Assessing Operational, Pricing, and Intelligent Transportation System Strategies for the I-40 Corridor Using DYNASMART-P

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16. Abstract

The Raleigh Durham area in North Carolina experienced tremendous growth in both population (50%) and travel (56%) in the decade spanning 1995-2005. The I-40 corridor, which encompasses I-40, I-85, I-440, I-540, NC147, and US-70 is under great strain. The I-40 corridor is vital to the economic health of the region and the entire state, and it is representative of the transportation mobility challenges faced in rapidly growing urban areas. Traditional highway construction approaches alone cannot meet these current and future challenges.

These realities render it imperative that the NCDOT and metropolitan and regional planning agencies have the tools necessary to assess the system performance impacts of a variety of operational strategies, including HOV/HOT lanes, congestion or value pricing, ramp metering, system-wide signal coordination, incident and work zone management, and expanded traveler information.

This project delivered a calibrated DynusT model of the Triangle region that provides this performance assessment capability. The DynusT tool is the federally-sponsored continuation of the DYNASMART-P meso-scale dynamic traffic assignment software development effort. The model's performance assessment capability was demonstrated through application of the Triangle DynusT model to a series of carefully selected evaluation scenarios. Although the project was self-contained and motivated through its focus on the I-40 corridor, the findings are envisioned as the first step toward bringing regional-scale mesoscopic dynamic traffic assignment modeling capability statewide for modeling North Carolina's strategic highway corridors and detailed transportation program support for each of the state's metropolitan and rural planning regions.

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EXECUTIVE SUMMARY

The rapid and continued growth in North Carolina's Triangle region has and will continue to place great strain on the I-40 corridor. This corridor is vital to the economic health of the region and the state and is representative of the challenges faced in all urban areas across the state and nation. As is now universally recognized, traditional highway construction approaches alone cannot meet these current and future challenges.

These realities render it imperative that the North Carolina Department of Transportation (NCDOT) and metropolitan and regional planning agencies have the tools necessary to assess the system performance impacts of a variety of operational strategies. The overarching goal of this project was to test such a tool at the scale of the Triangle Regional travel demand Model, or TRM. The tool tested is DynusT, a mesoscopic simulation based dynamic traffic assignment network model. DynusT is the version of the DYNASMART-P software development effort that is open source and continues to receive federal support through the Strategic Highway Research Program 2 (SHRP2) under SHRP2 project C-10 titled *Partnership to Develop an Integrated, Advanced Travel Demand Model*.

At the beginning of the project documented in this report, it was still an open question as to whether or not DynusT would effectively scale up to model the entire Triangle region travel demand model. As part of the testing, the project research involved the assessment of a series of non-construction mobility enhancement scenarios. The project is now successfully complete, and a workable DynusT model of the entire Triangle regional network was developed. The baseline scenario was created from the 2015 TRM network, zonal structure, and demand tables. Operational scenarios evaluated included (a) ramp metering based on the recent update of the Triangle Intelligent Transportation

Systems (ITS) strategic deployment plan, (b) High Occupancy Toll (HOT) lane implementation based on the 2003 I-40 High Occupancy Vehicle (HOV) study, and (c) low cost bottleneck improvements based on the ongoing work of the I-40 Regional Partnership.

Each of these scenarios was effectively modeled in DynusT. The operational performance was summarized in terms of impact at the following spatial levels:

- Regional Network
- I-40 corridor covering approximately 75 miles from near Graham, NC to just west of I-95
- Key I-40 origin-destination pairs
- Critical I-40 links

The numerical results presented must be viewed as preliminary and are provided primarily to demonstrate the effectiveness of the DynusT tool in analyzing major operational improvement alternatives within the context of the regional network. However, the results from the HOT lanes scenario are especially noteworthy in that they indicate that deployment of a HOT lane system within the boundaries of the HOV implementation recommended by the 2003 HOV study could provide nearly all the network, corridor, and key origin-destination pair benefits that would be provided by widening of the entire I-40 corridor through the Triangle region to the full build feasible cross section (four general purpose lanes and one HOV lane in each direction). Comparative analyses such as these will be essential to NCDOT and regional planning agencies in supporting decisions that lead to a sustainable transportation system that provides enhanced safety and mobility for people and goods for years to come.

The following key findings will be important points of consideration as the NCDOT works through decisions regarding the future role of DynusT in project and program support and evaluation. The findings are organized in four categories: 1) scalability and cost, 2) scenario analyses, 3) inherent limitations, and 4) correctible limitations.

Scalability and Cost

- A regional scale DynusT network model can be executed with reasonable run on a 64-bit Windows-based computer with sufficient memory resources.
- Direct software licensing costs are no longer an issue because DynusT is now available as a free, open-source software product.
- Direct costs of DynusT implementation will consist primarily of 64-bit computer purchases and technical support and training services.

Scenario Analyses

- Pricing and driver class based scenarios (such as the HOT lane scenario included in the project) are the most functionally well-developed scenario options in DynusT.
- Traffic-responsive ramp metering does not yield reliable results in the current software version. Follow on studies are needed to assess whether valid and robust traffic-responsive ramp metering functionality is provided in future software editions.
- Transit capabilities currently include only direct coding and modeling of fixed route transit (bus) operations. Although this feature could have value, route coding is time intensive. Transit scenario analysis could be enhanced if transit

service coding is streamlined in future versions. It is also possible that future versions may include transit mode split functionality.

- For comparative analysis of measures of effectiveness, the appropriate comparison level must be carefully selected. For example, an important bottleneck improvement project with significant localized benefit may demonstrate little or no improvement at corridor or network levels.

Inherent Limitations

- For cases where the network, zonal structure, and demand tables are created from a travel demand model, valid analyses will be limited to scenarios that can be well-modeled with the travel demand model's level of detail. Also, the network translation routine from TransCad to DynusT still requires some manual adjustment to the network features that are not fully captured in or are lost or misinterpreted in the automated process. Although this is likely to be improved in future editions, it is not feasible for an automated process to correctly deal with all possible network features.
- DynusT's six-second traffic model update interval limits the fidelity of signalized intersection and signalized corridor analysis.

Correctible Limitations

- Mesoscopic model fidelity is hampered by DynusT's use of one or two-regime traffic flow models. Enhancement to allow specification of three-regime traffic flow models would increase the accuracy and robustness of uninterrupted facility modeling.

- Problems with the traffic responsive ramp metering logic mentioned above made it necessary for the project team to implement a traffic responsive emulation using the fixed-rate ramp metering logic. Repair and validation of the basic traffic responsive ramp metering logic should be a high priority for the DynusT development team in order to enable a realistic assessment of this important feature in the model.
- Transit route coding is currently entirely manual and therefore too time-intensive to be generally viable for full scale evaluation of municipal and regional transit systems. Development of a transit route import and translation routine is needed. It is unclear whether there are plans to add mode split functionality, which would be an important component in a multimodal assessment of ITS strategies.

In summary, the project research team recommends that appropriate NCDOT personnel conduct informal analyses with the baseline network and scenario model files provided as project deliverables. These informal analyses are intended to build familiarity with the DynusT software features and functionality. This increased familiarity will in turn enable the NCDOT to make informed and effective decisions on the appropriate role for DynusT in future project and program scenario analyses within the state.

