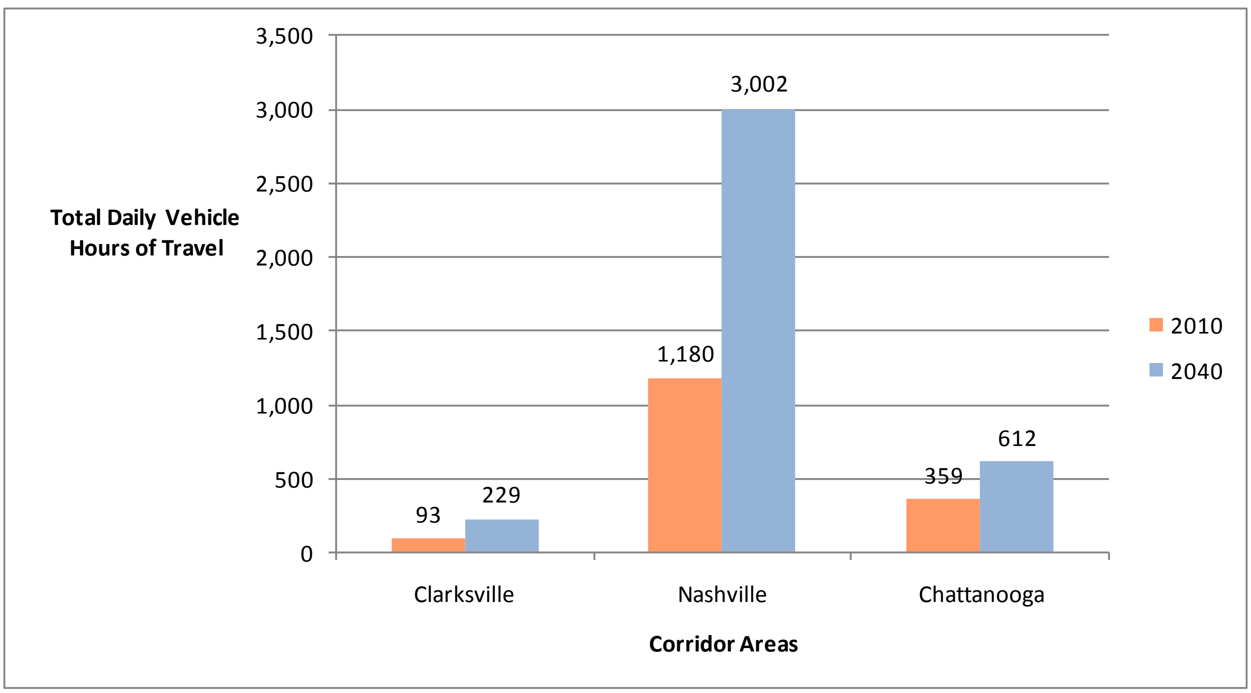
At the corridor-wide level, DVHT increases about 135%. The Nashville area is projected to experience the highest increase (154%), followed by the Clarksville area (146%) and Chattanooga area (70%).

Figure 3.3 shows 2010-2040 DVHT changes by corridor area. Congestion and delay is a significant factor in calculating DVHT. The particularly high DVHT projection for 2040 suggests that the Nashville area, in the baseline 2040 model scenario, has a high concentration of congested highways.

Table 3.3: Estimated 2010 and 2040 DVHT by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Total DVHT (1,000's) 2010	2040	Percent Change
Clarksville	Interstates	15	44	193%
	Arterials	62	146	135%
	Collectors	16	39	144%
	Subtotal	93	229	146%
Nashville	Interstates	415	998	140%
	Arterials	539	1,311	143%
	Collectors	226	693	207%
	Subtotal	1,180	3,002	154%
Chattanooga	Interstates	128	233	82%
	Arterials	177	289	63%
	Collectors	54	90	67%
	Subtotal	359	612	70%
Corridor-wide Total		1,632	3,843	135%

Figure 3.3: Estimated 2010 and 2040 DVHT by Corridor Area



3.4 Daily Vehicle Hours of Travel per Capita (DVHT/Person)

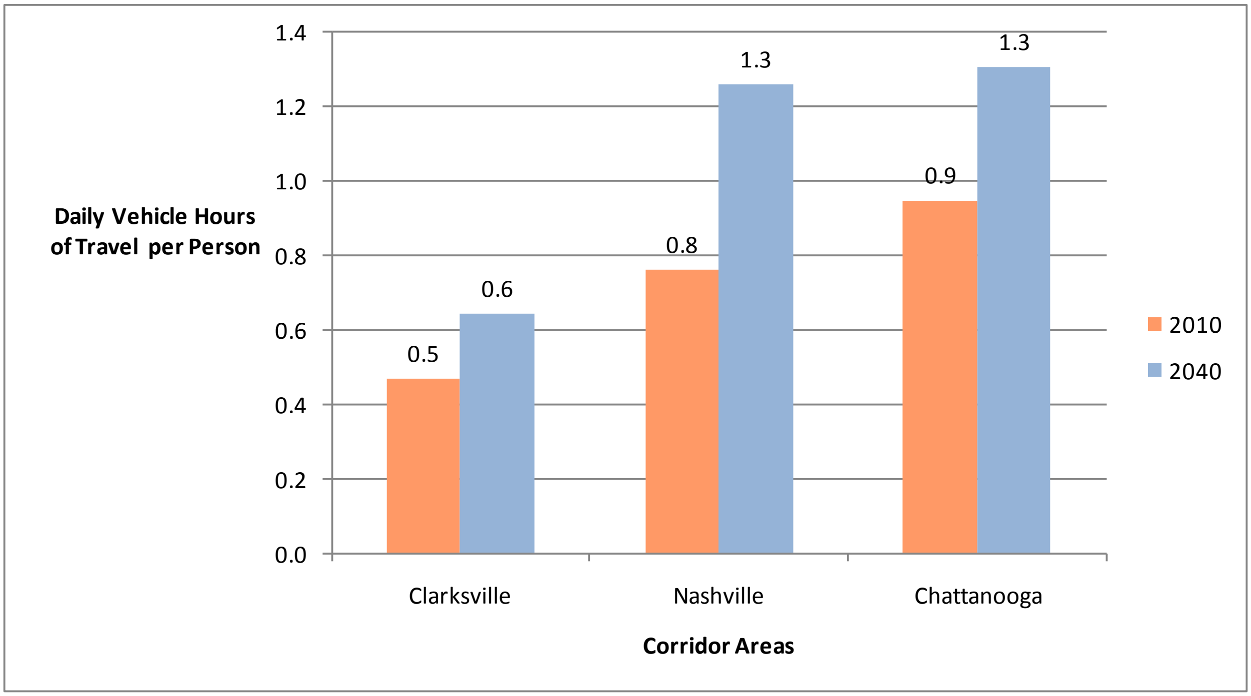
Base year 2010 and future year 2040 baseline daily vehicle hours of travel per person (DVHT per capita) data are presented in Table 3.4. This performance measure normalizes DVHT to account for projected population growth. As population increases during the 2010 to 2040 plan period, DVHT per capita is lower than ordinary DVHT. The modeled corridor-wide increase between 2010 and 2040 is (56%). The bulk of the growth occurs in the Nashville area (65%) and the Clarksville area accounts for the smallest (37%).

Table 3.4: Estimated 2010 and 2040 DVHT per Person by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	DVHT per Person 2010	DVHT per Person 2040	DVHT per Person Percent Change
Clarksville	Interstates	0.1	0.1	58%
	Arterials	0.3	0.4	32%
	Collectors	0.1	0.1	36%
	Subtotal	0.5	0.6	37%
Nashville	Interstates	0.3	0.4	56%
	Arterials	0.3	0.5	58%
	Collectors	0.1	0.3	99%
	Subtotal	0.8	1.3	65%
Chattanooga	Interstates	0.3	0.5	46%
	Arterials	0.5	0.6	32%
	Collectors	0.1	0.2	36%
	Subtotal	0.9	1.3	38%
Corridor-wide Total		0.8	1.2	56%

Figure 3.4 shows that the Chattanooga area has the highest DVHT per person among the three corridor areas for both 2010 and 2040. At the other end, the Clarksville area was forecast to experience the lowest DVHT per capita. This result may mean that there is a very high presence of pass-through traffic in Chattanooga in comparison with the other corridor areas. It could also mean that the Chattanooga area's hilly terrain could have a disproportionately negative impact on traffic conditions as travel demand increases, in comparison with Clarksville and Nashville.

Figure 3.4: Estimated 2010 and 2040 DVHT per Person by Corridor Area



3.5 Daily Vehicle Hours of Delay (DVHD)

Daily vehicle hours of delay (DVHD) is shown in Table 3.5 for 2010 and 2040. In the I-24 Corridor travel model, DVHD is calculated by subtracting DVHT (using free-flow link travel speeds) from DVHT (using average daily link travel speeds). It is very important to recognize that forecasted 2040 DVHD is predicated on using a future year 2040 highway network that does not contain any transportation improvements in comparison with the base year 2010 highway network.

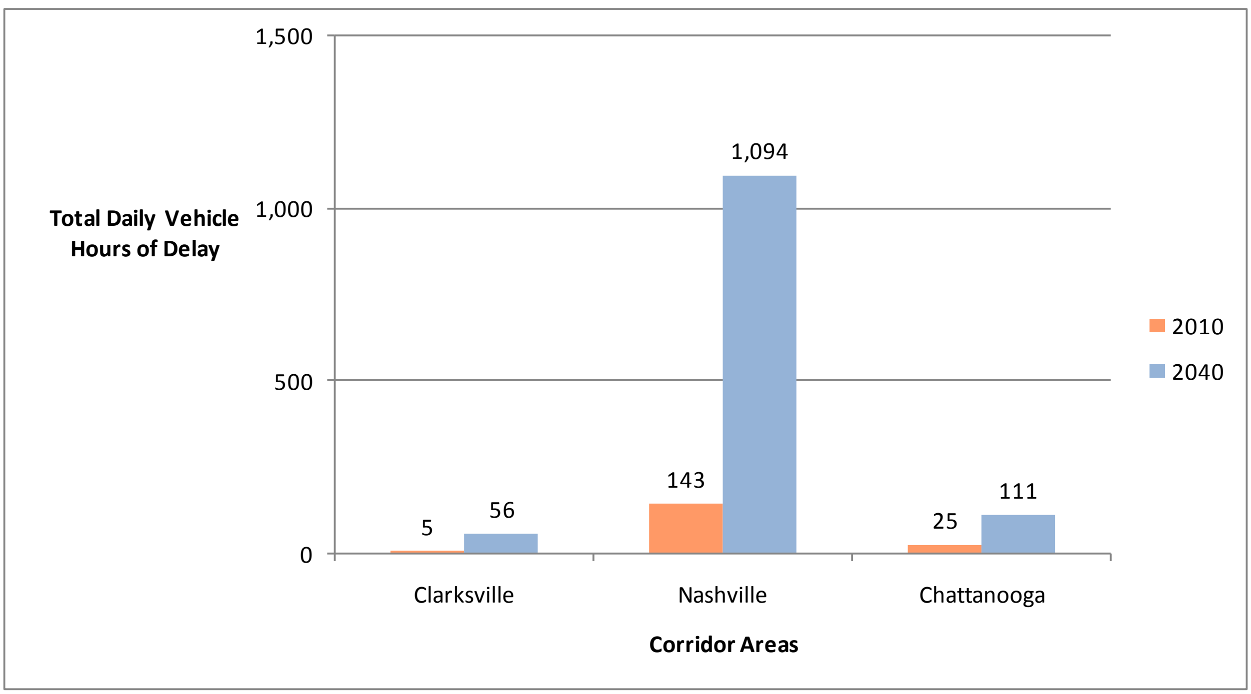
The projected corridor-wide DVHD increase was 629% between 2010 and future year 2040 indicating that there would be severe congestion throughout the corridor in the future. Of course, that is predicated on the false assumption that no transportation improvements would be implemented during that time frame. The highest increase is projected to occur in the Clarksville area, over ten (10) times the current level of delay. The rate of increase in Clarksville is partly due to its relatively low 2010 baseline figure. The Nashville area is forecast to experience six (6) times the existing level of delay while Chattanooga was forecast to experience three (3) times the current level of delay.

Figure 3.5 shows the absolute increase in daily traffic congestion delay across the three corridor areas between 2010 and 2040. These figures are presented in units of 1,000 hours. The amount of total delay in the Nashville area accounts for the majority of modeled delay in the I-24 model analysis area.

Table 3.5: Estimated 2010 and 2040 DVHD by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Total DVHD (1,000's) 2010	2040	Percent Change
Clarksville	Interstates	0	11	0%
	Arterials	4	39	875%
	Collectors	1	6	500%
	Subtotal	5	56	1020%
Nashville	Interstates	53	402	658%
	Arterials	74	503	580%
	Collectors	15	188	1153%
	Subtotal	143	1,094	665%
Chattanooga	Interstates	8	51	538%
	Arterials	16	49	206%
	Collectors	2	11	450%
	Subtotal	25	111	344%
Corridor-wide Total		173	1,261	629%

Figure 3.5: Estimated 2010 and 2040 DVHD by Corridor Area



3.6 Daily Vehicle Hours of Delay per 1,000 DVMT (DVHD/1,000 VMT)

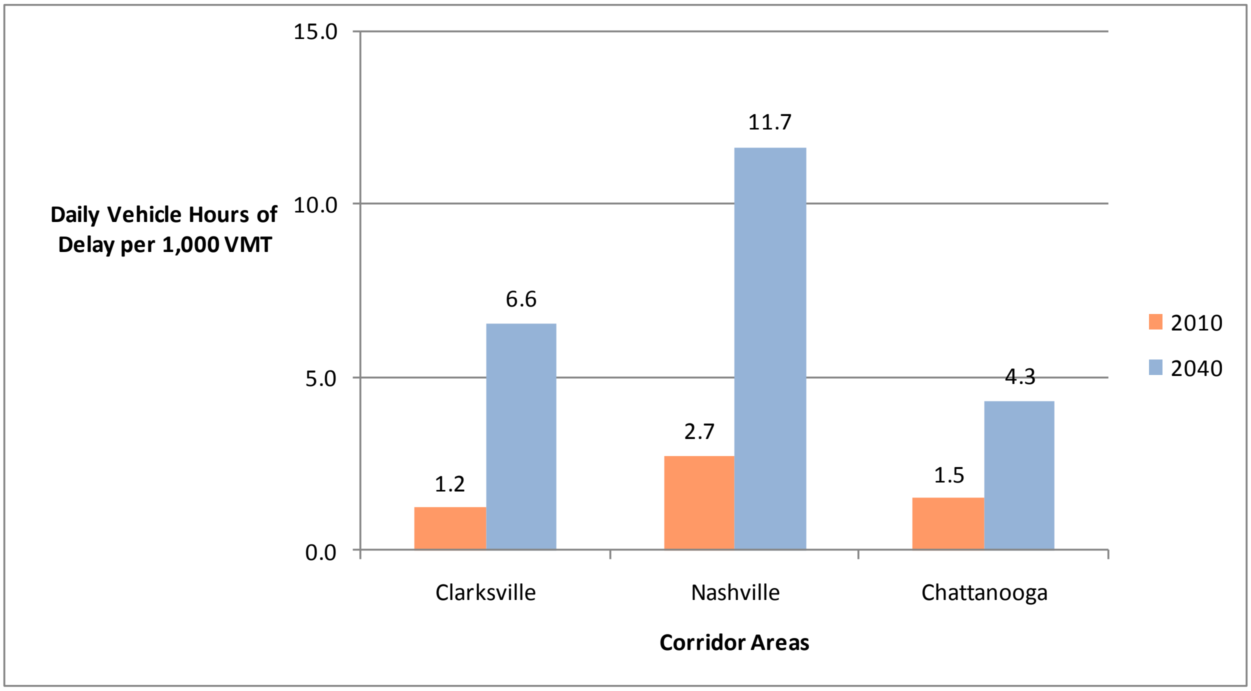
Since DVHD is highly correlated to the magnitude of modeled DVMT, a further analysis of DVHD was performed which normalizes the DVHD statistic for DVMT. Table 3.6 shows that the corridor-wide increase in modeled daily vehicle delay is 316%, over three (3) times higher than in the base year, per 1,000 DVMT. This performance measure shows that once overall travel demand in a road network starts to approach the design capacity of that road network, traffic congestion and delay will, in theory, increase exponentially. In real life, it is not clear what would happen since there clearly is insufficient capacity during peak weekday travel periods for all vehicle trips to fit on the road network.

Table 3.6: Estimated 2010 and 2040 DVHD per 1,000 DVMT by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	DVHD per 1,000 VMT		
		2010	2040	Percent Change
Clarksville	Interstates	0.2	4.7	1984%
	Arterials	1.6	8.1	408%
	Collectors	1.5	4.3	185%
	Subtotal	1.2	6.6	429%
Nashville	Interstates	2.3	10.4	359%
	Arterials	3.7	14.6	293%
	Collectors	1.8	9.1	410%
	Subtotal	2.7	11.7	325%
Chattanooga	Interstates	1.0	4.2	308%
	Arterials	2.3	4.8	109%
	Collectors	0.7	3.3	358%
	Subtotal	1.5	4.3	189%
Corridor-wide Total		2.4	9.9	316%

Figure 3.6 shows 2010 and 2040 DVHD per 1,000 DVMT for the three areas. The 11.7 thousand hours of delay per thousand VMT projected in the Nashville area still accounts for the majority of corridor-wide delay, even though it is normalized for VMT.

Figure 3.6: Estimated 2010 and 2040 DVHD per 1,000 DVMT by Corridor Area



3.7 Average Travel Speed

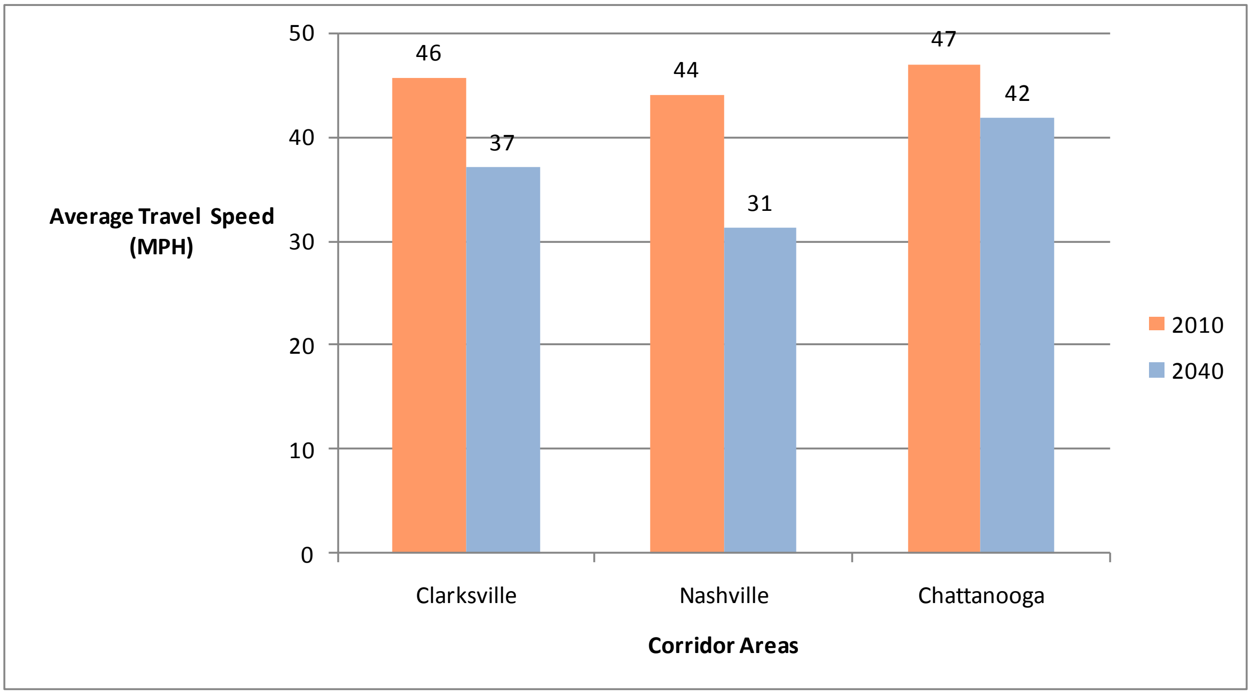
Rising levels of congestion lead to lower average daily operating speed in the I-24 model analysis network. Modeled average daily travel speeds by road functional class group are listed in Table 3.7 for 2010 and 2040. Overall, the corridor areas were forecast to experience a 26% reduction in average daily travel speed. The average daily speed reduction from 2010 to 2040 in the Nashville area is 29%. The biggest impact is on the Interstate System, where modeled travel speeds were forecast to fall by 24% in Clarksville, 31% in Nashville, and 16% in the Chattanooga area.

Figure 3.7 shows the 2010 to 2040 change in average daily travel speeds for the corridor areas that were produced by the travel model. These speeds represent weighted averages of the different road class groups. The sharpest average speed reductions between 2010 and 2040 were forecast in the Nashville area.

Table 3.7: Estimated 2010 and 2040 Average Travel Speed by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Average Travel Speed (MPH) 2010	2040	Percent Change
Clarksville	Interstates	69	53	-24%
	Arterials	41	33	-21%
	Collectors	40	36	-9%
	Average	46	37	-19%
Nashville	Interstates	56	39	-31%
	Arterials	37	26	-29%
	Collectors	38	30	-22%
	Average	44	31	-29%
Chattanooga	Interstates	62	52	-16%
	Arterials	38	35	-8%
	Collectors	40	36	-9%
	Average	47	42	-11%
Corridor-wide Average		45	33	-26%

Figure 3.7: Estimated 2010 and 2040 Average Travel Speed by Corridor Area



3.8 Daily Truck Miles of Travel (Truck DVMT)

Truck DVMT performance measure statistics are presented in Table 3.8. The corridor-wide Truck DVMT was forecasted to rise by 155% between 2010 and 2040, from 6.7 million to 17.2 million truck miles of travel. This is much higher than the 75% cumulative rate of change for total vehicle DVMT. The explanation for this could be that external to external (E-E) truck travel is a high growth segment of total truck travel. While there is abundant growth forecast for all three corridor areas, the Truck DVMT was forecast to increase the most inside the Nashville area at a rate of 168%. In the Clarksville area, a notable 300% gain in Truck DVMT was estimated on the Interstate system.

Table 3.8: Estimated 2010 and 2040 Truck DVMT by Corridor Area and Functional Class Group

		Truck DVMT (1000's)		
Corridor Area	**Functional Class Group**	**2010**	**2040**	**Percent Change**
Clarksville	Interstates	235	939	300%
	Arterials	214	289	35%
	Collectors	51	62	22%
	Subtotal	500	1,290	158%
Nashville	Interstates	3,420	9,474	177%
	Arterials	693	1,572	127%
	Collectors	143	362	153%
	Subtotal	4,256	11,408	168%
Chattanooga	Interstates	1,674	3,946	136%
	Arterials	260	454	75%
	Collectors	66	115	74%
	Subtotal	2,000	4,515	126%
Corridor-wide Total		6,756	17,213	155%

Modeled changes in Truck DVMT from 2010 to 2040 are illustrated using a bar diagram in Figure 3.8. Nashville area Truck DVMT was forecast to increase from 4.3 million to 11.4 million daily truck miles of travel. Nashville area truck statistics show that the concentration of trucks using the region's Interstate system is anticipated to sharply increase in the future.

3.9 Daily Truck Hours of Travel (Truck DVHT)

Truck DVHT performance measure statistics are presented in Table 3.9. Corridor-wide, truck DVHT was forecasted to rise 244% between 2010 and 2040, from 125.3 thousand to 431.1 thousand hours of travel per day. Modeled 2040 truck DVHT on the Interstate/Freeway system in Nashville alone is projected at 235.6 thousand vehicle hours per day. In terms of percentage change on Interstates between 2010 and 2040, modeled truck DVHT in the Clarksville area grew the most at 420%.

Figure 3.8: Estimated 2010 and 2040 Truck DVMT by Corridor Area (in 1,000's)

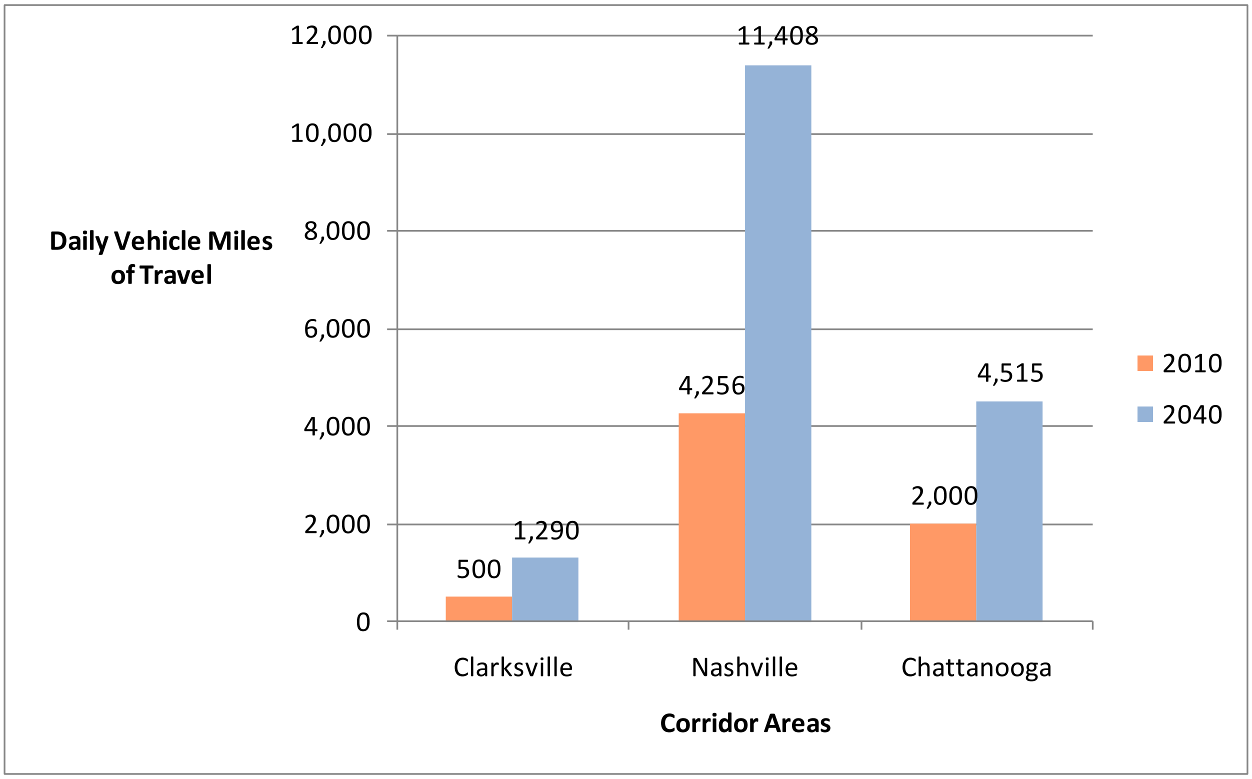
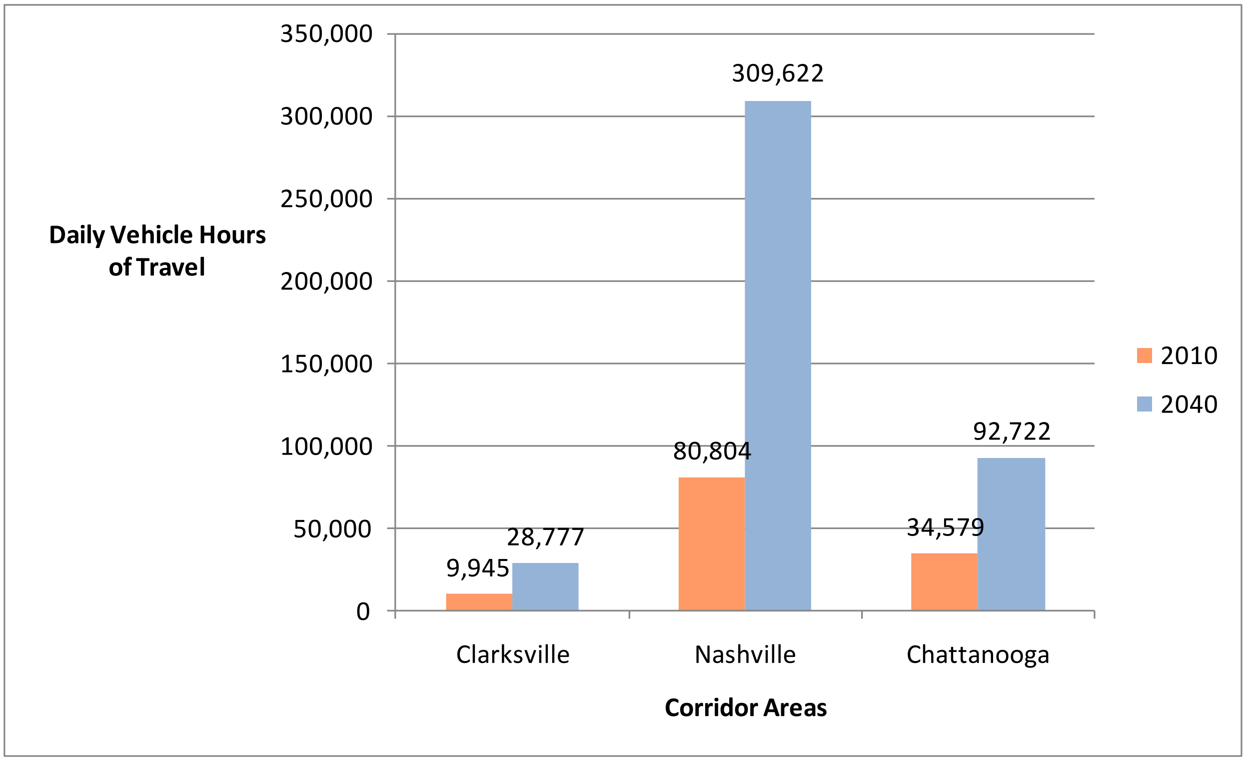


Table 3.9: Estimated 2010 and 2040 Truck DVHT by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Truck DVHT 2010	Truck DVHT 2040	Truck DVHT Percent Change
Clarksville	Interstates	3,410	17,745	420%
	Arterials	5,229	9,135	75%
	Collectors	1,306	1,897	45%
	Subtotal	9,945	28,777	189%
Nashville	Interstates	58,710	235,595	301%
	Arterials	18,310	61,173	234%
	Collectors	3,784	12,854	240%
	Subtotal	80,804	309,622	283%
Chattanooga	Interstates	26,321	76,051	189%
	Arterials	6,592	13,586	106%
	Collectors	1,666	3,085	85%
	Subtotal	34,579	92,722	168%
Corridor-wide Total		125,328	431,121	244%

A visual image of modeled DVHT on all roads in the study corridor between 2010 and 2040 is displayed in Figure 3.9 for each corridor area in a bar chart format. The bar showing 309.6 thousand estimated DVHT in Nashville for future year 2040 shows how truck traffic converges in Nashville and how average daily travel speeds on the Interstate system are forecast to decline between 2010 and 2040.

Figure 3.9: Estimated 2010 and 2040 Truck DVHT by Corridor Area



3.10 Daily Truck Hours of Delay (Truck DVHD)

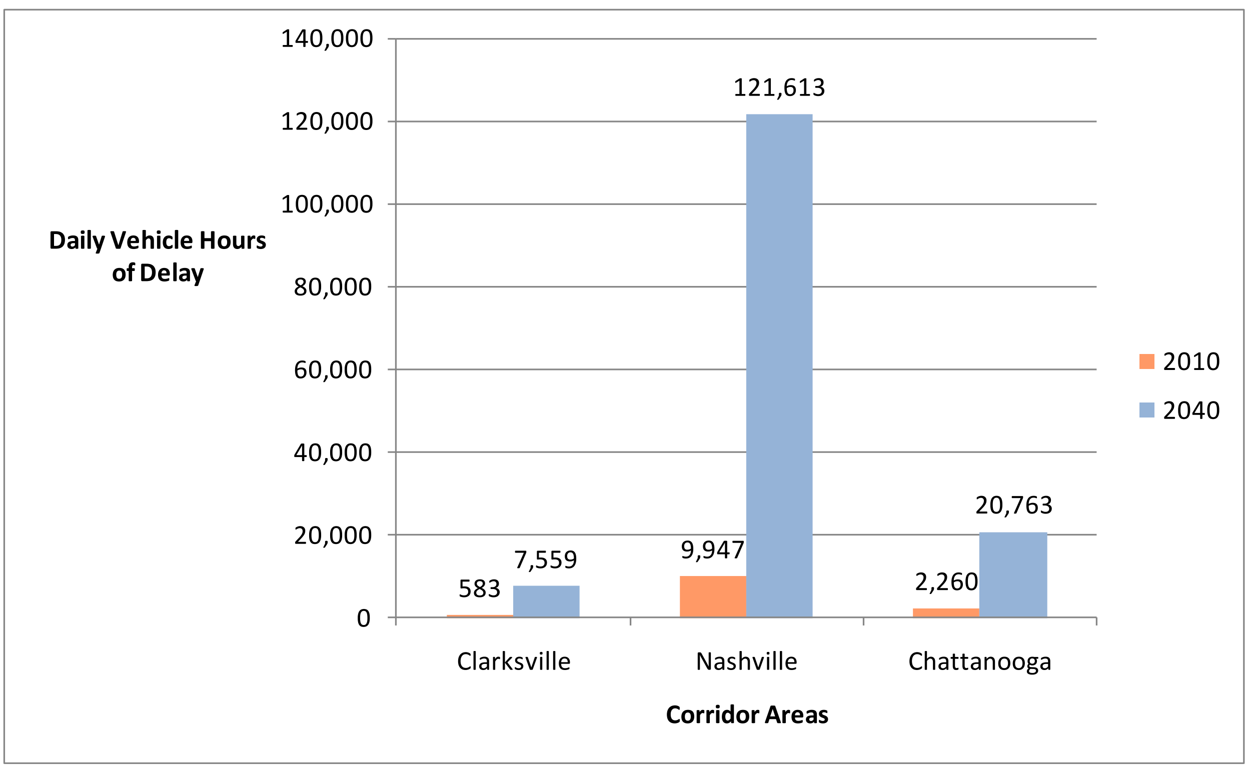
Daily truck hours of delay (DVHD) for base year 2010 and future year 2040 are presented in Table 3.10 by corridor area. Corridor-wide truck DVHD was forecasted to increase more than ten times between 2010 and 2040. Modeled DVHD in 2010 of 12.8 thousand truck delay hours was projected to climb to 149.9 thousand hours in 2040, a 1072% cumulative growth rate of truck delay. Of the three corridor areas, the magnitude of change was estimated to be highest in Nashville where modeled truck delay rose by more than 100 thousand hours. The 7.6 thousand hours of truck delay forecasted in Clarksville for 2040 was associated with the highest relative growth of the three areas, at 1197%.