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CHAPTER 1. INTRODUCTION

The Raleigh Durham area in North Carolina experienced tremendous growth in both population (50%) and travel (56%) in the period of 1995-2005. This growth trend in population and travel demand has continued in the years since 2005 even in the face of a global economic recession. As a result, the I-40 corridor, which encompasses I-40, I-85, I-440, I-540, NC 540, NC 147, and US 70 is under significant and increasing strain. The I-40 corridor is vital to the economic health of the region and the entire state, and it is representative of the challenges faced in all economically vibrant urban areas. Traditional highway construction approaches alone cannot meet these current and future challenges.

These realities render it imperative that the NCDOT and metropolitan and regional planning agencies have the tools necessary to assess the system performance impacts of a variety of operational strategies, including HOV/HOT lanes, congestion or value pricing, ramp metering, system-wide signal coordination, incident and work zone management, and expanded traveler information. This report documents an NCDOT sponsored research project aimed at providing an important network modeling capability along these lines.

This introductory chapter provides a brief review of the motivation and background for the project. The original task descriptions are then documented along with the further task definition and revisions that occurred during the project. Finally, the organization of the remaining report chapters and appendices is provided.

1.1 Background and Problem Statement

It is becoming increasingly evident at both the national and state levels that our society cannot build its way out of the growing congestion problem. Therefore, the transportation community, i.e. governmental and business leaders and the professional that support their efforts, has shifted to a new strategic paradigm aimed at optimizing the use of the existing system of facilities through a combination of improved operational efficiency, pricing and ITS strategies. This need to focus on operational strategies is particularly acute in urban areas, where the capital costs both for new facilities and for major capacity improvements to existing facilities are becoming prohibitively expensive and/or unwise from an environmental sustainability perspective. An integrative tool that estimates the relative transportation system performance impacts of traffic management, pricing policies, and traveler information systems is required in order to assess the potential success of such strategies and to produce metrics to support comparison of these strategies to traditional construction-based approaches. The FHWA is presently advocating the use of DynusT, a combined dynamic traffic assignment and simulation model, as the integrative tool to achieve many of these objectives. DynusT grew out of the DYNASMART-P development effort.

Just prior to the initiation of the research project documented in this report, the research team has completed an NCDOT study on the effectiveness of Advanced Traveler Information Systems (ATIS) strategies in North Carolina using an earlier version of the DYNASMART-P modeling tool. The ATIS research involved an extensive case study for a sub-area of the I-40 corridor. The current research expanded the I-40 analysis area to include the entire highway system in the Triangle Regional Model (TRM). The current research also included calibration of the DYNASMART-P regional network model using high-resolution traffic surveillance data (Traffic.com) that became operational in the corridor during the course of the project.

The current research aligns well with the NCDOT strategic goal of making significant improvements in the state transportation network's ability to provide safe and efficient movement of people and goods. The I-40 corridor represents a major public investment that is vital to the economic health of the Triangle Region and the entire state. Therefore, the operational efficiency of the corridor needs to be monitored, evaluated, and improved through a variety of operational strategies. The research presented in this report identified and provided initial evaluation of a carefully selected set of candidate operational strategies. The calibrated regional DynusT network model was applied to estimate and compare the system performance impact of the candidate strategies.

As mentioned above, the I-40 corridor has, and continues to experience tremendous growth in traffic demand. Concurrently, fiscal and environmental realities are making it increasingly difficult to add capacity through physical expansion of the key facilities. Congestion statistics for the Raleigh-Durham area cited in the 2007 project proposal bore this out –

- The region was rated 4th in the nation in terms of mobility problems for midsize urban areas
- Freeway vehicle miles of travel increased by 60% from 1995 to 2005, while freeway lane miles increased by about 40% in the same period
- Compared to the region's peer group in 2005, regional travelers experienced 18 million hours of delay vs. 11 million for the average midsize region

These problems cited in 2007 have continued and are not likely to diminish in the future. Therefore new strategies based on effective traffic management need to be developed, assessed, and field tested. This process must be done at the system level, must be consistent with current and projected travel demand patterns, and must include any planned free and toll facilities that may impact corridor operation.

Looking forward, the project motivation is also driven by the need to jointly evaluate and compare transit alternatives. Although the project focused primarily on non-transit strategies, the current and planned capabilities of DynusT were evaluated, and this report provides recommendations for follow-on efforts to expand the model's capability to provide full-featured assessment of transit strategies.

1.2 Research Approach and Task Descriptions

This project was designed to deliver a calibrated DYNASMART-P model of the Triangle region that will provide this performance assessment capability and that can be adapted for use throughout the state. Between the time the project proposal was written and the project commenced, the development thread supported by the FHWA and carried out by Dr. Yi-Chang Chiu of the University of Arizona, renamed the software tool DynusT. DynusT is a direct descendant of the DYNASMART-P development program. One of the primary innovations in DynusT is use of improved traffic flow models that provide more realistic representation of the relationship of vehicle speed to dynamically evolving traffic stream conditions.

Although the project was self-contained and motivated, it was envisioned as the first step in a multi-year program to bring DynusT capability to statewide modeling of North Carolina's strategic highway corridors and detailed program support modeling for each of the state's metropolitan areas and regions. As the research project draws to a close, the project research team still considers this to be a worthwhile goal for NCDOT to consider and investigate.

In summary, the principal objective of this research was to develop, enhance, calibrate, and validate a DynusT model of the I-40 corridor to enable an evaluation of operational, pricing, and traveler information strategies on network-wide and corridor-wide performance. In keeping with the vision just described of bringing this modeling capability to the entire state, a secondary objective was to support professional capacity building to enable effective use of the model by NCDOT.

The project tasks were designed to achieve these objectives and were organized into two phases. The project task descriptions from the project proposal are documented verbatim below. The only change that has been made in the original task descriptions is the substitution of "DynusT" for "DYNASMART-P." This was done for clarity and to avoid confusion. Following each of the original task descriptions is a description of further definition and revisions to the task details that were necessary during the course of the project.

1.2.1 Phase I

1.2.1.1 Task 1 – Define the Model Study Area and the Operational Scenarios

Proposal Description

The research team will consult with the project steering and implementation committee to develop the final extents of the project study area. Although it is anticipated that the project study area will be identical to the Triangle Regional Model network extents, the factors influencing the decision regarding the study area boundary will be fully vetted in the initial stages of the project.

The team will also develop detailed recommendations regarding the operational scenarios that will be evaluated for the I-40 corridor. In crafting the scenario recommendations, the team will aim to include all feasible alternatives that are under consideration or may be so in the future. The team will also expand the list of feasible alternatives in order to provide a robust evaluation of DynusT's performance assessment capabilities. The final definition of the study area and the candidate operational scenarios will be made in consultation with the project steering and implementation committee. In fact, it is anticipated that close communication and coordination with the leadership of the committee will be needed throughout this important foundational task. For example, preliminary consultation with the Intelligent Transportation System Section 1) points to a need to investigate a ramp metering strategy that includes synchronization with adjacent surface street signals and 2) highlights the I-40 bottleneck analysis report prepared for the NCDOT by Parsons, Brinckerhoff, Quade, & Douglas in 2002 as a key foundational document for scenario development.

Revisions during the Project

No revisions were needed. At the project kickoff meeting, the project steering and implementation committee confirmed that the project team should use the Triangle Regional Model network structure for the DynusT modeling.

1.2.1.2 Task 2 – Design of 511/TIMS User Surveys

Proposal Description

Phone intercept surveys will be designed and conducted using the user survey capabilities of NC's 511 system. These surveys will be designed to provide valuable insight about behavioral responses to information that will in turn be an important foundation for assessing the value and impacts of traveler information. Questions will be developed based on traveler perceptions of 511/TIMS[1], behavioral changes, and socio-demographics. Traveler perceptions surveyed will also include offering travelers the opportunity to provide feedback and opinions on future deployments, including details on when and where future devices and features should be deployed.

In addition to the opportunity for automated survey participation, phone callers to 511 will also be invited to leave their name and phone number in order to participate in a more detailed call back survey by a project team member. In addition to the 511 user surveys, users of http://apps.dot.state.nc.us/tims/ will be invited to click on a link to the evaluation website and complete the survey questions online. The team will require assistance from the NCDOT ITS Operations Unit in order to implement the survey. These surveys will initially focus on the

[1] Traveler Information Management System

Triangle and may later be expanded to other metro areas. Finally, the results of this task will include general recommendations on effective survey design.

Revisions during the Project

The project team later learned that the NC511 system did not have the built-in capability for conducting surveys within a 511 call. The actual capability allows callers the opportunity to leave their phone number in order to be called back for a phone survey. A short call back survey was designed and implemented. The steering and implementation committee decided to not proceed with a longer survey and to not move forward with a web based survey. A longer survey was developed by the project team. This longer survey instrument is provided in Appendix B. The longer survey can be used in the future as a starting point should NCDOT decide to conduct a more extensive survey of use and perception of traveler information sources.

1.2.1.3 Task 3 – Identify Required Model Modifications and Additions

Proposal Description

The recently completed "Effectiveness of Traveler Information Tools" project was focused solely on evaluating the system impact of advanced traveler information system (ATIS) investments. Even with this tight focus, three key enhancements in DynusT were implemented to strengthen the program's evaluative and comparative functionality. It is anticipated that the more comprehensive operational strategy assessment involved in the proposed project will necessitate additional program modifications, extensions, and additions. Although further enhancements may be identified during the execution of subsequent tasks, the research team will identify as many required enhancements as possible near the beginning of the project. FHWA has committed to continue the software support that provided program updates for the ATIS project.

Revisions during the Project

No revisions were needed.

1.2.1.4 Task 4 – Identify and Specify Data Needs for Calibration, Validation, and Scenario Analysis

Proposal Description

Although DynusT's functionality includes the capability to receive network and origin and destination data directly from the regional travel demand model, there will be extensive additional data needs to support calibration and validation of the baseline model and comprehensive analysis and comparative assessment of operational strategy scenarios. For example, signal timing data for key regional signal systems and key isolated intersections will need to be gathered and coded. Also, a thorough identification of all available traffic operational data, including the new Traffic.com system data, will be needed along with an assessment of how this data can support model calibration and validation. The final data needs specifications will be informed by the strategy scenarios that are selected for the phase II modeling.

Revisions during the Project

No revisions were needed.

1.2.1.5 Task 5 – Phase I Report and Presentation

Proposal Description

The results of Tasks 1 through 4 will be documented in a Phase I report to the project steering and implementation committee. It is also anticipated that the key results and recommendations for Phase II will be presented at an interim project meeting of the full committee.

Revisions during the Project

No revisions were needed.

1.2.2 Phase II

1.2.2.1 Task 6 – Analysis of Survey Data and Recommendations for Ongoing Survey Efforts

Proposal Description

The analysis of survey data collected during the initial part of the study will include statistical evaluation of behavioral responses, especially about the use of 511/TIMS. The results will facilitate realistic assumptions about how people will respond to information and dynamic traffic conditions in the DynusT simulations.

Revisions during the Project

No revisions were needed.

1.2.2.2 Task 7 – Develop Baseline DynusT Model for the Triangle Region

Proposal Description

Network and travel demand data for the entire Triangle region model will be imported from the regional travel demand model to DynusT. If necessary, the DynusT network and travel demand data will be augmented or otherwise modified to conform to the study area definition from Task 1. Additional network data such as traffic signal control details will be acquired and coded as identified in Task 4. Travel demand data will be also refined as necessary including, for example, the creation of time dependent origin-destination flows from the static origin-destination tables in the travel demand model.

Revisions during the Project

No revisions were needed.

1.2.2.3 Task 8 – Calibrate the Baseline Model

Proposal Description

The baseline model from Task 7 will be calibrated using all relevant available data identified in Task 4. It is anticipated that the new Traffic.com data will play a key role in supporting a higher degree of model calibration than would otherwise be possible. It is also anticipated that the Traffic.com data, because it will provide high resolution link flow information, will inform and increase the reasonableness and accuracy of the time dependent origin-destination estimations.

Revisions during the Project

Traffic.com data did play a key role in validating the reasonableness of the baseline model. However, given the scale and complexity of the Triangle regional travel demand model and more importantly given the steering and implementation committee's decision to use 2015 as the base year, the Traffic.com data could not be used to evaluate the reasonableness and accuracy of the 2015 origin-destination tables provided by the TRM Service Bureau.

The committee's decision to use the 2015 as the base year was driven by multiple factors. The primary factor was that the types of scenarios envisioned for evaluation are most appropriately considered in a mid-range time frame. The committee and research team also felt that testing of direct translation of a travel demand model network and demand tables was an important project objective. Therefore, given that a TRM network and demand tables were available for the year 2015 and that this date met the essential criteria of a mid-range analysis horizon, the 2015 TRM model was the consensus committee choice for the analysis baseline.

1.2.2.4 Task 9 – Conduct Operational Scenario Analyses

Proposal Description

The candidate operational scenarios defined in Task 1 will be analyzed using the calibrated baseline model from Task 8. The analyses will be conducted with the goal of providing the clearest and most direct comparison possible between the system performance impacts of the various scenarios. In addition to being compared to one another, the operational strategies will be compared to one or more corresponding traditional construction alternatives.

Revisions during the Project

No revisions were needed.

1.2.2.5 Task 10 – Phase II Report

Proposal Description

The results of Tasks 6 through 9 will be documented in a Phase II report to the project steering and implementation committee. It is also anticipated that the key findings and recommendations for the training workshops will be presented at an interim project meeting of the full committee.

Revisions during the Project

The timing of completion of the scenario analyses, which were delayed due to software updates and difficulties near the end of Phase II, led the steering and implementation committee chair and the project research engineer to decide that a separate Phase II report would create an unnecessary review burden for the committee. This was decided in meetings with the project team in the fall of 2010 in which the team presented preliminary analysis results and the committee chair, project engineer, and team made planning decisions regarding the workshop schedule, location, audience, and agenda. The material that would have been included in the originally planned Phase II report was summarized in the workshop materials and documented in this project final report.

1.2.2.6 Task 11 – Conduct Training Workshops

Proposal Description

Two training workshops will be delivered by the project team in conjunction with the FHWA DynusT support team. The audience(s) and training goals for these workshops will be defined in consultation with the project steering and implementation committee.

Revisions during the Project

No revisions were needed.

1.2.2.7 Task 12 – Project Final Report

Proposal Description

The Phase I and II interim reports, along with the training material designed for and evaluations of the training workshops will be documented in the project final report.

Revisions during the Project

No revisions were needed.