A visual image of modeled truck DVHD on all roads in the study corridor between 2010 and 2040 is displayed in Figure 3.10 for each corridor area in a bar chart format. The bar showing 121.6 thousand hours of truck delay in Nashville for future year 2040 reinforces how trucks congregate on the Nashville area's road system and how average daily operating speeds on those roads are projected to decline. It is important to recognize that no planned transportation improvements are included in the future year 2040 highway network that was used in this model scenario.

Table 3.10: Estimated 2010 and 2040 Truck DVHD by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Truck DVHD 2010	2040	Percent Change
Clarksville	Interstates	50	4,335	8570%
	Arterials	450	2,827	528%
	Collectors	83	397	378%
	Subtotal	583	7,559	1197%
Nashville	Interstates	6,573	91,011	1285%
	Arterials	3,070	26,591	766%
	Collectors	304	4,011	1219%
	Subtotal	9,947	121,613	1123%
Chattanooga	Interstates	1,543	17,523	1036%
	Arterials	658	2,966	351%
	Collectors	59	274	364%
	Subtotal	2,260	20,763	819%
Corridor-wide Total		12,790	149,935	1072%

Figure 3.10: Estimated 2010 and 2040 Truck DVHD by Corridor Area



3.11 Daily Truck Hours of Delay Per 1,000 Truck VMT (Truck DVHD/1,000 VMT)

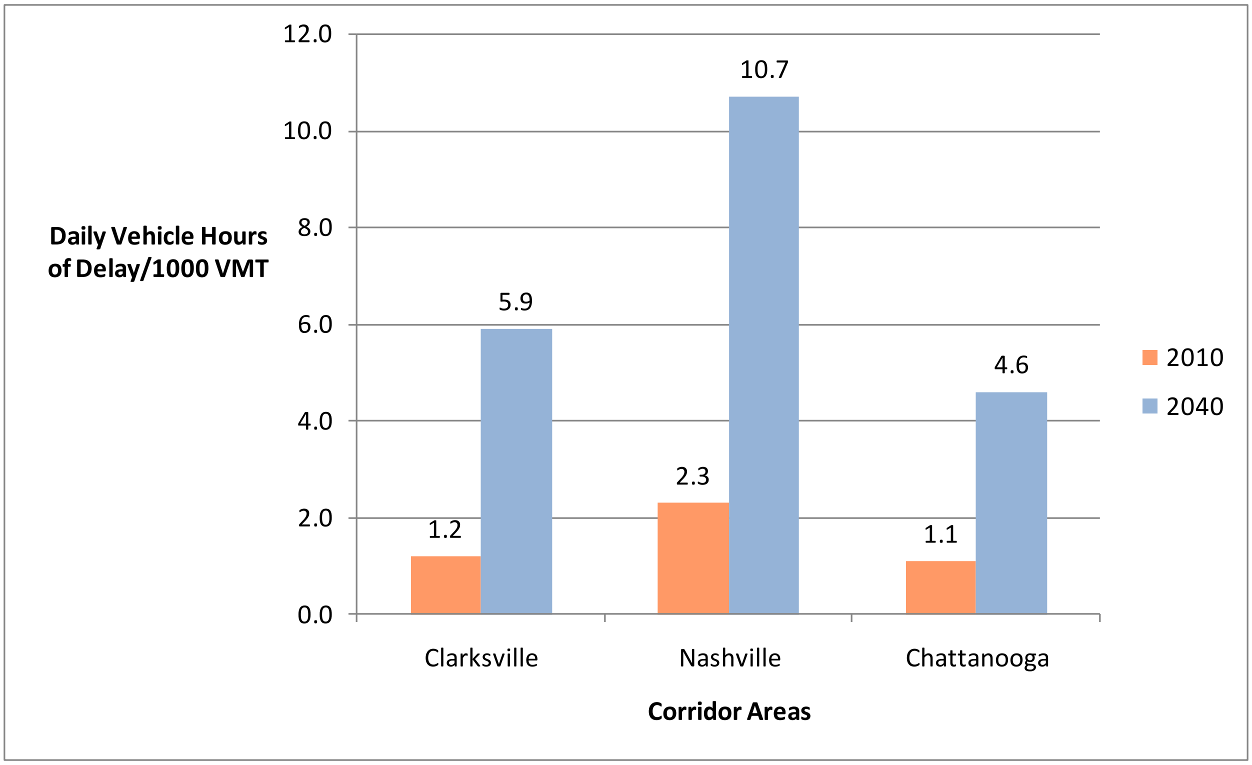
Daily truck hours of delay per 1,000 truck VMT (DVHD/1,000 VMT) for base year 2010 and future year 2040 are presented in Table 3.11 by corridor area. This variant of truck DVHD is an attempt to show similar results to the DVHD performance measure, but normalized to account for the correlation with truck VMT. The modeled relative growth figure of 2090% in DVHD/1,000 VMT on Interstate facilities in the Clarksville area was a striking change.

Table 3.11: Estimated 2010 and 2040 Truck DVHD/1000 Truck VMT by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Truck DVHD/1000 Truck VMT 2010	2040	Percent Change
Clarksville	Interstates	0.2	4.6	2090%
	Arterials	2.1	9.8	367%
	Collectors	1.7	6.4	276%
	Subtotal	1.2	5.9	392%
Nashville	Interstates	1.9	9.6	405%
	Arterials	4.4	16.9	284%
	Collectors	2.1	11.1	429%
	Subtotal	2.3	10.7	365%
Chattanooga	Interstates	0.9	4.4	389%
	Arterials	2.5	6.5	160%
	Collectors	0.9	2.4	167%
	Subtotal	1.1	4.6	318%
Corridor-wide Total		1.9	8.7	357%

A visual image of modeled truck DVHD/1,000 truck VMT on all roads in the study corridor between 2010 and 2040 is displayed in Figure 3.11 for each corridor area. The relative magnitude of bars representing 2040-level truck DVHD/1,000 VMT are different from their un-normalized counterparts shown earlier. The bar showing 10.7 hours of truck delay per 1,000 VMT in Nashville for future year 2040 is not as large in relation to Clarksville and Chattanooga in comparison with the un-normalized bar chart.

Figure 3.11: Estimated 2010 and 2040 Truck DVHD/1000 Truck VMT by Corridor Area



3.12 Daily Operating Costs for Total Vehicles

Daily operating costs for all vehicles computed from the base year 2010 and future year 2040 model scenarios are presented in Table 3.12 by corridor area. Looking at the entire corridor, 2010 operating costs for a typical weekday were estimated to be $12.5 million. The projection for 2040 climbed up to $23.8 million which resulted in a 90% cumulative increase between 2010 and 2040. The Nashville area's estimated 2040-level daily operating cost of $17.0 million was clearly the largest of the three corridor areas. In terms of relative growth between 2010 and 2040, Clarksville was projected to experience the highest cumulative rate of 113%.

Table 3.12: Estimated 2010 and 2040 Daily Operating Costs for All Vehicles by Corridor Area and Functional Class Group

Corridor Area	Functional Class Group	Total Vehicle Operating Costs		
		2010	2040	Percent Change
Clarksville	Interstates	$230,934	$650,924	182%
	Arterials	$428,772	$761,428	78%
	Collectors	$107,133	$218,155	104%
	Subtotal	$766,839	$1,630,507	113%
Nashville	Interstates	$4,456,262	$8,718,045	96%
	Arterials	$3,011,915	$5,336,400	77%
	Collectors	$1,241,052	$2,991,248	141%
	Subtotal	$8,709,229	$17,045,693	96%
Chattanooga	Interstates	$1,700,224	$3,077,775	81%
	Arterials	$1,024,035	$1,568,950	53%
	Collectors	$320,864	$496,786	55%
	Subtotal	$3,045,123	$5,143,511	69%
Corridor-wide Total		$12,521,191	$23,819,711	90%

Daily operating costs estimated for all vehicles in base year 2010 and future year 2040 are presented graphically in Figure 3.12 by corridor area. At the high end of the cost scale, projected daily operating costs grew the most in Nashville from 2010 to 2040 rising by more than $8 million per day. In Chattanooga and Clarksville, these changes were a little over $2 million and below $1 million, respectively. These statistics are highly related to total DVMT and truck DVMT.

3.13 Daily Travel Time Costs for Total Vehicles

Daily travel time costs for all vehicles computed from the base year 2010 and future year 2040 model scenarios are presented in Table 3.13 by corridor area. Modeled estimates for the time cost of travel were dependent on values of time (VOTs) for autos and trucks. The estimate for auto time is partially dependent on average composite wage rates in the region of analysis and also reflects a higher vehicle occupancy factor than for trucks. The hourly rate for time in trucks is more directly related to the local wage rate for persons employed in the trucking industry. Values of time used in these calculations were:

- Autos - $23/hour; and,
- Trucks - $35/hour.

Modeled 2010 and 2040 travel time costs for total vehicles are presented in Table 3.13, subdivided by generalized road class and corridor area. Throughout the entire corridor, travel time costs were forecast to increase by 140% from 2010 to 2040, climbing from $39.0 million in

Figure 3.12: Estimated 2010 and 2040 Daily Vehicle Operating Costs by Corridor Area

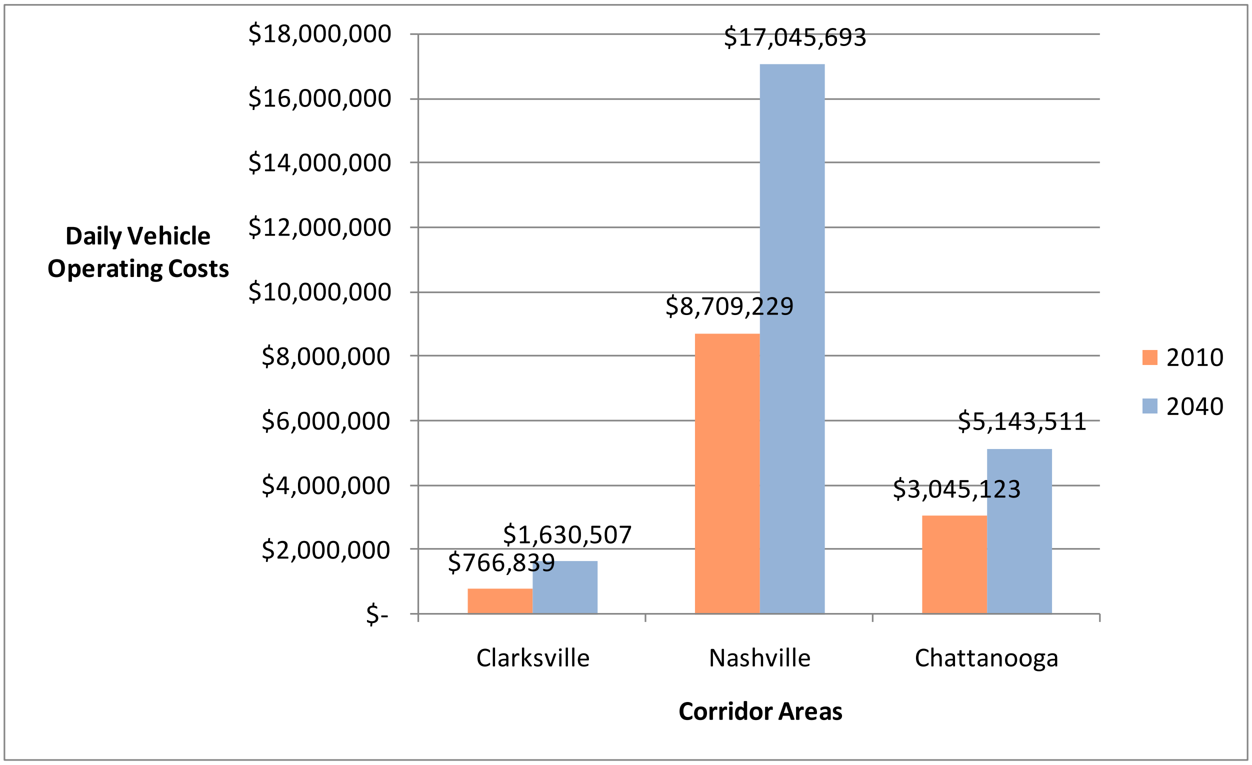


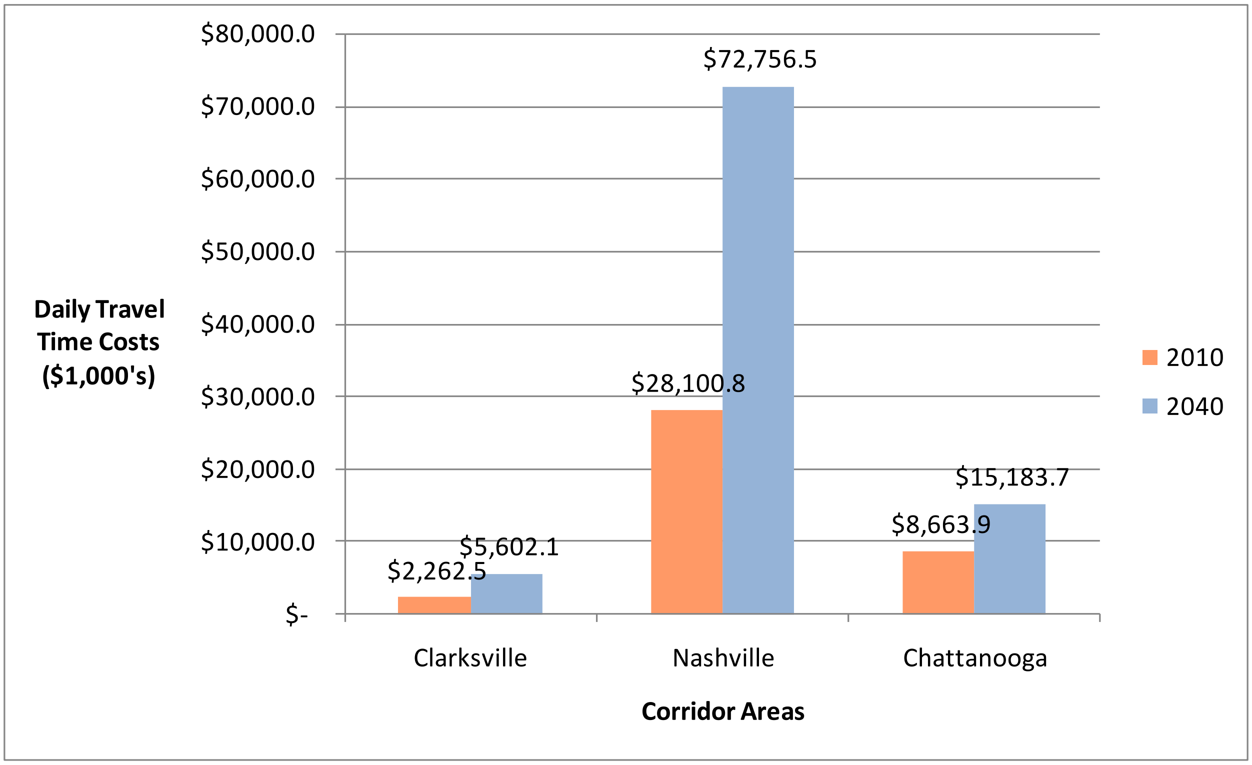
Table 3.13: Estimated 2010 and 2040 Daily Travel Time Costs by Corridor Area and Functional Class Group (in $1000's)

Corridor Area	Functional Class Group	Total Travel Time Costs ($1000's) 2010	2040	Percent Change
Clarksville	Interstates	$396.4	$1,217.4	207%
	Arterials	$1,478.0	$3,458.3	134%
	Collectors	$388.1	$926.4	139%
	Subtotal	$2,262.5	$5,602.1	148%
Nashville	Interstates	$10,238.2	$25,786.7	152%
	Arterials	$12,619.9	$30,884.1	145%
	Collectors	$5,242.7	$16,085.7	207%
	Subtotal	$28,100.8	$72,756.5	159%
Chattanooga	Interstates	$3,270.0	$6,260.6	91%
	Arterials	$4,142.5	$6,812.0	64%
	Collectors	$1,251.4	$2,111.1	69%
	Subtotal	$8,663.9	$15,183.7	75%
Corridor-wide Total		$39,027.2	$93,542.3	140%

2010 to $93.5 million in 2040. The Nashville area accounted for approximately $45 million of the corridor-wide average daily travel time cost in the model analysis area. Chattanooga and Clarksville were forecast to experience $6.5 million and $3.3 million travel time increases, respectively.

Total travel time costs for all vehicles are displayed graphically by corridor area in Figure 3.13 for base year 2010 and future year 2040. Modeled average daily travel time costs in the corridor are dominated by the Nashville area. Nashville's 2010 and 2040 travel time costs were estimated to be $28.1 million and $72.8 million, respectively.

Figure 3.13: Estimated 2010 and 2040 Daily Travel Time Costs by Corridor Area



3.14 Distribution of Commodity Flow by Mode (in annual tons of cargo)

This performance measure is defined to include commodities shipped into, out of and through the I-24 Corridor model analysis area. The source of information used to calculate the mode distribution of freight shipments by tonnage is called the Transearch commodity flow database. It was prepared by a third party vendor, IHS Global Insight, Inc. in 2008. The database includes origin-destination commodity flow tables by mode for a base year of 2007 and future planning year of 2035. In this analysis, the Transearch commodity flow tables for 2007 were used to represent 2010. This was considered a reasonable simplification since the movement of goods throughout the United States was affected for several years by a recession that began in 2007. Commodity flow forecasts in the 2035 Transearch tables were increased by a factor of 10% to represent the future year 2040 in the I-24 Multimodal Corridor Study.

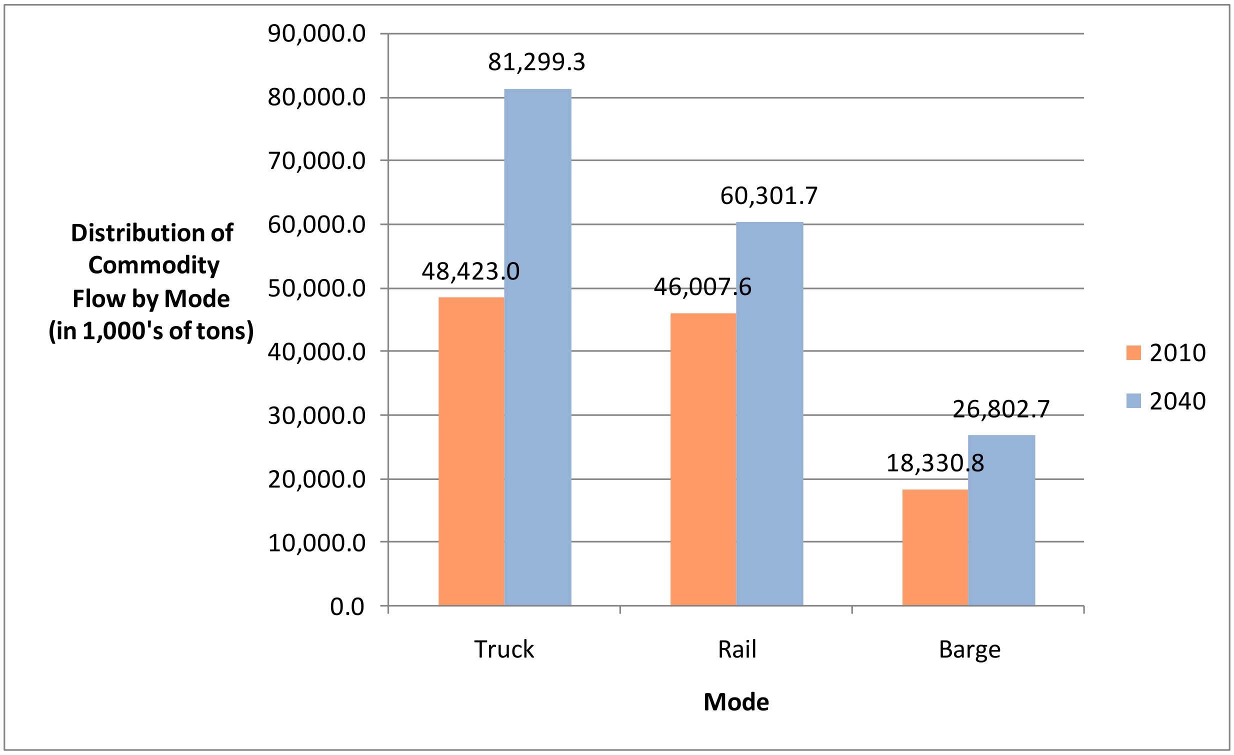
A list of freight mode splits, according to annual commodity flow tonnage moving into, out, and through the study area is presented in Table 3.14 for base year 2010 and future year 2040. The distribution 'percentages' of freight by mode are the performance measures of interest. The Transearch commodity flow data tables show a modest shift in baseline mode split between trucks and rail comparing 2010 to 2040. The 2010 mode share for trucks is 43%, and rises to 48% in 2040. In contrast, the rail mode share drops from 41% in 2010 to 36% in 2040.

Table 3.14: Distribution of Freight by Mode (in annual tons)

Transport Mode	Annual Tons of Commodity Flow (1,000's)			
	2010		2040	
	Commodity Flow	Mode Share	Commodity Flow	Mode Share
Truck	48,423.0	43%	81,299.3	48%
Rail	46,007.6	41%	60,301.7	36%
Barge	18,330.8	16%	26,802.7	16%
Total	112,761.4		168,403.7	

Mode split tonnages for 2010 and 2040 are displayed in Figure 3.14 by means of a bar chart. Annual freight movements by tonnage are expected to increase from 2010 to 2040 for all freight modes. The 32.9 million more tons of additional cargo projected to be shipped by truck in 2040 exemplifies the high end of that growth. Rail and barge shipments are expected to increase by 14.3 million and 8.5 million annual tons, respectively.

Figure 3.14: Distribution of Freight by Mode (in annual tons)



4.0 Mesoscopic Model Performance Measures

This section presents performance measures for the I-24 Corridor based on results from the existing conditions (i.e., 2010) mesoscopic model output. TransModeler produces summary statistics of simulation results at various levels of aggregation as shown below:

Name	Selection Layer	Contents
Trip Statistics	n/a	Number of Trips, Average Trip Length, Vehicle Miles Traveled, Vehicle Hours Traveled, Average Speed, Total Delay, Average Delay, Total Stopped Time, Average Stopped Time, Total Number of Stops, Average Number of Stops
Flow & Travel Time	Segments	Vehicle Flow, Average Speed, Standard Deviation of Speed, Average Density, Number of Vehicles, Total Travel Time, Average Travel Time, Standard Deviation of Travel Time
Delay	Nodes/Links	Total Delay, Average Delay, Total Stopped Time, Average Stopped Time, Total Number of Stops, Average Number of Stops
Lane Queue	Nodes	Average Queue Length, Maximum Queue Length, Average Number of Vehicles Queued, Maximum Number of Vehicles Queued, Percent Spillback
Spillback Tree	Nodes	Total Vehicles Queued, Length of Longest Queue, Number of Vehicles in Longest Queue

Source: TransModeler product documentation, Caliper Inc.

The basic units of analysis in TM are the segment, where segment travel times are computed and the node where the movement times are computed. All of the available model performance measures can be reported at this basic level of analysis. When running a simulation, one of the input definitions is what set of outputs are required. If an output type is not selected when setting up the simulation project then this output data in not captured and summarized in the output data files. TM provides an output manager tool that allows the user to select output reports of various types.

4.1 Trip Level Performance Measures

Table 4.1 presents summary performance measures at the trip based level by model time interval for the entire I-24 Corridor. The numbers of trips in the table by interval are the number of completed trips during the interval. Complete trips are trips that reach their destination zone during the interval. Some completed trips may have departed their origin zone in prior time intervals. Incomplete trips at the end of the model period are trips still in route to their destination zone at the end of the model period. Loaded trips are trips loaded at the origin zone but, due to delay on their first entry link to the network, experience some delay in loading onto the network that extends beyond the end of the model period and thus do not actually begin their journey. Because these loaded trips do have a path associated with them, the statistics reported for these trips represent statistics that would accumulate beyond the end of the model period. Queued trips represent those trips that experienced queuing during their journey.

Table 4.1: Trip Level Performance Measures in the 2010 Peak Period by Model Time Segment

Interval	Time	Trips	VMT	Average Speed	VHD	Average Delay (min/mi)	VHT	Trip Length (mi)
1	15:20	26,590	88,125	57	172	0.23	1,556	3.3
2	15:40	36,160	202,807	59	329	0.20	3,420	5.6
3	16:00	37,606	251,113	59	438	0.21	4,235	6.7
4	16:20	39,668	262,503	58	576	0.26	4,548	6.6
5	16:40	40,102	267,740	55	798	0.32	4,849	6.7
6	17:00	42,782	292,904	52	1,257	0.42	5,683	6.8
7	17:20	44,109	335,003	50	1,607	0.52	6,650	7.6
8	17:40	42,873	356,785	47	2,189	0.75	7,543	8.3
9	18:00	37,652	321,716	43	2,627	0.94	7,448	8.5
Incomplete		26,896	569,705	43	5,032	n/a	13,315	21.2
Loaded		7,718	119,178	58	99	n/a	2,070	15.4
Queued		7,843	n/a	n/a	2,172	n/a	2,172	n/a
Total		389,999	3,067,579	50	17,297		63,489	8.2

The performance measures presented in Table 4.1 include Vehicle Miles of Travel (VMT), Average Speed (mph), Vehicle Hours of Delay (VHD), Average Delay (min/mi), Vehicle Hours of Travel (VHT) and Average Trip Length (mi). For queued trips, the VHD and VHT are the same and represent the delay for these trips associated with time spent in the queue. VMT grows consistently across the PM peak period only declining in the final time interval after two successive intervals of lower trip activity. Average speeds are fairly stable until about 5:00PM when growing congestion levels begin to impact speeds. The reduction in average speed across the final hour of the peak period is mirrored by the growth in VHD and VHT across the final hour of the period. Average trip lengths grow across the entire model period and this should be expected given the overall length of the corridor. Short trips will almost entirely complete their journey in the same or next time interval in which they began. Longer distance trips may not complete their journey for several time intervals following their departure time interval tending to elevate average trip lengths for completed trips in later time intervals. Figures 4.1 through 4.3 provide charts of the relationships in Table 4.1 for VMT, average speed and VHD.

Figure 4.1: Total Vehicle Miles of Travel by 2010 Peak Period Time Interval

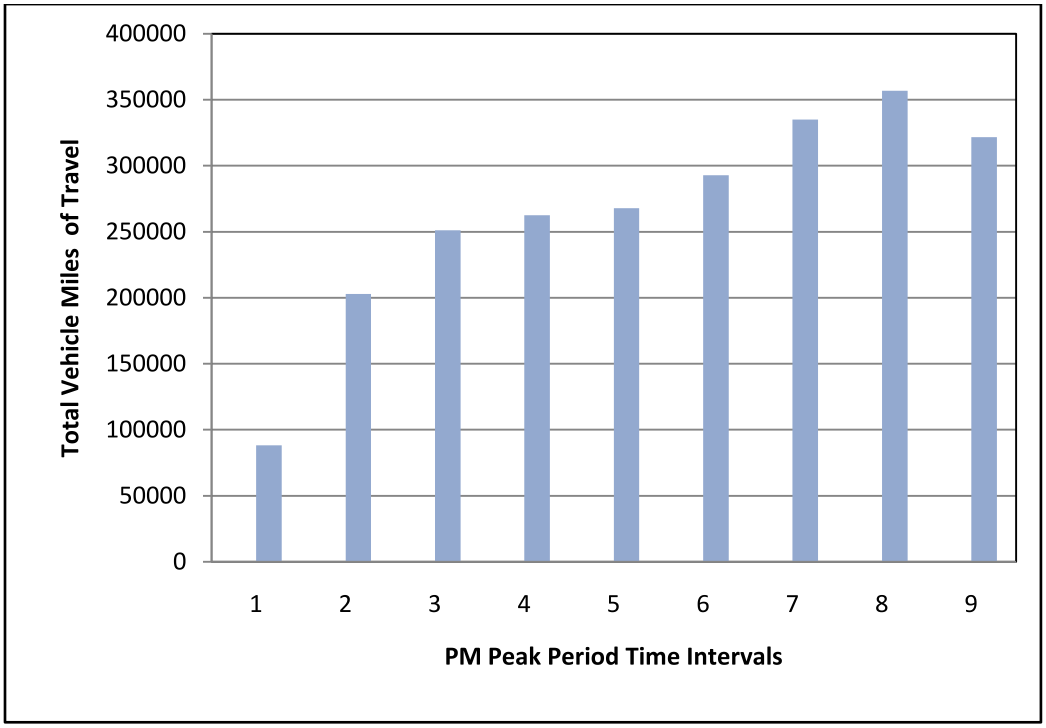


Figure 4.2: Average Speed by 2010 Peak Period Time Interval

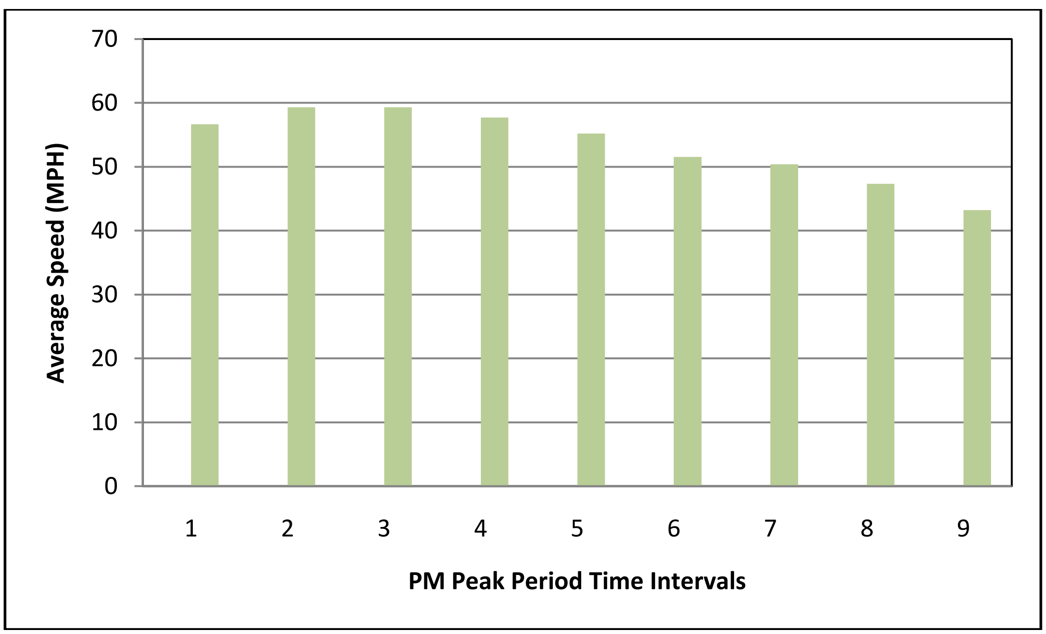
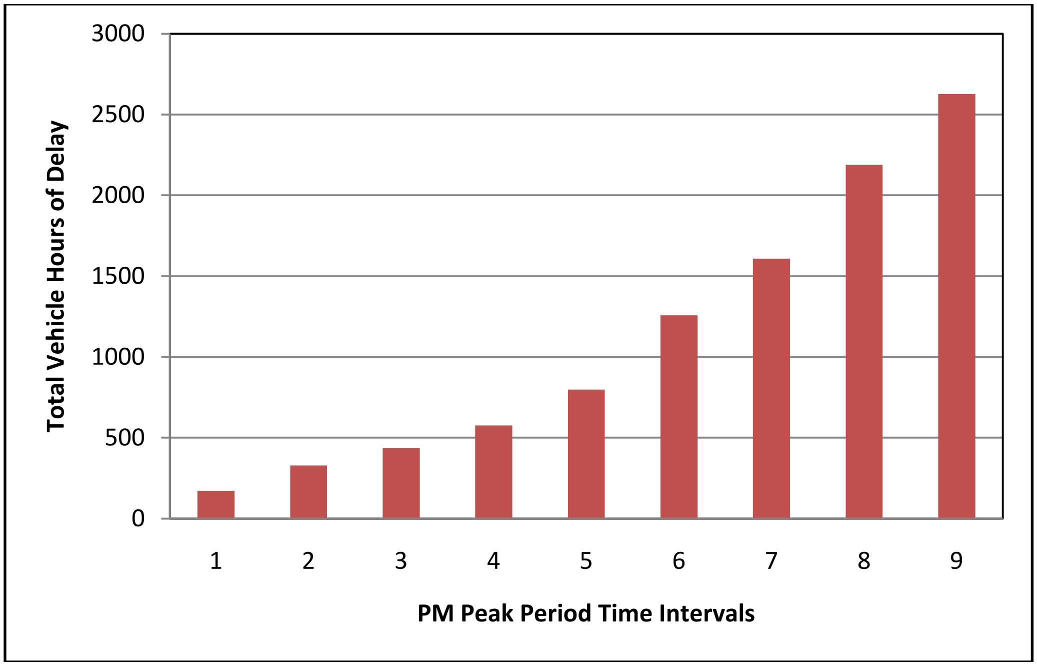


Figure 4.3: Total Vehicle Hours of Delay by 2010 Peak Period Time Interval



4.2 Segment Level Performance Measures

The I-24 Corridor mesoscopic modeling network contains 1,457 model segments and 1097 nodes. Generating output reports at the segment or node level produces hundreds of pages of output. For this study, the main area of interest is the performance of mainline I-24 freeway segments. The results of the mesoscopic model evaluation of I-24 were summarized by corridor segments for ease of identification for the reader and for data management purposes. The I-24 Corridor was divided up into 36 segments based on several guidelines. Segment boundaries were mandatory at county lines, state lines, TDOT Region boundaries and at urban boundaries. Further segmentation of the I-24 Corridor was based on optional boundaries such as city limits and major interchanges. It should be noted that the section of I-24 in Georgia was not included in this evaluation. Please refer to Figure 4.4 for a general display of the segments in the I-24 Corridor. Refer to Appendix A for a detailed definition of each I-24 segment as well as for detailed maps of the I-24 segments.