1.3 Organization of the Report

Chapters 2 through 8 provide detailed discussions of the findings of the project tasks. The relationship of the chapters to the project tasks is as follows:

- Chapter 2

  Task 1 – Define the Model Study Area and the Operational Scenarios

- Chapter 3

  Task 3 – Identify Required Model Modifications and Additions

- Chapter 4

  Task 4 – Identify and Specify Data Needs for Calibration, Validation, and Scenario Analysis

- Chapter 5

  Task 7 – Develop Baseline DynusT Model for the Triangle Region

- Chapter 6

  Task 8 – Calibrate the Baseline Model

- Chapter 7

  Task 9 – Conduct Operational Scenario Analyses

- Chapter 8

  Task 2 – Design of 511/TIMS User Surveys

Task 6 – Analysis of Survey Data and Recommendations for Ongoing Survey Efforts

Tasks 5, 10, and 12 are report preparation tasks and therefore are not represented in the chapter sections that discuss the research findings. Task 11 – Conduct Training Workshops – is a technology transfer and implementation assistance task. Therefore, Task 11 is discussed in the Implementation and Technology Transfer Plan, Chapter 11.

The overall project findings and conclusions are presented in Chapter 9, and the recommendations and implementation considerations are presented in Chapter 10. A series of appendices follow the report chapter as detailed in the report table of contents.

CHAPTER 2. MODEL STUDY AREA AND THE OPERATIONAL SCENARIOS

2.1 Model Study Area

The project proposal anticipated using the Triangle Regional Model study area for the project DynusT implementation. There were several reasons for this plan. First, creation of a near identical network and traffic analysis zone structure in DynusT would enable evaluation of network wide impacts of operational strategies in the I-40 corridor within a regional transportation supply and demand context identical to the approved travel demand model. Second, the potential benefits of modeling the entire regional demand model network motivates an investigation of the scalability and practical effectiveness of DynusT when applied to an extensive regional network like the TRM. Finally, using the entire TRM network and zone structure provides the most straightforward opportunity to evaluate operational strategies using the accepted regional origin-destination demand tables.

After a thorough discussion of model study area definition at the project kickoff meeting held on August 7, 2008, the project steering and implementation committee agreed that the research team should pursue developing a DynusT model based on the full TRM network. The committee also instructed the project team to use 2015 as the baseline year for operational scenario analysis. Figure 2.1 shows the approximate extent of the study area network represented by the boundary line superimposed on a Triangle region excerpt of the North Carolina 2011-2012 State Transportation Map.

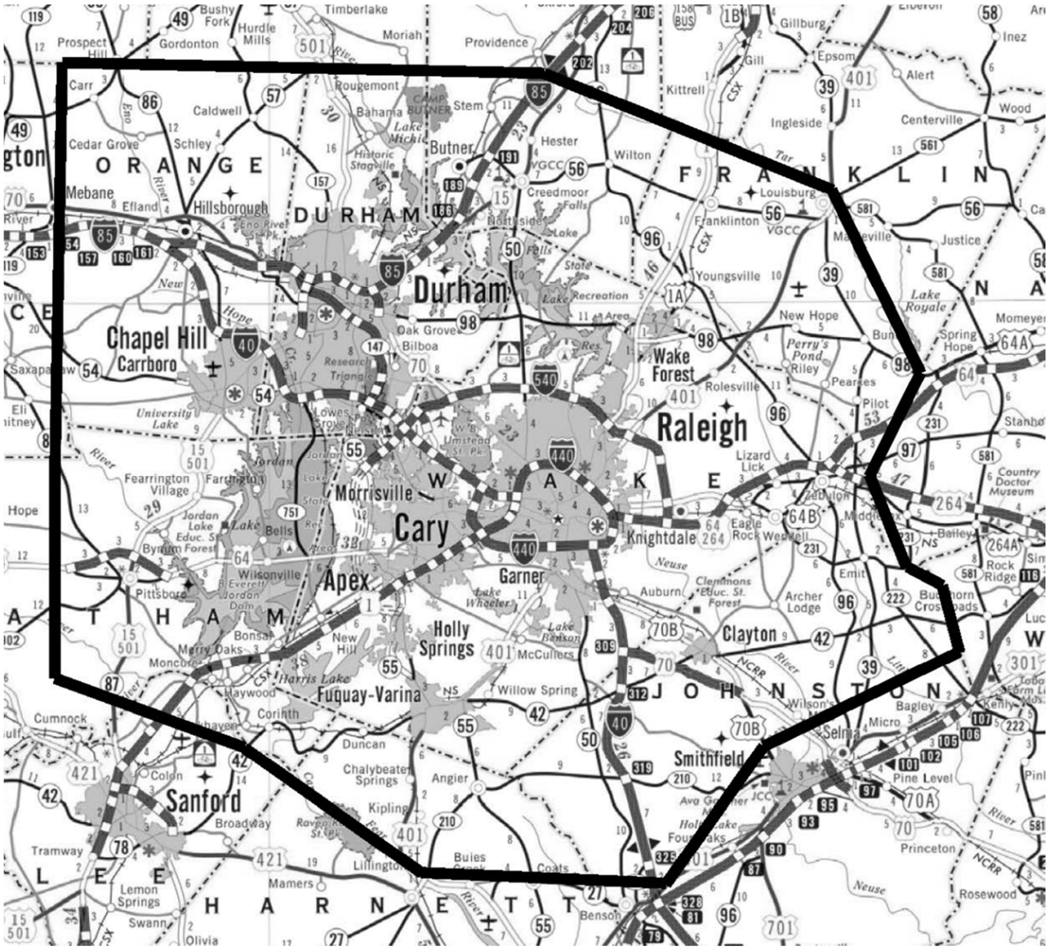


Figure 2.1 TRM 2015 Network Extent

2.2 Operational Scenarios

As made clear in the project title, the focus of the operational analyses was the I-40 corridor. The operational scenario development was guided by a desire to provide preliminary analysis of non-construction mobility enhancement strategies that were planned or under consideration for the corridor and by a desire to provide an extensive test of the comparative analysis capabilities of the DynusT network modeling tool. Candidate scenarios were presented to the project steering and implementation committee and were discussed in a Phase I interim project meeting held on August 6, 2009. In conjunction with the steering and implementation committee, the project team defined five scenarios divided into three categories, namely *primary*, *secondary*, and *benchmark*. The three primary scenarios were focused on realistic options for the I-40 corridor that were under consideration at least at a conceptual level. These scenarios cover the range of options anticipated by the proposal and represented in the project title. The primary scenarios were 1) comprehensive ramp metering, 2) low cost bottleneck improvements, and 3) HOT lanes. DynusT was judged to be capable of modeling these scenarios with sufficient accuracy and provide meaningful corridor and network level performance measure to support preliminary comparative scenario evaluation. Descriptions of these scenarios follow –

Comprehensive Ramp Metering – The ramp metering ITS strategy was of particular interest to the committee. This freeway operational strategy has been widely deployed and studied through the U.S. but had not been previously used in North Carolina. The project team worked with members of the committee and other interested NCDOT professionals identified by the committee to define a detailed plan for implementing ramp metering in the I-40 corridor. As this part of the project unfolded, the final scenario details were based on the ITS strategic plan update that was published in March of 2010. (Kimley-Horn, 2010). In the end, the project team analyzed a two phase scenario with a phase 1 scenario including all ramp metering projects designated at "Short" timeframe projects in the strategic plan update's evaluation matrix and a phase 2 scenario that included both the "Short" and "Medium" timeframe ramp metering projects. With the concurrence of the steering and implementation committee, the project team decided to include ramp metering projects not specifically on the I-40 facility in order to accurately reflect the network effects of potential ramp metering deployments. The project team anticipated having the ability to emulate specific ramp metering logic within the software. However, as discussed in Chapter 7, the final analysis involved an emulation of simple traffic responsive ramp metering logic.

Low Cost Bottleneck Improvements – The project team consulted with previous corridor studies, such as the PBQ&D Bottleneck Analysis, and with the committee and other designated NCDOT personnel to identify the low cost bottleneck improvement opportunities for I-40 that will exist in the 2015 network. This effort was coordinated with the emerging work of the I-40 Regional Partnership. A draft version of a list of candidate operational improvements was provided to the team by Meredith McDiarmid, State Systems Operations Engineering and Corridor Executive for the I-40 Regional Partnership. Beginning with this list, the project team selected a subset of the candidate improvements that could be considered low cost improvements and that were likely to yield measurable operational impact within the DynusT tool. The selected list of low cost improvements are presented in Table 7.1.

HOT Lanes – The project team will worked with the committee and other designated NCDOT personnel to develop a conceptual design of the most likely HOT lane implementation for the I-40 corridor. Development of this conceptual plan is described in detail in Section 7.2.4.

CHAPTER 3. MODEL MODIFICATIONS AND ADDITIONS

In the earlier stages of this project, the study team encountered a number of issues while constructing the baseline network. These issues were reported to the developers and most have been addressed. Below is a summary of the enhancements that have been made to the software in support of this project. Also included below is a list of desirable features that will need to be addressed by developers to make DynusT more user-friendly.

3.1 Key Enhancements Made to DynusT and NEXTA

- **N**etwork **EX**plorer for **T**raffic **A**nalysis (NEXTA) - maximum number of zones. In the previous version of NEXTA, a static multi-dimensional array used for the vehicle and path analysis is limited to 2000 zones. Given the size of our TRM network, the number of zones limit was extended to 2500. Note: NEXTA is the graphical user interface that is used by both DynusT and DYNASMART-P.

- DynusT bus functionality. In earlier versions of DynusT, the bus modeling capability was not available. This capability has been added or enabled by the developers to support our scenario analyses.

- DynusT custom codes for ramp metering. The developers provided the study team with a customizable module where any type of algorithm could be developed for ramp metering. Such codes would then need to be compiled into a dynamic linked library (DLL) and that DLL will need to be placed into the working directory for the developed algorithm to be recognized by DynusT. Now that DynusT is an open source software, users will be able to make changes to the codes directly without having to use this workaround.

- DynusT output data extraction. It was discovered in the latter stages of the project that there was a bug in NEXTA in exporting the measures of effectiveness. The developers provided the study team with a utility named “link_statistics.” When executed, this utility will output two files, named LinkStatspd.dat and LinkStatVol.dat.

3.2 Desirable Features for Ease of Development and Calibration of Models

- DynusT and NEXTA compatibility for ramp metering. In the current version of DynusT (version 3.0), there exists an incompatibility of the file format between NEXTA and DynusT. Specifically, NEXTA is writing the ramp.dat in a different format than what DynusT expects.

The workaround is to manually create the ramp.dat and place it into the working directory just prior to running the simulation model.

- OD matrix editing utility. The study team experienced difficulties with manipulating the origin-destination (OD) matrix due to the high number of zones. It is nearly impossible to manipulate the contents of demand.dat in Notepad. A good program we found that would allow us to do extensively editing such as zeroing out the intra-zonal trips is SAS business analytics. Unfortunately, SAS is not an inexpensive program to own and it requires a steep learning curve. Thus, it would be convenient if developers provide a simple utility to allow users to copy OD matrix and manipulate the cell values.

- Network cleaning utility. The network imported from TransCAD is likely to have many imperfections such as connectivity issues and extra nodes. Having a utility to automatically fix these problems will save considerable time and effort. The developers did provide the study team with a "networkclean" utility; however, it did not work for our particular model. Such a utility would be very beneficial during the model development phase.

- Limitations to speed-density model form. DynusT only allows a modified Greenshields speed-density model form, which could be limiting in our ability to calibrate the model to field data. The minimum speed specification in the currently implemented two-regime traffic flow model can also result in unrealistic flow density relationship whereby flow increases with densities approaching jam density. This limitation has been communicated to the developer.

CHAPTER 4. DATA NEEDS FOR CALIBRATION, VALIDATION, AND SCENARIO ANALYSIS

The research team performed the TRM calibration and validation in two phases. The first represents a qualitative check and the second a quantitative check. The qualitative check was done simply to ensure that the model was producing a stable solution and was free of gridlock and that the resulting overall traffic flow patterns somewhat resemble the real-world patterns. The quantitative check involves identifying those model inputs and parameters that affect model outputs, particularly the link counts and speeds. The goal is then to adjust their values, within practical range, so that the outputs are reasonably close to those measured in the real world. In this study, we chose to focus on comparing link traffic counts (i.e. volume) between the model estimates and those in the real world. In typical transportation planning applications, if the relative difference between the two values is less than or equal to 25%, the model estimates are deemed to be sufficiently accurate. The following sections list the data the study team used to perform the qualitative and quantitative checks.

4.1 Qualitative Check

- Average travel time from the regional travel demand model.
- Average trip length from the regional travel demand model.
- Highest travel time OD pairs from regional travel demand model.
- Local knowledge of typical congested and non-congested locations.
- Signal timing data.

4.2 Quantitative Check

- Link counts at locations where the team, in conjunction with the project steering committee, identified as those unlikely to change between 2005 and 2015 in terms of their current traffic counts. The link flows were extracted from sensors in the Traffic.com database which cover the Research Triangle Region . For the links of interest, Traffic.com data was the only source to yield traffic volume estimates; INRIX only reports link traffic speeds and travel times, while another sensor system SPEEDINFO reports spot speeds at selected points only.

- Traffic flow model specification (i.e. whether to use single versus two regimes) and model parameters (minimum speed, density break point, free-flow speed, jam density, and alpha) for different facility types.

To carry out the scenario analyses, additional scenario-related data were needed for entry to the model. The following list provides a summary of the scenarios evaluated and the additional key input data required for the corresponding scenario.

- Scenario #1 - 2015 Baseline: no additional data needed.
- Scenario #2 - Full Build Network: maximum possible number of lanes in a cross section, number of HOV lanes, and applicable freeway links where lanes can be added.
- Scenario #3 - Low-Cost Bottleneck Improvements: location of dual left turn lanes, separate right turn lanes, dual ramp loops, etc.
- Scenario #4 - HOT Lanes: location of HOT lanes and toll rates.
- Scenarios #5 & 6 - Ramp Metering: locations of on-ramps and desired metering rates.

CHAPTER 5. BASELINE DYNUS-T MODEL FOR THE TRIANGLE REGION

This chapter describes the procedures for building the DynusT Baseline network to conduct the operational scenarios analysis (Task 7). Network and travel demand data for the entire Triangle region were imported from the regional travel demand model, TRM 2015 into DynusT. Additional network data such as selected traffic signal control details were acquired and coded. Time dependent origin-destination flows from the static origin-destination tables in the travel demand model were created for the analysis time periods.