The I-24 mesoscopic model links were aggregated in TransModeler to a set of 72 directional "super links" representing the 36 corridor segments shown in Figure 4.4. From the model segment level output, data tables could be aggregated from the model segment level to the model link level and finally to the I-24 Corridor segments presented in this section. The corridor segment performance measures presented here are all distance weighted averages based on the model segment level statistics and aggregated across the final three model time intervals to represent a peak hour average within the three hour peak period.

Figure 4.4: I-24 Corridor Segments

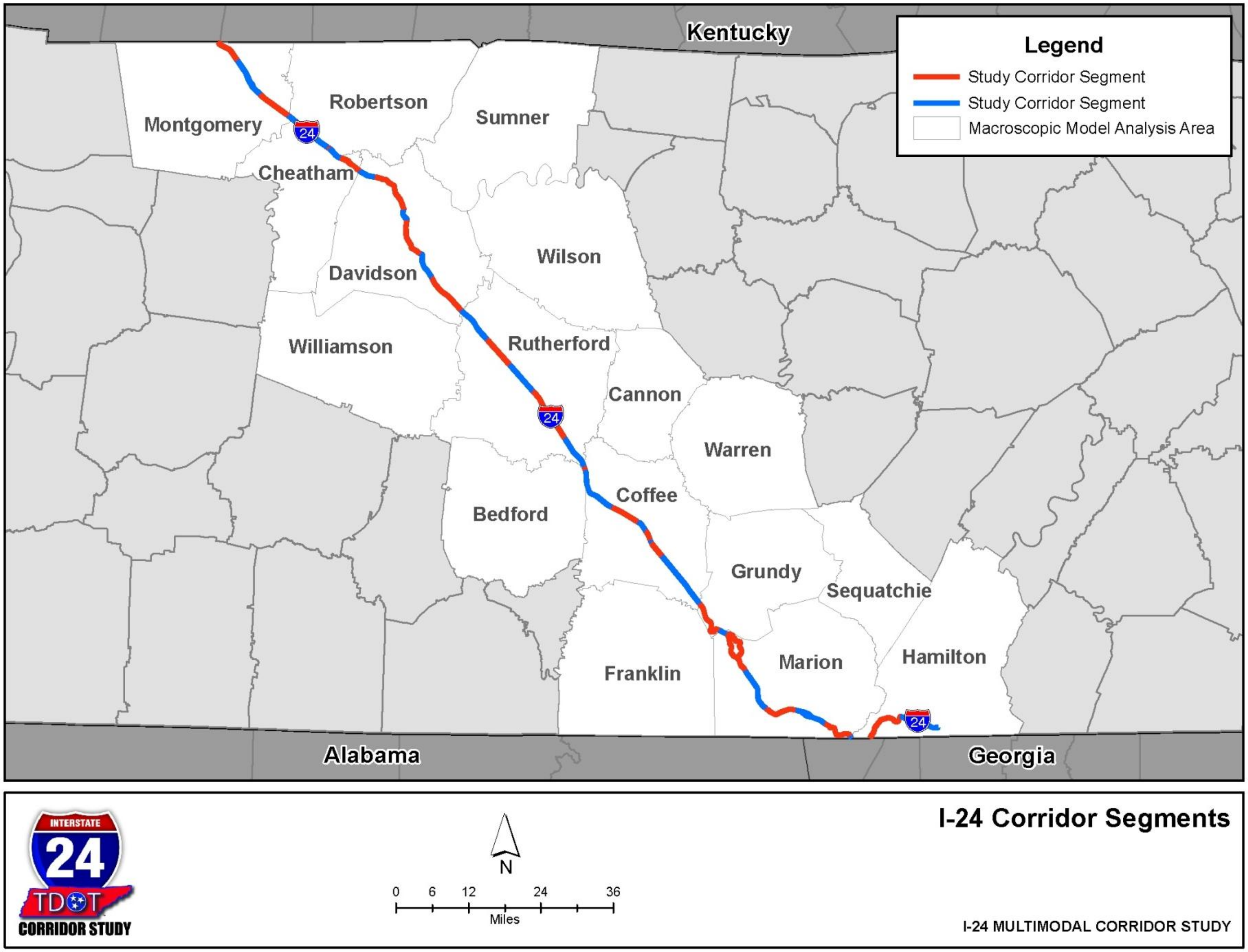


Figure 4.5 presents a map of 2010 peak hour average speeds by corridor segment. This figure depicts degraded speeds in and through the greater Nashville area extending southeast to Murfreesboro. Speed improves through Murfreesboro but degrades again southeast of Murfreesboro where the HOV lanes end and I-24 becomes 2 lanes in each direction continuing southeast. There is also some modest degradation of speeds through both corridor segments in Chattanooga.

Figure 4.6 presents 2010 peak hour level of service (LOS) by corridor segment based on average segment densities (veh/mi/ln) and Highway Capacity Manual (HCM) criteria. This figure generally mirrors the speed profiles. LOS E or F conditions are indicated on the corridor in the greater Nashville area from just northwest of downtown southwest to the edge of the metropolitan region. LOS E or F conditions are also indicated on the I-24 Corridor in the Chattanooga area east of US-27 to I-75.

Viewing the data graphically for the entire corridor masks some of the level of detail and directionality differences that exist at the individual corridor segment level. For a more detailed presentation of 2010 peak hour mesoscopic performance measures, refer to Appendix B. Appendix B presents 2010 peak hour directional performance measures for all 36 segments including average number of lanes, average speed, standard deviation of average speed, average traffic volume and average density.

The mesoscopic model was also used to identify locations in the I-24 Corridor where significant vehicular queuing occurs in the peak hour. While the mesoscopic model shows some level of queuing occurring at the end of most ramp termini in the corridor, the only area where queuing occurred on I-24 itself according to the mesoscopic model is in Nashville. Figure 4.7 presents the average number of vehicles in a queue in downtown Nashville during the 2010 peak hour. As seen in Figure 4.7, significant queues develop in the peak hour on I-24 between Briley Parkway North and Harding Place, especially south of I-40 and on the common section of I-40 and I-24.

In addition to the aggregated summaries, the full simulation can be rerun and viewed anytime as long as the TM software is available and the model output folder is available. Because the TM Trip Data Table from which the simulation run is based is stored and available and its assumed path costs were input from congested costs based on a dynamic traffic assignment, the same simulation that produced the results presented here can be effectively replayed in the software for viewing. This allows for more focused review and analysis of the traffic dynamics taking place in the simulation at a local area of interest. Figure 4.8 provides an example image of the mesoscopic simulation in progress. This view shows the vehicle movements taking place on the network at approximate 4:25PM at the intersection of Murfreesboro Pike and I-24 and includes the I-24/I-40 interchange.

Figure 4.5: Mesoscopic Model Average Speeds in the 2010 Peak Hour

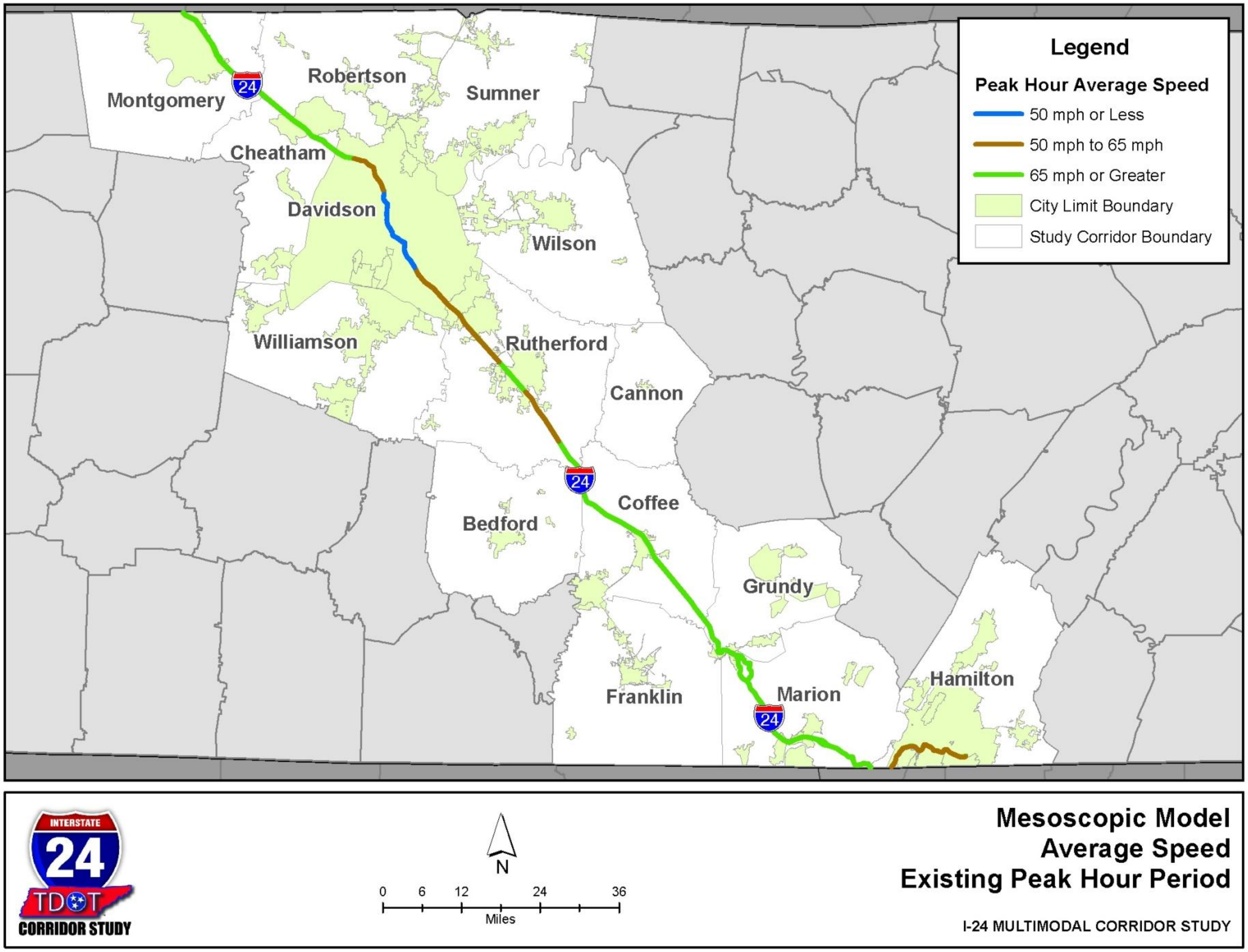


Figure 4.6: Mesoscopic Model Level of Service in the 2010 Peak Hour

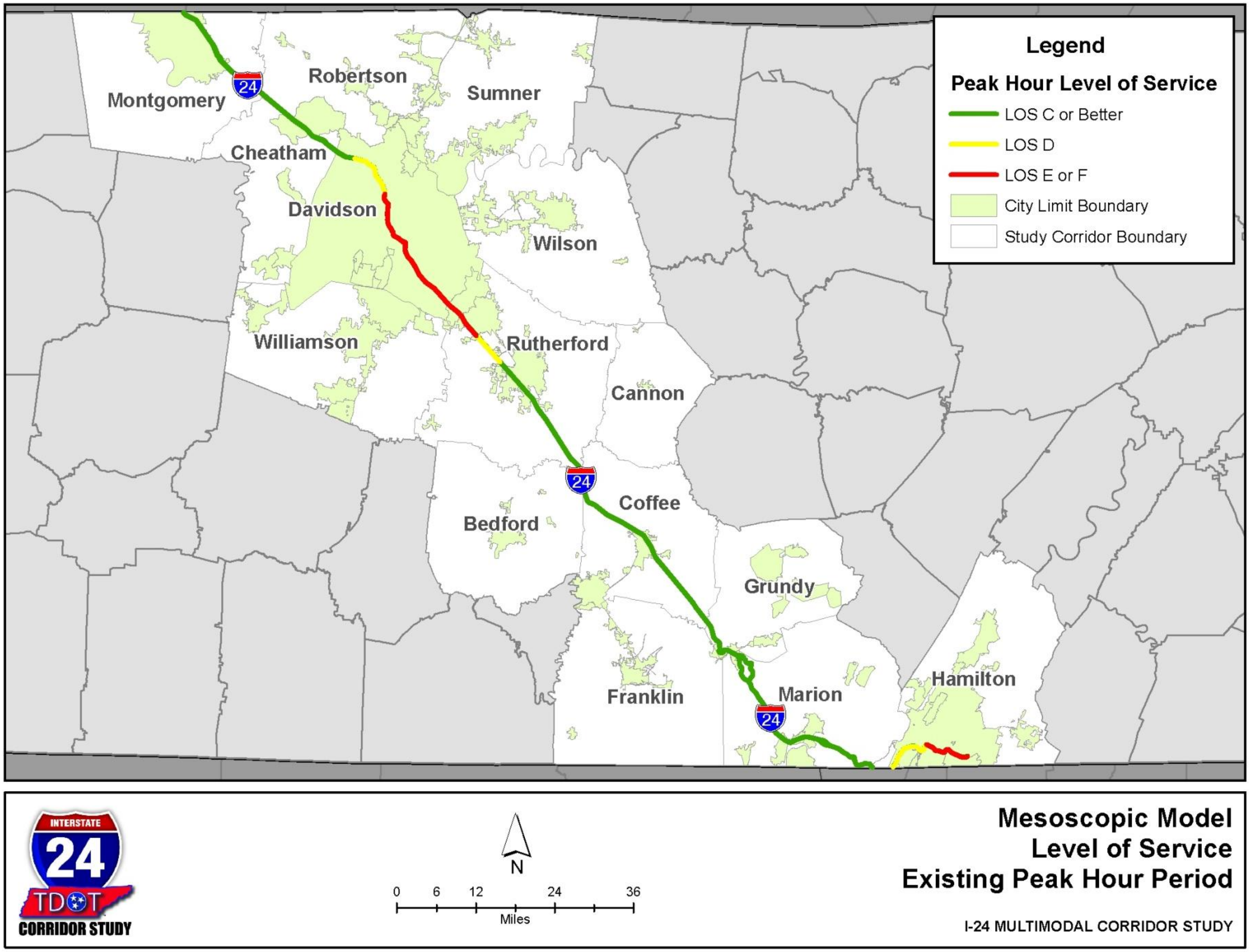


Figure 4.7: Mesoscopic Model 2010 Peak Hour Average Vehicular Queues in Nashville