5.1 Travel Demand Model for the Triangle Region (TRM 2015)

The TRM (Triangle Regional Model) is built in TransCAD format and has been continuously updated. The recent model was developed in 2010 for the planning year 2015. Figure 5.1 is a screen capture for the TRM 2015 network from the TransCAD map view. This model contains network data elements such as nodes, links, zonal information, and OD demands, all of which were used for building the DynusT network for this project. The TRM 2015 model consists of 11,883 nodes; 15,958 links; and 2,389 zones. It has OD matrix demand sets for three analysis time periods: AM peak 4 hours (6:00 am to 10:00 am), PM peak 4 hours (3:30 pm to 7:30 pm), and off peak 16 hours. Each OD matrix set consists of three matrices for three vehicle types, namely HOV (High Occupancy Vehicle), SOV (Single Occupancy Vehicle), and CV (Commercial Vehicle).

Figure 5.1 TRM 2015 Physical Network

5.2 Network Conversion Process (TransCAD to DynusT)

The TRM TransCAD network was converted into a DynusT network for the purpose of this project. Figure 5.2 shows the DynusT network preparation steps which were carried out by the team. First, the network data such as node, link, zone, and traffic demand were exported from the TRM TransCAD network to Microsoft Excel or in text file formats. Using a spreadsheet program and a text editor, these files were edited in order to create the appropriate input files for DynusT import procedure. Detailed explanations about how to prepare these input files and several tips for editing and correcting run errors are detailed in Appendix A. of this report.

NEXTA has various functionalities for preparing DynusT or DYNASMART-P networks (importing and editing), setting simulation run scenarios, viewing simulation results, and post processing of raw results for further analysis. Even though the NEXTA import function builds the DynusT network automatically from TRM 2015, there remains significant time-consuming manual effort in preparing the necessary import files and correcting network translation errors. Furthermore, network calibration intended for generating realistic simulation results requires significant time and effort. The network calibration method employed in this research is explained in Chapter 6. The selected operational scenarios, modeling procedures for each scenario, and scenario analysis outputs are described in Chapter 7.

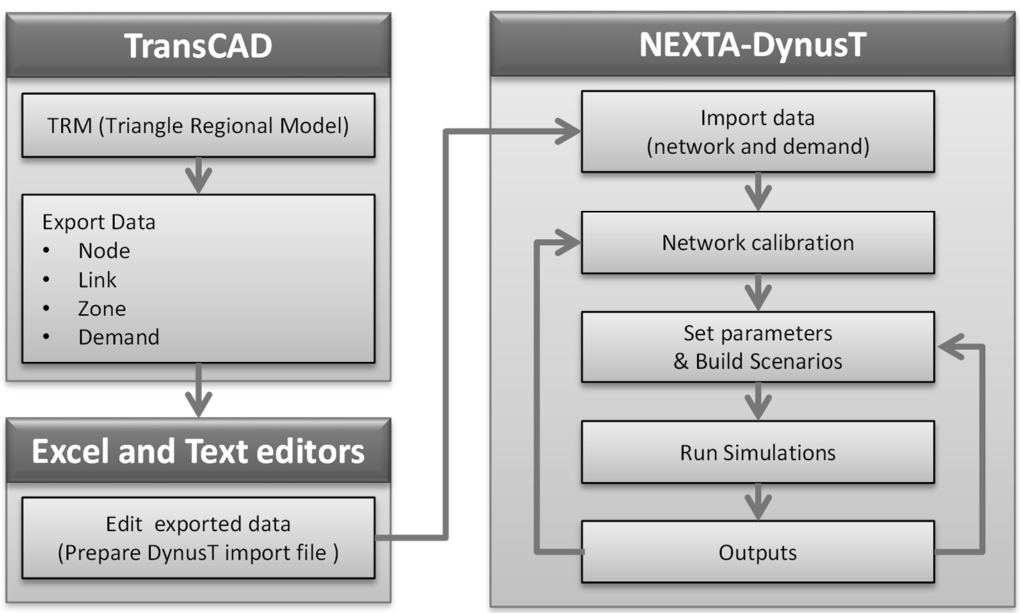


Figure 5.2 DynusT Network Preparation

5.3 DynusT Network characteristics

Figure 5.3 illustrates the DynusT network which was converted from TRM 2015. Darker lines represent freeway and highway (principal arterial) facilities. I-40, I-85, I-440, and I-540 constitute the major interstate freeways in the network. Lighter weight lines represent minor arterials and collector roads. The DynusT network comprises 2,389 zones; 9,527 nodes; and 20,250 links. The reason why the number of nodes in DynusT is less than those in the TRM TransCAD network is because all centroid nodes must be removed from the node set. The number of links is also different because the centroid connectors must also be deleted from the link set and two-way links in the TransCAD network must be re-coded as separate one-way links in the DynusT network.

Figure 5.3 DynusT Baseline Network

5.3.1 Link Characteristics

The physical properties of links and geometric configurations are important elements of the traffic simulation model in DynusT. Items such as link length, the number of lanes and free flow speed information can be readily acquired from the TransCAD network. Since the number of left turn bays, the number of right turn bays, and grade information for a link cannot be extracted from a TransCAD network, these values for most of links were assumed to be initially zero. However, several left turn and right turn bays were manually input for those links at major intersections.

All links were classified into freeway, highway, or arterial links in DynusT according to the link types specified in the TRM TransCAD network, as shown in Table 5.1. On-ramp and off-ramp links were manually specified in NEXTA.

Table 5.1 also shows the key traffic flow parameters for each link type as well. The maximum service flow rate is the maximum capacity of a given lane providing the upper limit of the flow rate through a section under any conditions. The saturation flow rate is applied to downstream vehicles discharging from a queue. Figure 5.4 provides the traffic flow model setup parameters used for this network. The traffic model parameter values for the two-regime modified Greenshields model were developed by the freeway model calibration effort described in Chapter 6. Details of the traffic flow model forms follow.

For the single regime Greenshield model, vehicle speeds for the anisotropic flow regimes are determined by the following expression –

$$v = v_0 + \left(v_f - v_0\right)\left(1 - \frac{k}{k_j}\right)^{\alpha}$$

Where

v is vehicle speed
v_0 is the model minimum speed
v_f is the model free flow speed
k is the anisotropic flow regime density
k_j is the model jam density
α is the fitted model shape parameter

For the single-regime model, the free flow speed is taken to be the link speed limit plus an optional link speed adjustment factor. For the two regime Greenshields model, vehicle speeds for the anisotropic flow regimes are determined by the following expression –

$$v = v_0 + \left(v_i - v_0\right)\left(1 - \frac{k_b}{k_j}\right)^{\alpha} \quad for\ k < k_b$$