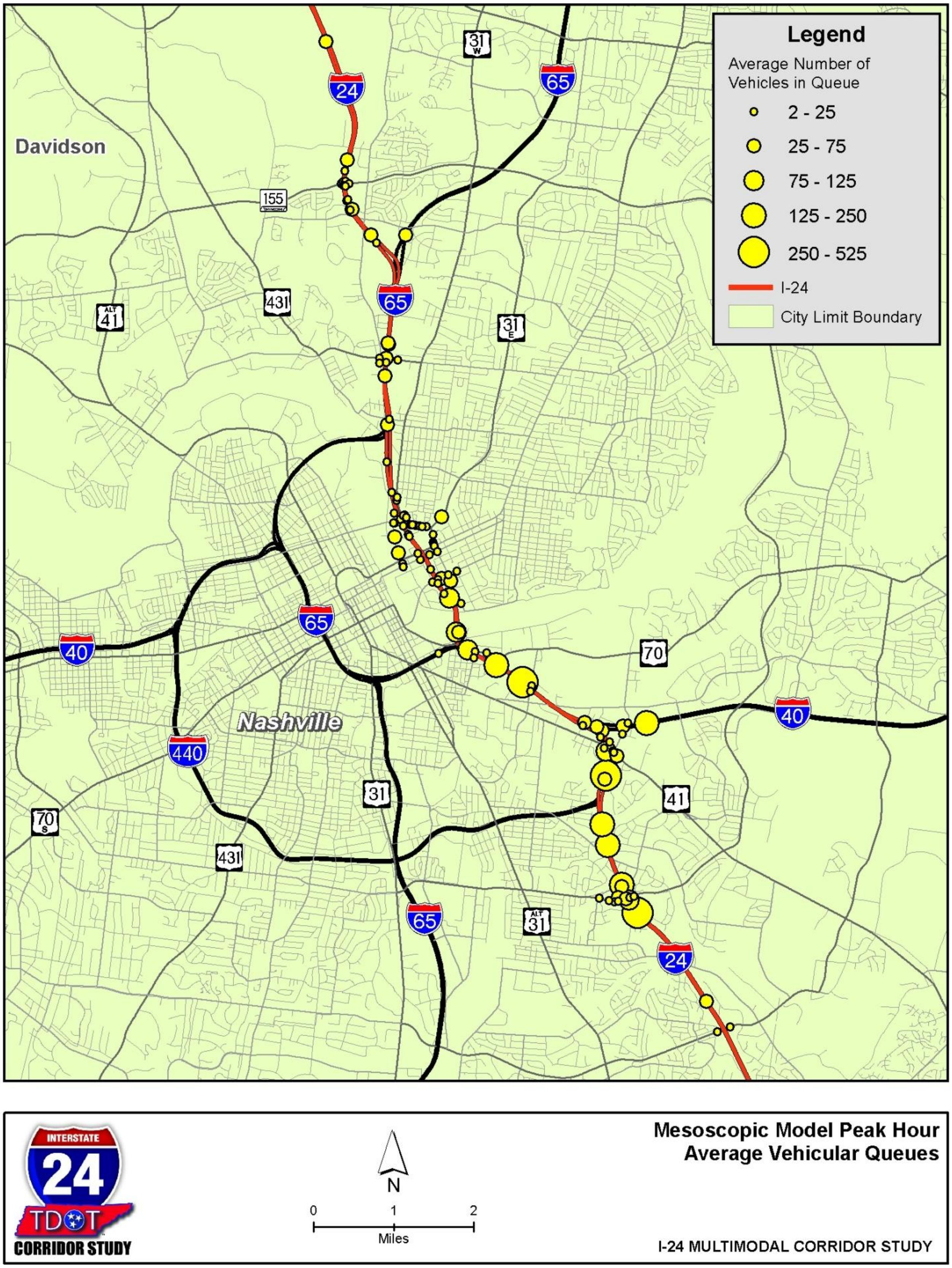


Figure 4.8: Mesoscopic Model Peak Period Simulation in Progress

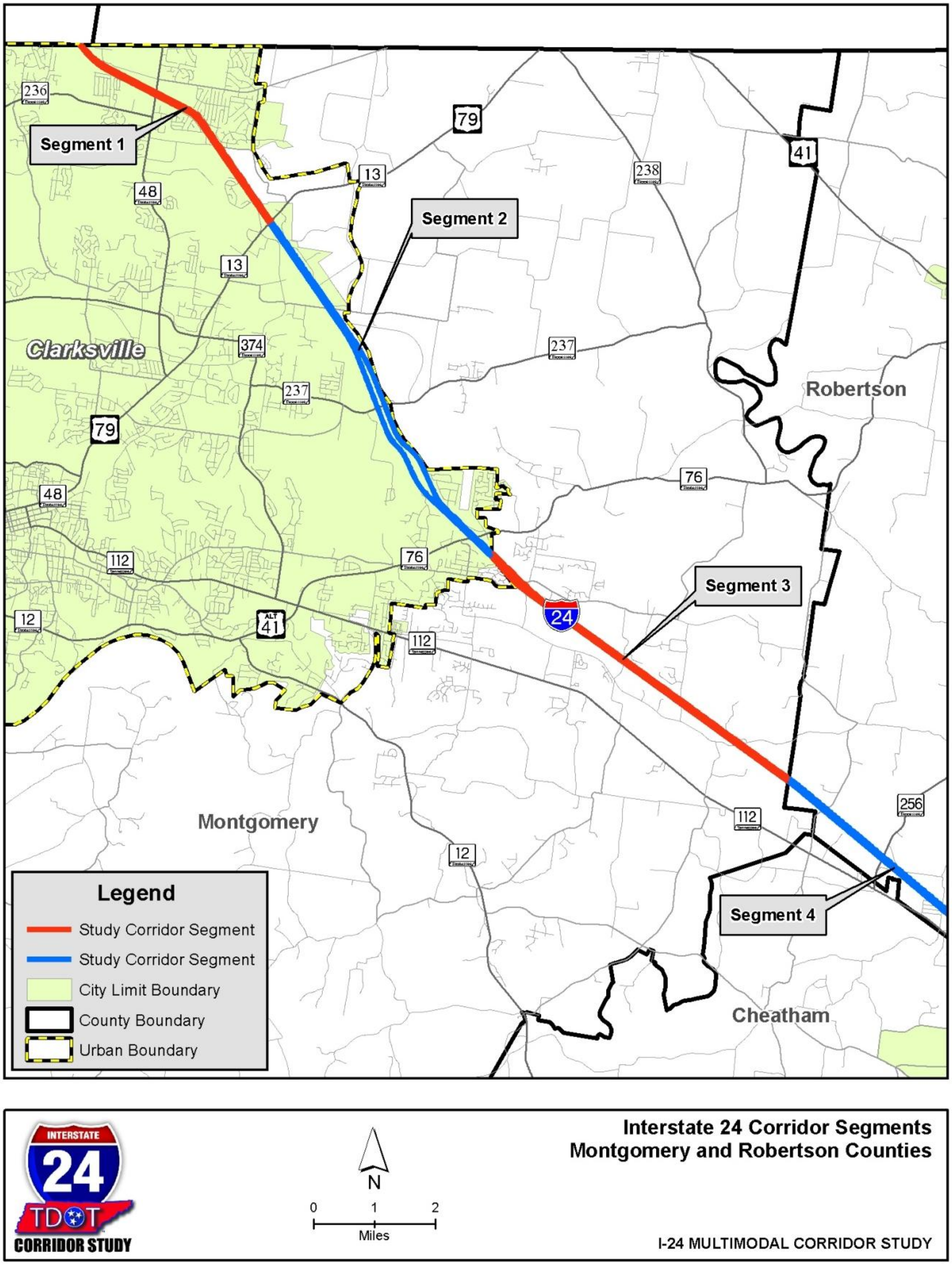
Source: Caliper Corporation's TransModeler

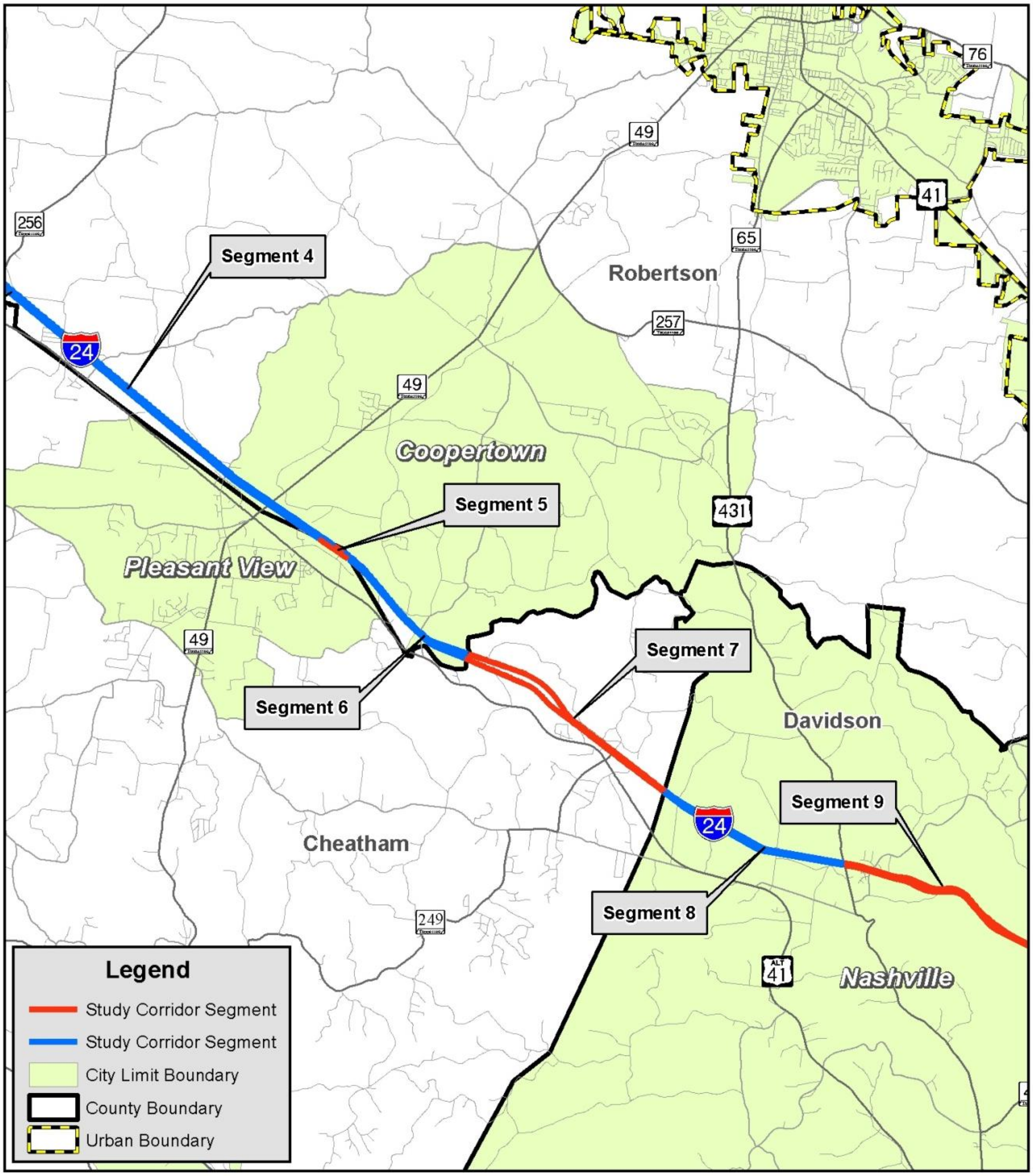
Appendix A

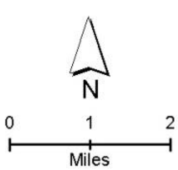
Definition and Maps of I-24 Corridor Segments

I-24 Corridor Segments

I-24 Segment	TDOT Region	TN County Number	TN County Name	Beginning Mile Log (by County)	Ending Mile Log (by County)	Segment Distance	TRIMS env_Type	TRIMS beginning description	TRIMS ending description
1	3	63	MONTGOMERY	0.000	4.410	4.410	URBAN	KENTUCKY-TENNESSEE STATE LINE	SR-13 WILMA RUDOLPH BLVD. / CENTER OF OVERHEAD
2	3	63	MONTGOMERY	4.410	11.033	6.623	URBAN	SR-13 WILMA RUDOLPH BLVD. / CENTER OF OVERHEAD	LEAVE CLARKSVILLE CITY LIMITS
3	3	63	MONTGOMERY	11.033	17.200	6.167	RURAL	LEAVE CLARKSVILLE CITY LIMITS	MONTGOMERY-ROBERTSON COUNTY LINE
4	3	74	ROBERTSON	0.000	8.120	8.120	RURAL	MONTGOMERY-ROBERTSON COUNTY LINE	ROBERTSON-CHEATHAM COUNTY LINE
5	3	11	CHEATHAM	0.000	0.700	0.700	RURAL	ROBERTSON-CHEATHAM COUNTY LINE	CHEATHAM-ROBERTSON COUNTY LINE
6	3	74	ROBERTSON	0.000	2.330	2.330	RURAL	CHEATHAM-ROBERTSON COUNTY LINE	ROBERTSON-CHEATHAM COUNTY LINE
7	3	11	CHEATHAM	0.000	3.630	3.630	RURAL	ROBERTSON-CHEATHAM COUNTY LINE	CHEATHAM-DAVIDSON COUNTY LINE
8	3	19	DAVIDSON	0.000	3.000	3.000	RURAL	CHEATHAM-DAVIDSON COUNTY LINE	SR-65 WHITES CREEK PK. / CENTER OF OVERHEAD
9	3	19	DAVIDSON	3.000	10.822	7.822	RURAL	SR-65 WHITES CREEK PK. / CENTER OF OVERHEAD	ENTER NASHVILLE URBAN BOUNDARY
10	3	19	DAVIDSON	10.822	12.990	2.168	URBAN	ENTER NASHVILLE URBAN BOUNDARY	I-65 SB LNS. RT. & LT.
11	3	19	DAVIDSON	12.990	16.060	3.070	URBAN	I-65 SB LNS. RT. & LT.	I-40 EB LNS. RT. & LT.
12	3	19	DAVIDSON	16.060	20.323	4.263	URBAN	I-40 EB LNS. RT. & LT.	SR-255 HARDING PL. / CENTER OF UNDERPASS
13	3	19	DAVIDSON	20.323	27.810	7.487	URBAN	SR-255 HARDING PL. / CENTER OF UNDERPASS	DAVIDSON-RUTHERFORD COUNTY LINE
14	3	75	RUTHERFORD	0.000	6.784	6.784	URBAN	DAVIDSON-RUTHERFORD COUNTY LINE	ENTER SMYRNA CITY LIMITS
15	3	75	RUTHERFORD	6.784	12.109	5.325	URBAN	ENTER SMYRNA CITY LIMITS	ENTER MURFREESBORO CITY LIMITS
16	3	75	RUTHERFORD	12.109	18.170	6.061	URBAN	ENTER MURFREESBORO CITY LIMITS	UNDERPASS [75I00240029]: SR-10 S. CHURCH ST.
17	3	75	RUTHERFORD	18.170	27.302	9.132	URBAN	UNDERPASS [75I00240029]: SR-10 S. CHURCH ST.	LEAVE NASHVILLE URBAN BOUNDARY
18	3	75	RUTHERFORD	27.302	33.290	5.988	RURAL	LEAVE NASHVILLE URBAN BOUNDARY	RUTHERFORD-BEDFORD COUNTY LINE
19	3	2	BEDFORD	0.000	0.450	0.450	RURAL	RUTHERFORD-BEDFORD COUNTY LINE	BEDFORD-COFFEE COUNTY LINE
20	2	16	COFFEE	0.000	8.420	8.420	RURAL	BEDFORD-COFFEE COUNTY LINE	SR-2 MURFREESBORO HWY. / CENTER OF UNDERPASS
21	2	16	COFFEE	8.420	13.137	4.717	RURAL	SR-2 MURFREESBORO HWY. / CENTER OF UNDERPASS	ENTER MANCHESTER CITY LIMITS
22	2	16	COFFEE	13.137	15.328	2.191	URBAN	ENTER MANCHESTER CITY LIMITS	LEAVE MANCHESTER URBAN BOUNDARY
23	2	16	COFFEE	15.328	16.828	1.500	RURAL	LEAVE MANCHESTER URBAN BOUNDARY	ENTER MANCHESTER URBAN BOUNDARY
24	2	16	COFFEE	16.828	17.601	0.773	URBAN	ENTER MANCHESTER URBAN BOUNDARY	LEAVE MANCHESTER CITY LIMITS & URBAN BOUNDARY
25	2	16	COFFEE	17.601	20.400	2.799	RURAL	LEAVE MANCHESTER CITY LIMITS & URBAN BOUNDARY	UNDERPASS [16I00240039]: 0918 ARNOLD CENTER RD.
26	2	16	COFFEE	20.400	30.160	9.760	RURAL	UNDERPASS [16I00240039]: 0918 ARNOLD CENTER RD.	COFFEE-GRUNDY COUNTY LINE
27	2	31	GRUNDY	0.000	7.310	7.310	RURAL	COFFEE-GRUNDY COUNTY LINE	GRUNDY-MARION COUNTY LINE
28	2	58	MARION	0.000	1.380	1.380	RURAL	GRUNDY-MARION COUNTY LINE	SR-2 DIXIE LEE AVE. / CENTER OF UNDERPASS
29	2	58	MARION	1.380	8.360	6.980	RURAL	SR-2 DIXIE LEE AVE. / CENTER OF UNDERPASS	SR-2 BATTLE CREEK RD. / CENTER OF UNDERPASS
30	2	58	MARION	8.360	16.073	7.713	RURAL	SR-2 BATTLE CREEK RD. / CENTER OF UNDERPASS	ENTER KIMBALL CITY LIMITS
31	2	58	MARION	16.073	21.354	5.281	RURAL	ENTER KIMBALL CITY LIMITS	LEAVE JASPER CITY LIMITS
32	2	58	MARION	21.354	26.810	5.456	RURAL	LEAVE JASPER CITY LIMITS	SR-156 STATE HWY. 156 / CENTER OF UNDERPASS
33	2	58	MARION	26.810	32.130	5.320	RURAL	SR-156 STATE HWY. 156 / CENTER OF UNDERPASS	MARION-HAMILTON COUNTY LINE
34	2	33	HAMILTON	0.000	0.310	0.310	RURAL	MARION-HAMILTON COUNTY LINE	TENNESSEE-GEORGIA STATE LINE
35	2	33	HAMILTON	0.000	7.520	7.520	URBAN	TENNESSEE-GEORGIA STATE LINE	OVERHEAD [33I00240015]: I-124 US-27 NB LNS. / RT. LNS. ONLY
36	2	33	HAMILTON	7.520	14.710	7.190	URBAN	OVERHEAD [33I00240015]: I-124 US-27 NB LNS. / RT. LNS. ONLY	I-75 US-74 NB LNS. RT. & LT.

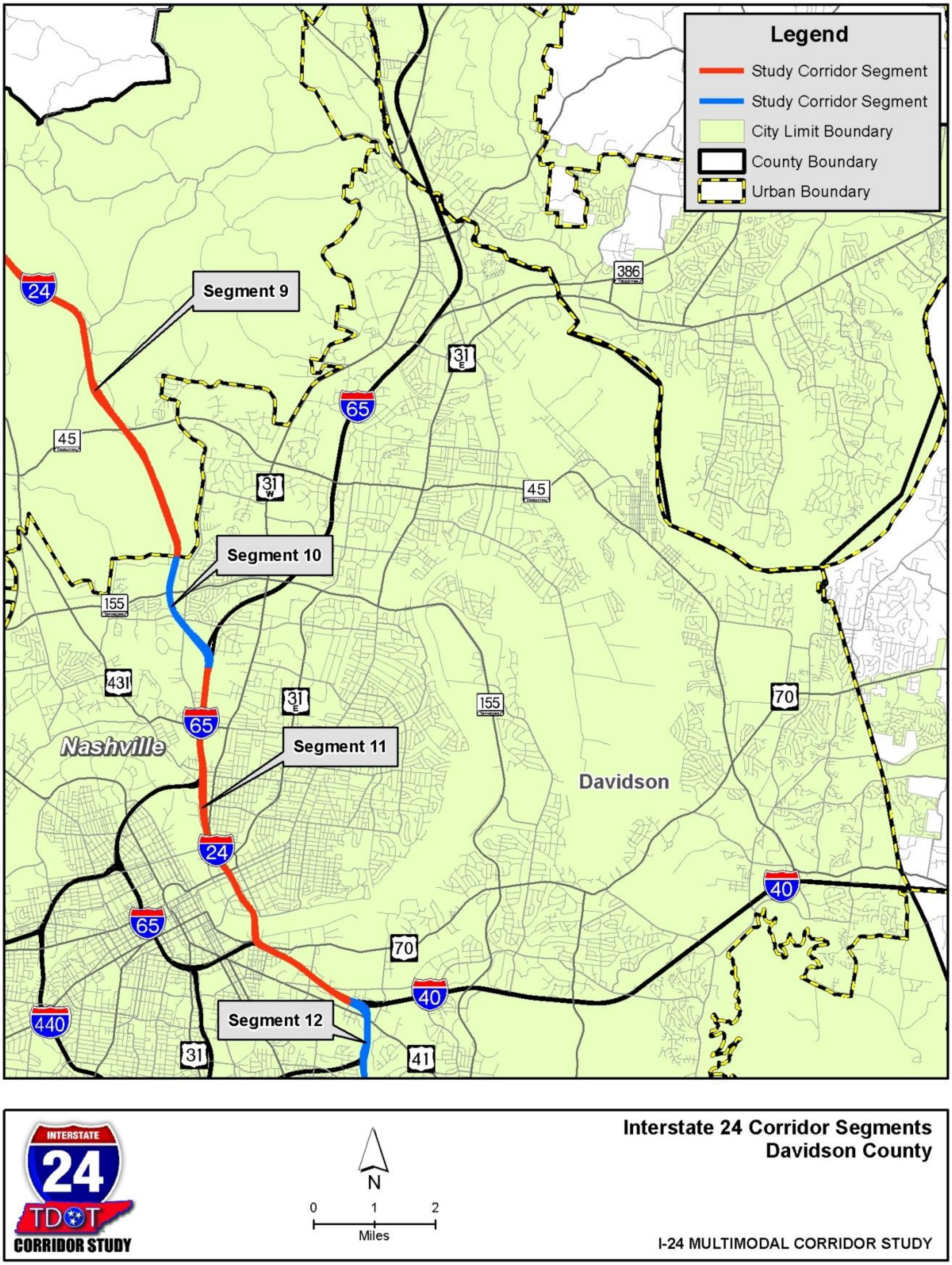

Segment 1
Segment 2
Segment 3
Segment 4
Clarksville
Robertson
Montgomery
Cheatham
Legend
Study Corridor Segment
Study Corridor Segment
City Limit Boundary
County Boundary
Urban Boundary
N
0
1
2
Miles
Interstate 24 Corridor Segments
Montgomery and Robertson Counties
I-24 MULTIMODAL CORRIDOR STUDY

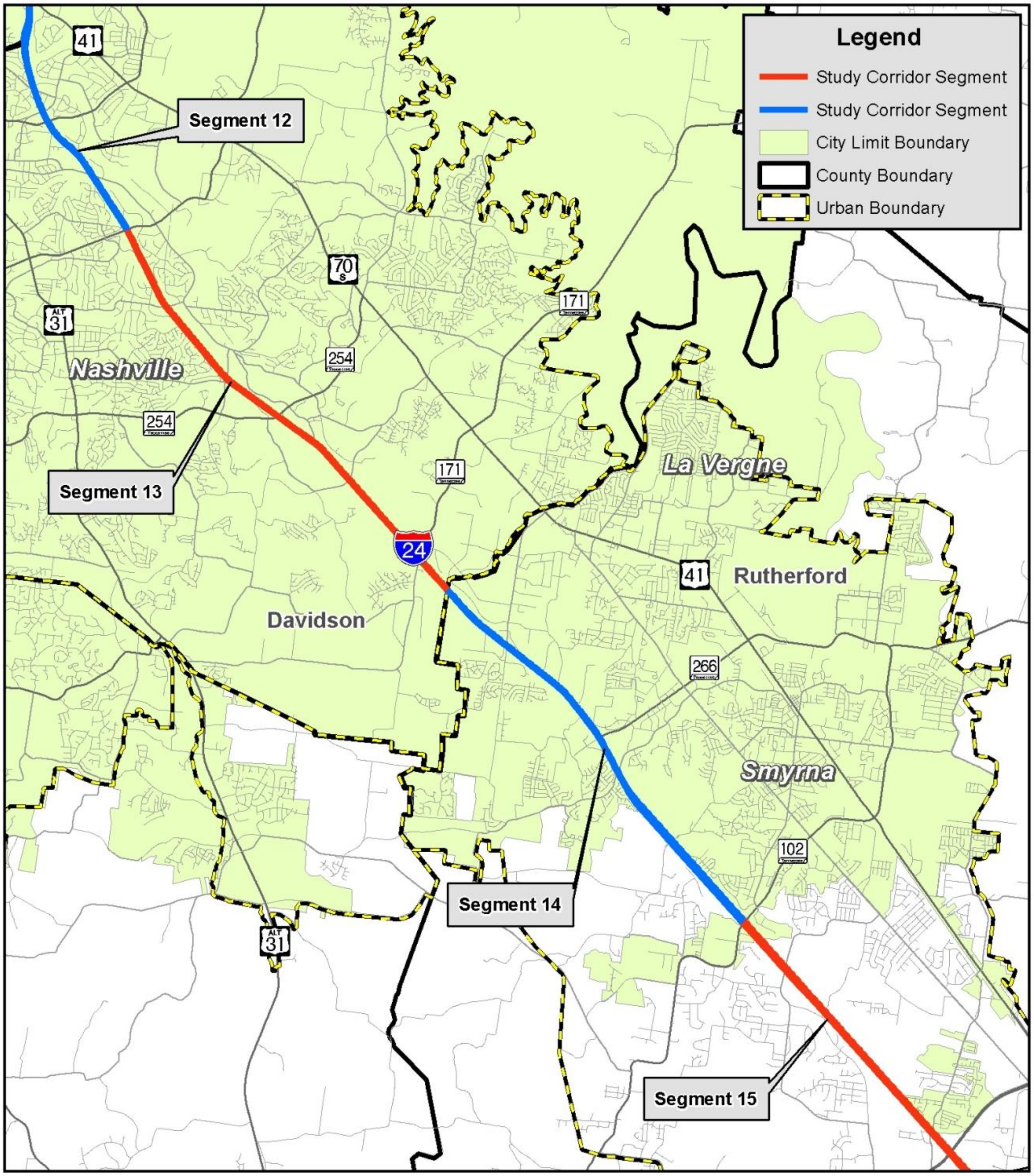


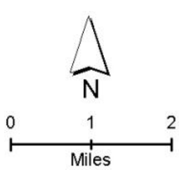


Interstate 24 Corridor Segments
Robertson, Cheatham, and Davidson Counties

I-24 MULTIMODAL CORRIDOR STUDY

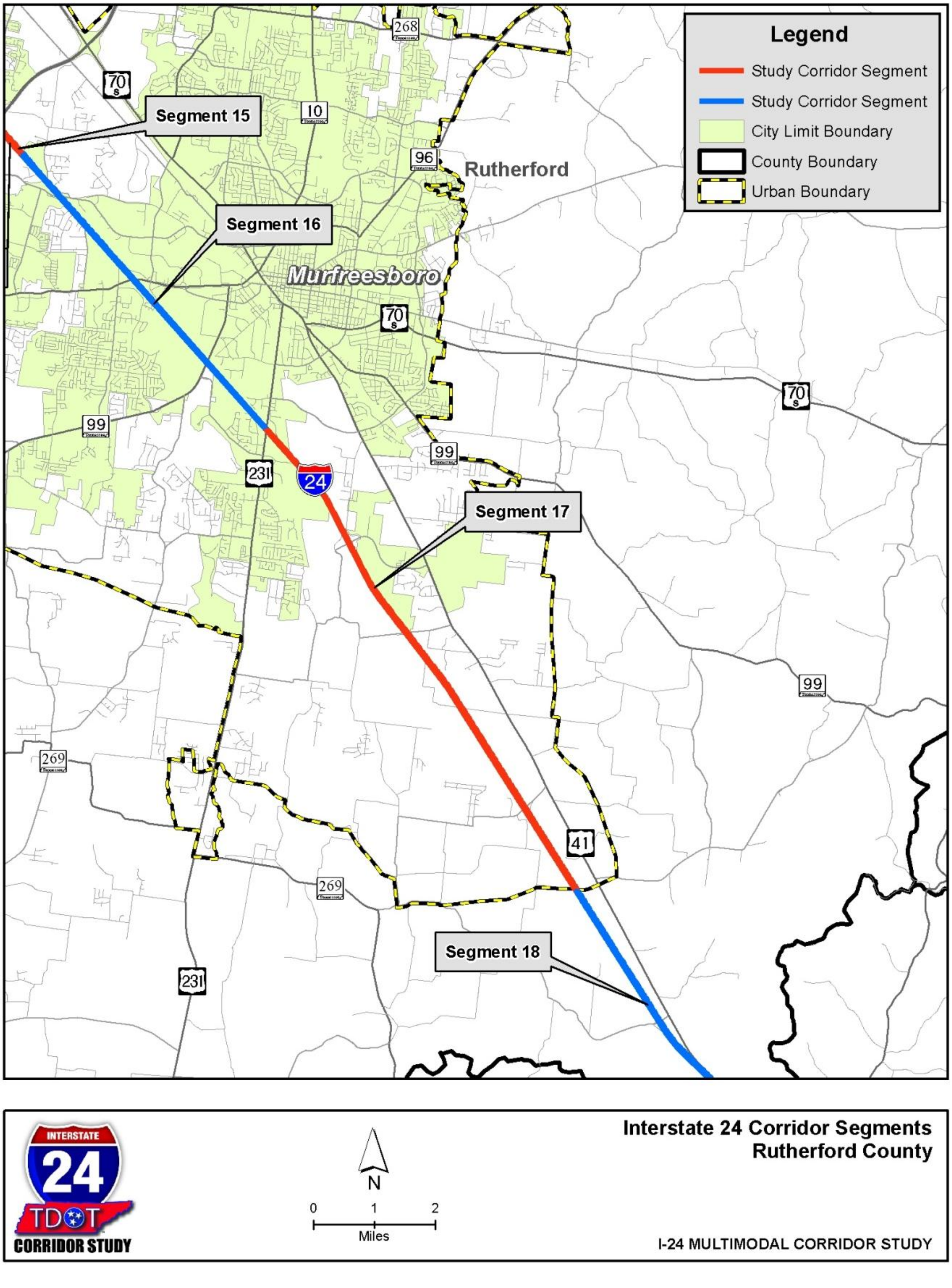

Legend
Study Corridor Segment
Study Corridor Segment
City Limit Boundary
County Boundary
Urban Boundary
Segment 9
Segment 10
Segment 11
Segment 12
Nashville
Davidson
24
65
40
440
45
155
431
31 E
31 W
386
70
41
31
Interstate 24 Corridor Segments
Davidson County
N
0
1
2
Miles
INTERSTATE
24
TDOT
CORRIDOR STUDY
I-24 MULTIMODAL CORRIDOR STUDY





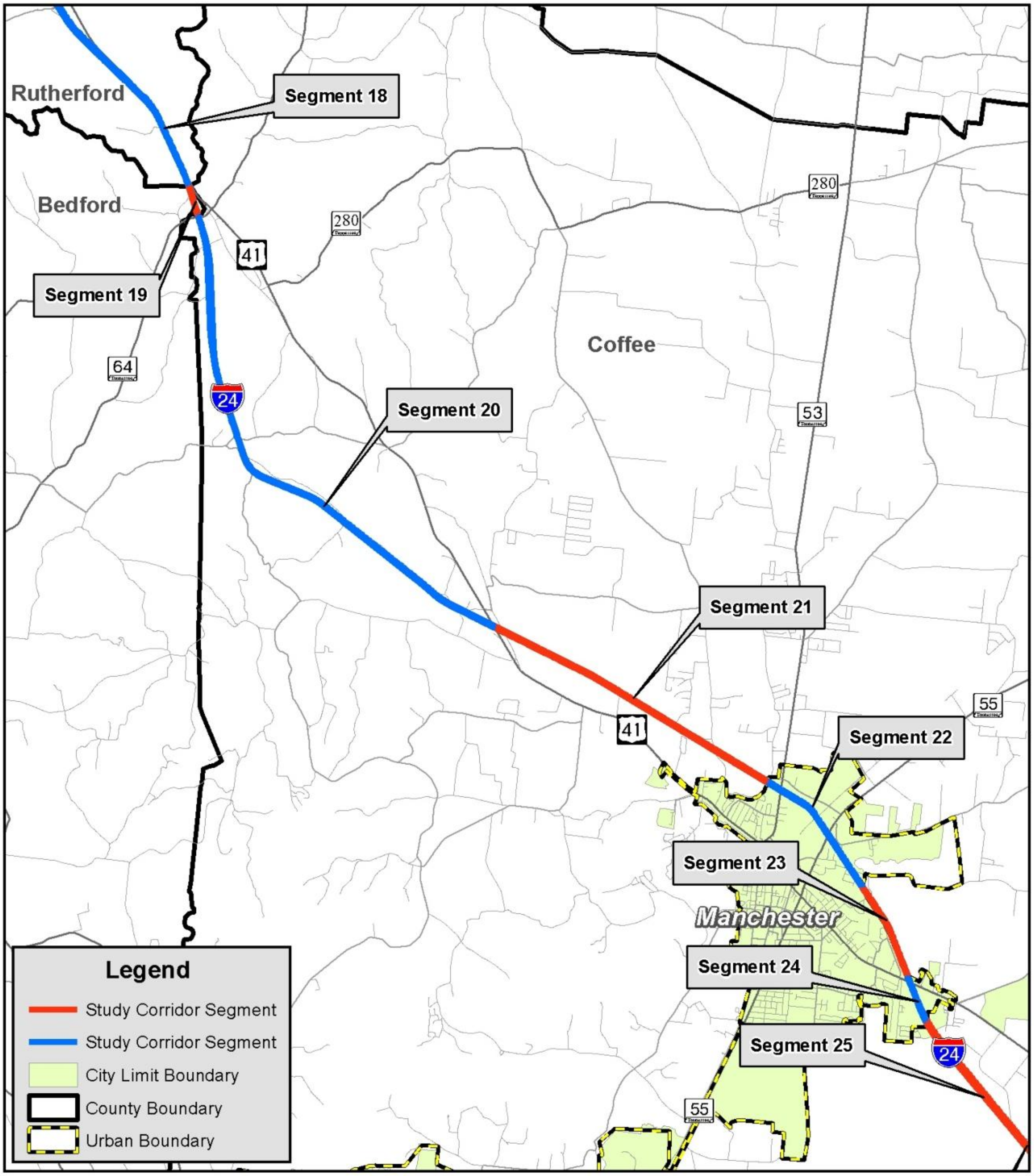
Interstate 24 Corridor Segments
Davidson and Rutherford Counties