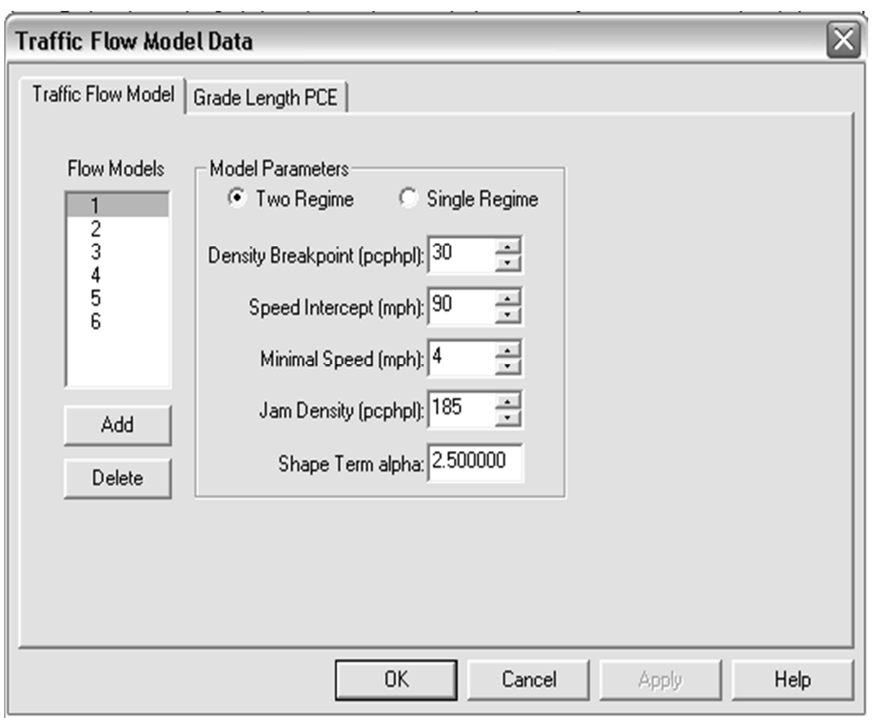
$$v = v_0 + \left(v_i - v_0\right)\left(1 - \frac{k}{k_j}\right)^{\alpha} \quad for\ k \geq k_b$$

Where

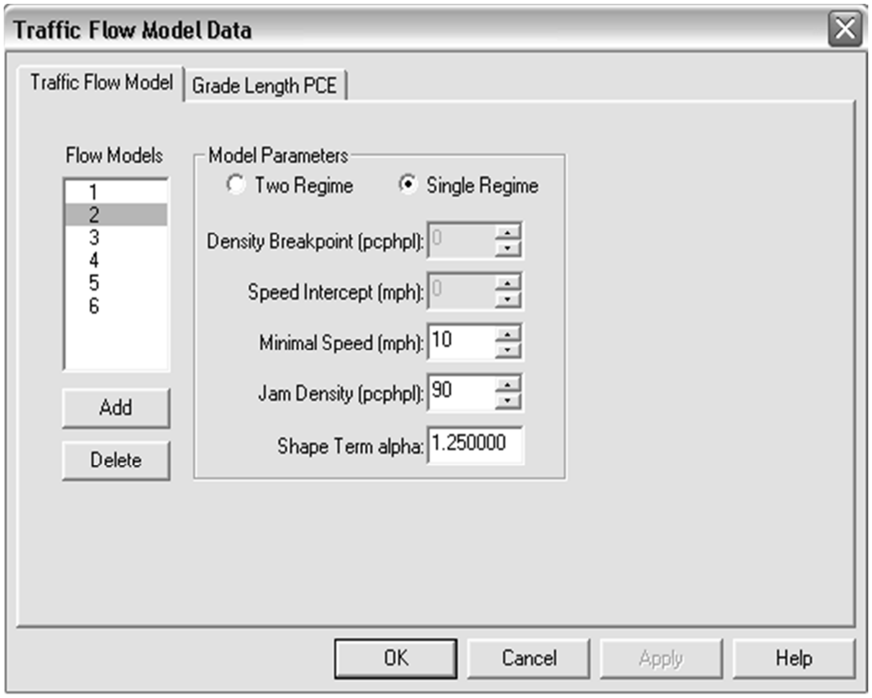
v is vehicle speed
v_0 is the model minimum speed
v_i is the model speed intercept of regime 2
k is the anisotropic flow regime density
k_b is the model density breakpoint (transition from regime 1 to regime 2)
k_j is the model jam density
α is the fitted model shape parameter

Table 5.1 Link Characteristics of the TRM DynusT network

DynusT Link type	TransCAD link type	# of links	Traffic Flow model	Maximum service flow rate	Saturation flow rate
Freeway	Urban Interstate, Urban Freeway/Expressway, Rural Interstate	1,165	1	2300	2300
Highway	Urban Principal Arterial, Rural Principal Arterial	2,644	2	2005	2005
Arterial	Urban Minor Arterial, Urban Collector, Urban Local/Unclassified/Centroid Connectors, Rural Minor Arterial, Rural Major Collector, Rural Minor Collector, Rural Local/Unclassified/Centroid Connectors	15,792	2	2000	2000
On/Off ramp	Define manually	649	1	2000	2000



a. Two regime Greenshields model



b. Single regime Greenshields model

Figure 5.4 Traffic flow model setup panels in DynusT

5.3.2 Node characteristics

The TRM TransCAD network doesn't explicitly model node control information. However, the "Signal density" field in the TRM TransCAD network is a good indicator about whether traffic signal controls exist at the nodes. Of course, the TransCAD network does not provide any detailed information on the traffic signal plan for each intersection. In the absence of this information, most signalized intersections were set as actuated traffic signals. The team initially assumed that all actuated traffic signals operated in two phases' with 100 seconds of maximum green, 5 seconds of minimum green, and 4 seconds of amber.

After completing the import procedure, if nodes on a freeway link were coded as signalized, these node controllers were removed from the network manually. If an intersection showed significant congestion upon running the model, the signal plan for the intersection was modified into a phase plan with protected left turns and additional maximum green times to those movements experiencing significant delay. Signal plans for some intersections were modified based on the actual signal plans the team acquired from the signal unit at NCDOT. At the conclusion of this process, the DynusT network contained 1,915 intersections with actuated signal controller and 7,610 intersections under no control.

5.3.3 Time Dependent Origin Destination Demand Flows

Two analysis time periods for traffic demands were prepared: AM peak and PM peak. Each analysis time period contains three OD matrices for three vehicle types, which are SOV, HOV, and truck (CV).

5.3.3.1 Time Dependent Demand Distribution

Figure 5.5 illustrates the time dependent OD demand distribution. Vehicles were generated one hour before the start of the analysis time period, in order to populate the network to better measure the impact of operation scenarios with background traffic in place. The first through fourth hour time periods generated the vehicles by the specified demand level. The hourly distribution ratios were derived by tracking and emulating traffic count data distributions from an ATR station located in the network. . During the "Flushing" period no traffic is generated. This period was modeled to ensure that all generated traffic during the analysis period has reached its destination. This is critical since most of the performance measures related to trip based information is not reported until the vehicle has reached its destination. It is noted that the data collection time for analysis is from minute 60 through minute 450.

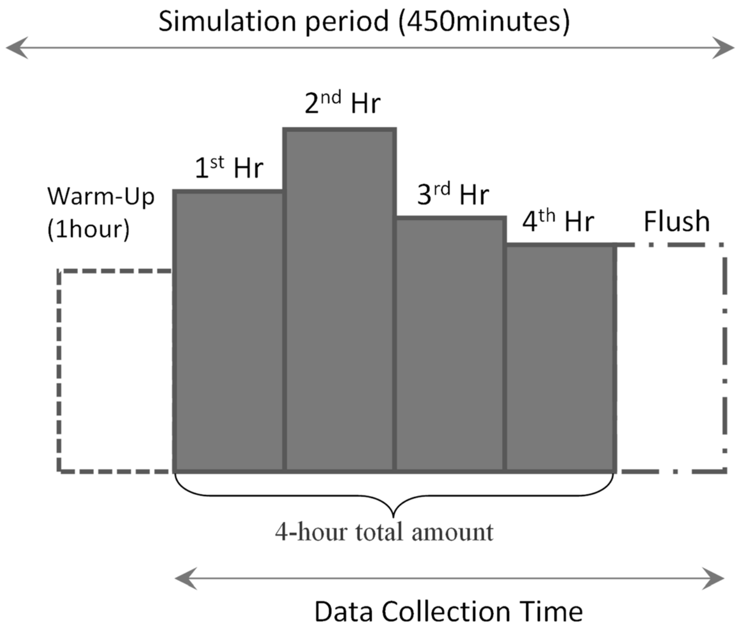


Figure 5.5 Diagram for Time dependent OD demand

Table 5.2 summarizes the AM peak period demand profile. Each one hour OD matrix was created by multiplying hourly distribution ratio with the TRM four-hour AM peak demand matrix. A total 1,092,648 vehicles were generated during the AM peak.