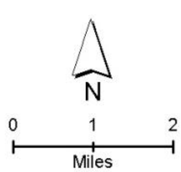
I-24 MULTIMODAL CORRIDOR STUDY



Interstate 24 Corridor Segments
Rutherford County

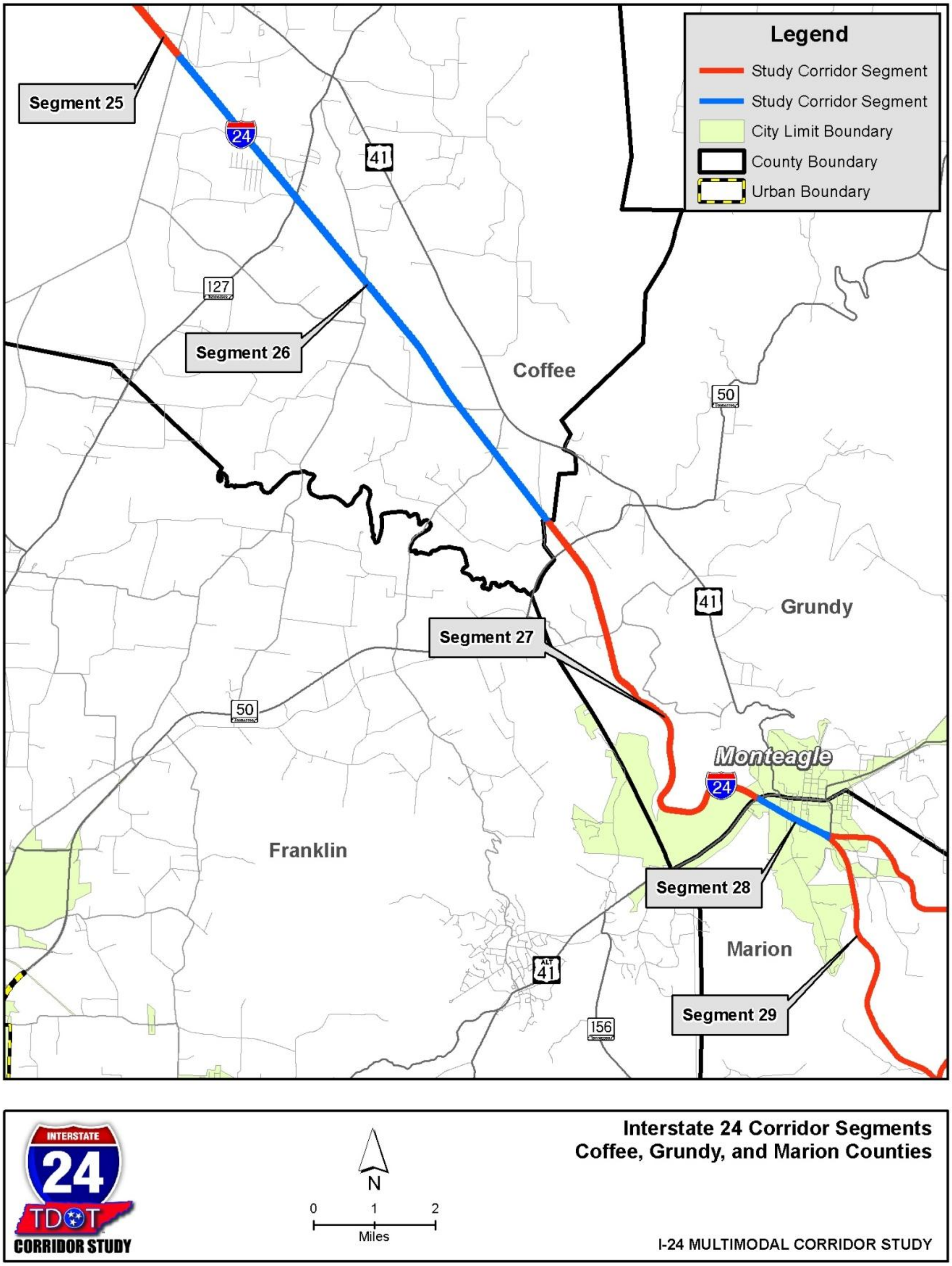
I-24 MULTIMODAL CORRIDOR STUDY

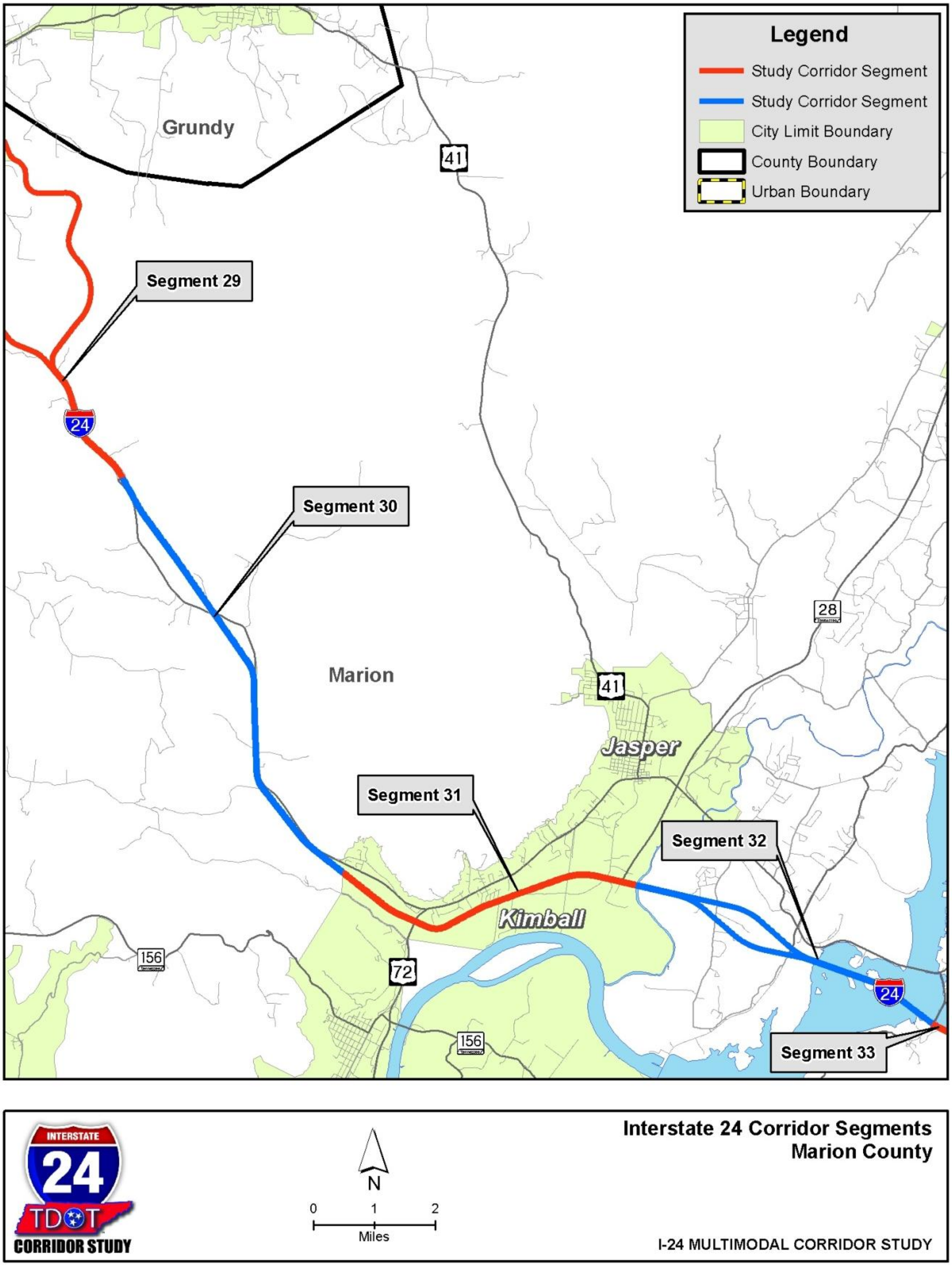


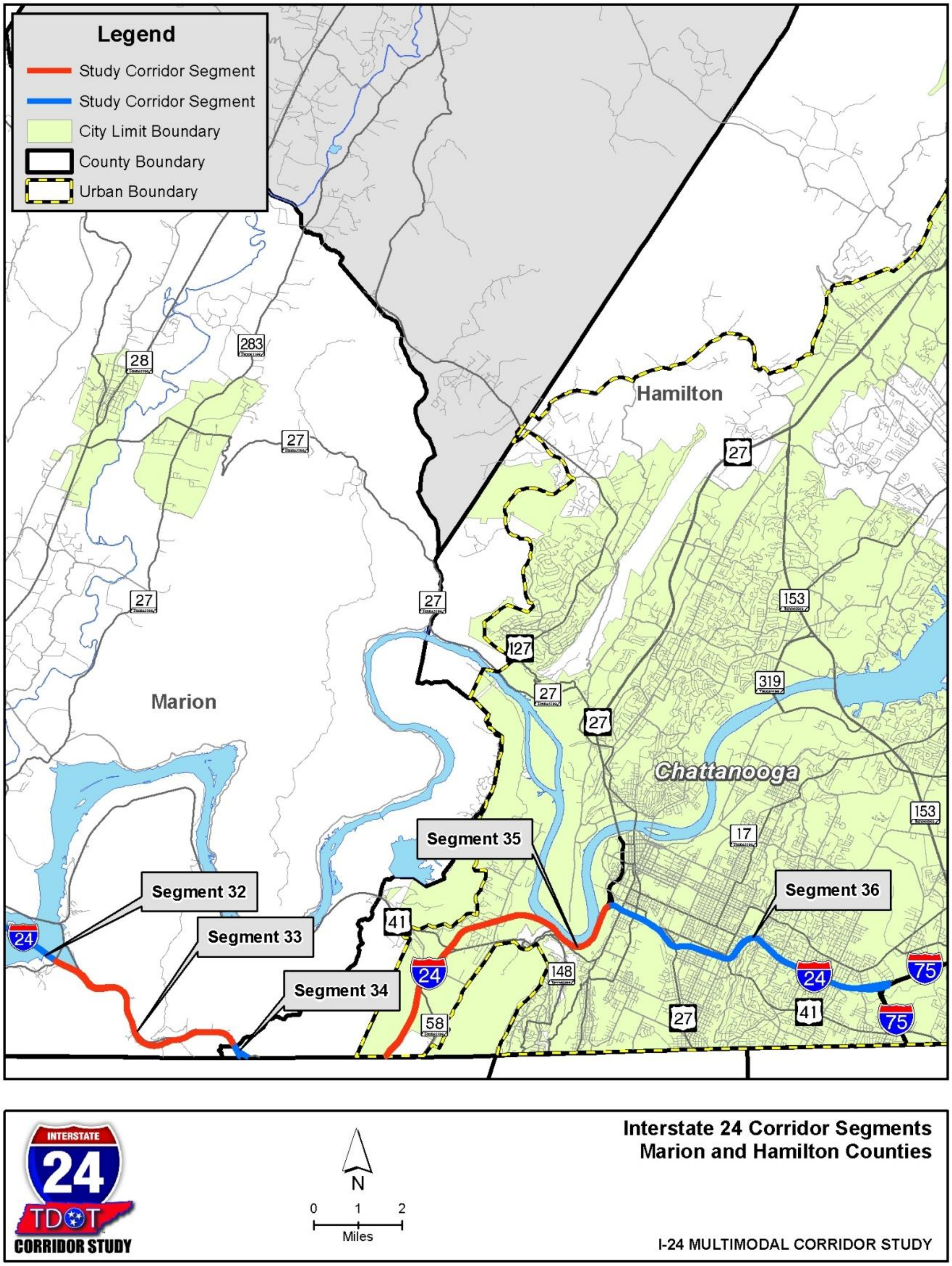


Interstate 24 Corridor Segments
Rutherford, Bedford, and Coffee Counties

I-24 MULTIMODAL CORRIDOR STUDY


Legend
Study Corridor Segment
Study Corridor Segment
City Limit Boundary
County Boundary
Urban Boundary
Segment 25
Segment 26
Segment 27
Segment 28
Segment 29
24
41
127
50
ALT 41
156
Coffee
Grundy
Franklin
Marion
Monteagle
INTERSTATE
24
TDOT
CORRIDOR STUDY
N
0
1
2
Miles
Interstate 24 Corridor Segments
Coffee, Grundy, and Marion Counties
I-24 MULTIMODAL CORRIDOR STUDY


Legend
Study Corridor Segment
Study Corridor Segment
City Limit Boundary
County Boundary
Urban Boundary
Grundy
Marion
Jasper
Kimball
Segment 29
Segment 30
Segment 31
Segment 32
Segment 33
41
24
28
72
156
INTERSTATE
24
TDOT
CORRIDOR STUDY
N
0
1
2
Miles
Interstate 24 Corridor Segments
Marion County
I-24 MULTIMODAL CORRIDOR STUDY


Legend
Study Corridor Segment
Study Corridor Segment
City Limit Boundary
County Boundary
Urban Boundary
Hamilton
Marion
Chattanooga
Segment 32
Segment 33
Segment 34
Segment 35
Segment 36
24
41
58
148
27
127
153
319
17
75
28
283
Interstate 24 Corridor Segments
Marion and Hamilton Counties
INTERSTATE
24
TDOT
CORRIDOR STUDY
N
0 1 2
Miles
I-24 MULTIMODAL CORRIDOR STUDY

Appendix B

Mesoscopic Model Performance Measures by I-24 Segment and Direction

Mesoscopic Model Performance Measures for the 2010 Peak Hour Period by I-24 Segment and Direction

		Eastbound					Westbound				
I-24 Segment	County	Average Number of Lanes	Average Speed (MPH)	Speed Standard Deviation (MPH)	Average Traffic Volume	Average Density (Veh/Mi/Ln)	Average Number of Lanes	Average Speed (MPH)	Speed Standard Deviation (MPH)	Average Traffic Volume	Average Density (Veh/Mi/Ln)
1	Montgomery	2	68.5	2.7	1,444	14.5	2	68.4	2.7	1,363	12.3
2	Montgomery	2	68.1	2.6	1,673	16.6	2	68.3	2.5	1,591	14.3
3	Montgomery	2	67.8	2.6	1,891	18.8	2	68.0	2.1	1,742	16.2
4	Robertson	2	67.8	2.5	1,881	19.0	2	68.0	2.2	1,854	16.9
5	Cheatham	2	68.1	2.3	1,694	16.8	2	67.3	2.6	2,148	19.0
6	Robertson	2	68.2	2.3	1,661	17.2	2	67.4	2.4	2,099	18.9
7	Cheatham	3	68.1	1.9	1,659	13.6	2	67.4	2.6	2,139	19.3
8	Davidson	2	67.9	2.5	1,693	17.7	2	66.1	3.9	2,336	21.9
9	Davidson	2	57.2	10.2	2,483	30.9	2	65.7	3.7	2,556	20.4
10	Davidson	2	40.4	18.2	3,189	48.0	2	32.6	10.5	2,609	79.2
11	Davidson	4	29.4	14.4	6,237	89.1	4	36.8	8.5	2,967	83.1
12	Davidson	4	58.0	8.5	7,050	43.7	4	17.8	25.5	3,675	90.9
13	Davidson	4	63.0	4.3	8,409	37.4	4	63.9	4.7	6,661	31.1
14	Rutherford	4	61.6	5.3	7,903	38.3	4	65.6	2.9	5,173	25.8
15	Rutherford	4	63.8	3.0	6,442	29.8	4	67.5	2.2	3,505	17.5
16	Rutherford	4	67.1	2.8	5,039	21.0	4	68.3	2.3	2,496	12.4
17	Rutherford	2	64.8	4.0	2,568	27.2	2	67.8	3.6	884	14.6
18	Rutherford	2	66.6	3.3	2,189	24.7	2	68.3	3.0	707	13.6
19	Bedford	2	66.0	2.9	2,398	25.2	2	66.9	4.6	775	14.3
20	Coffee	2	66.9	3.9	1,918	21.7	2	68.2	3.1	726	13.8
21	Coffee	2	67.2	3.0	2,039	23.6	2	68.4	2.7	997	15.6
22	Coffee	2	67.2	3.0	2,088	23.6	2	67.4	3.9	1,073	16.1
23	Coffee	2	68.2	2.8	1,507	18.1	2	68.1	3.5	1,037	16.3
24	Coffee	2	67.3	3.5	1,573	18.5	2	67.2	3.9	953	14.5
25	Coffee	2	68.0	2.8	1,606	19.2	2	68.1	2.9	998	15.8
26	Coffee	2	67.9	2.7	1,531	20.3	2	68.2	2.9	969	16.2
27	Grundy	2	67.9	2.8	1,645	20.0	2	68.2	3.1	904	14.6
28	Marion	2	66.7	4.3	1,742	21.3	2	66.7	4.6	1,094	16.6
29	Marion	3	68.0	2.2	1,638	16.3	3	68.1	1.8	1,081	12.8
30	Marion	2	67.8	2.9	1,632	21.8	2	68.2	2.7	1,140	17.5
31	Marion	2	66.6	3.8	1,918	23.4	2	68.1	3.3	1,029	15.9
32	Marion	2	66.3	3.7	2,083	25.7	2	68.1	3.2	1,034	17.0
33	Marion	2	67.1	3.3	1,978	25.0	2	68.4	2.6	1,086	17.3
34	Hamilton	2	65.6	3.6	2,108	26.1	2	68.5	2.5	1,167	17.3
35	Hamilton	2	62.1	4.8	3,032	33.9	2	65.1	4.5	2,394	27.6
36	Hamilton	3	62.3	5.0	5,771	37.3	3	67.0	3.2	2,846	20.7