Table 5.2 Demand profile for AM baseline network

Period	Time (AM)	Hourly ratio	Simulation Time	Description
Warm-up	5:00~6:00	0.085	0~ 60 min	1 hour demand*
1	6:00~7:00	0.25	60~120 min	1 hour demand*
2	7:00~8:00	0.35	120~180 min	1 hour demand*
3	8:00~9:00	0.25	180~240 min	1 hour demand*
4	9:00~10:00	0.15	240~300 min	1 hour demand*
Flush	10:00~	0	300~450 min	For clearing network

*1 hour demand = 4 hour AM demand *Hourly ratio

Table 5.3 summarizes the PM peak period demand profile. Each one hour OD matrix was constructed by multiplying the hourly distribution ratio and the TRM four-hour PM peak demand matrix. A total 2,124,827 vehicles were generated during the PM peak.

Table 5.3 Demand profile for PM baseline

Period	Time (PM)	Hourly ratio	Simulation Time	Description
Warm-up	3:00~4:00	0.15	0~ 60 min	1 hour demand*
1	4:00~5:00	0.25	60~120 min	1 hour demand*
2	5:00~6:00	0.30	120~180 min	1 hour demand*
3	6:00~7:00	0.25	180~240 min	1 hour demand*
4	7:00~8:00	0.2	240~300 min	1 hour demand*
Flush	8:00~	0	300~450 min	For clearing network

*1 hour demand = 4 hour AM demand *Hourly ratio

5.4 Simulation setting for Baseline network

5.4.1 Vehicle Generation mode

DynusT has two vehicle generation methods. The first method generates vehicles based on the input OD demand matrix. This method is used in the first simulation run, which produces a vehicle and a path file as outputs. The second method uses these two files for comparing between scenarios. In this case, the network uses the same vehicles and paths under different network conditions (such as geometry change, or deployment of ITS strategies or incident). In other words, this method uses these two files to ensure the same vehicles generated in the first run are retained and to have these vehicles use the same paths they used in the first run. In the second simulation run, if the same drivers began their travels at the same times and used the same paths as they did in the first run, the second run captures how much a traffic event affects their initial trip performance.

5.4.2 User Class Definition (Reference: DynusT online user manual)

DynusT adopts a behavioral response system which assigns drivers to separate response classes based on the percent distributions as defined by the user. These classes are referred to as Multiple User Classes (MUC). The response system assigned to each class is based on the rules of that class.

- Class 1 - Unresponsive (Historical Data)

This class of users does not respond to any information that may alter their current shortest path. Drivers continue on the same path assigned to them unless there is a mandatory Detour (DMS type 2) that all vehicles must comply with.

- Class 2 - System Optimal (SO)

Travel path assignments for this class are based on optimal system perspective, not on the individual drivers' choice. In this class a vehicle may be assigned a longer path in order for all vehicles to experience the shortest overall travel time. This class is only available in an iterative mode, not in one-shot simulations. This class of users will only respond to speed warnings or detour DMS types.

- Class 3 - User Equilibrium (UE)

This class of users is assigned the paths that will reduce the individual travel times for the driver. Once the driver has reached its user equilibrium path it becomes its habitual path. This class is only available in an iterative mode and is the default setting for the route assignment.

- Class 4 - En-Route Information

Two types of information are considered for this class.

(1) Radio type of information in which an incident location is presented to drivers at a pre-defined frequency (the time interval of each information broadcast can be changed in the Advanced Parameter List). One can define a fraction of drivers that are able to receive such information. Upon receiving the information, the driver will select a route to their destination based on their prior knowledge about the network condition as well as their speculation about possible congestion around the incident area.

(2) GPS navigation devices that present new paths based on updated travel time retrieved from the base station. The driver decides whether the new route is followed based on a bounded rational behavior. The switching criteria are based on the "Indifference Band" and "Threshold Bound" parameters. A driver considers switching routes whenever the en-route travel information is updated at each predefined interval.

- Class 5 - Pre-trip Information

Pre-trip shortest path information is equivalent to the driver previous knowledge that there is road work or a lane closure prior to leaving (VMS responsive), and thus the driver avoids the congestion by choosing an alternate route and/or departure time. DynusT simulates this scenario by assigning a class 5 vehicle the quickest path at the time that it is generated. It is noted that once a path has been selected at the origin, it is not subject to re-consideration even if an incident would to occur later on that path.

5.4.3 Scenario Modeling Concept

Figure 5.6 illustrates the basic modeling concepts and corresponding modeling procedures for DynusT. First, the user should establish the Baseline scenario for the existing conditions. The best assignment option is to use the User Equilibrium (User Optimal) condition, in which case all routes chosen by trip-makers between the same origin-destination (OD) pair exhibit the same travel time. To create the basic UE scenario, the vehicle generation by OD table and iterative UE Runs can be set up as shown in Figure 5.7 and Figure 5.8.

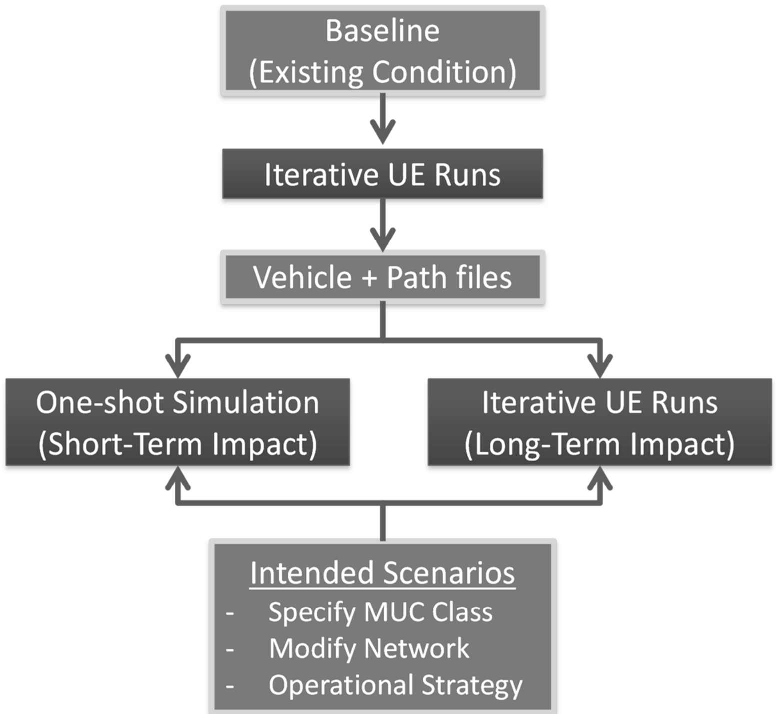


Figure 5.6. Scenario Modeling Concept for DynusT

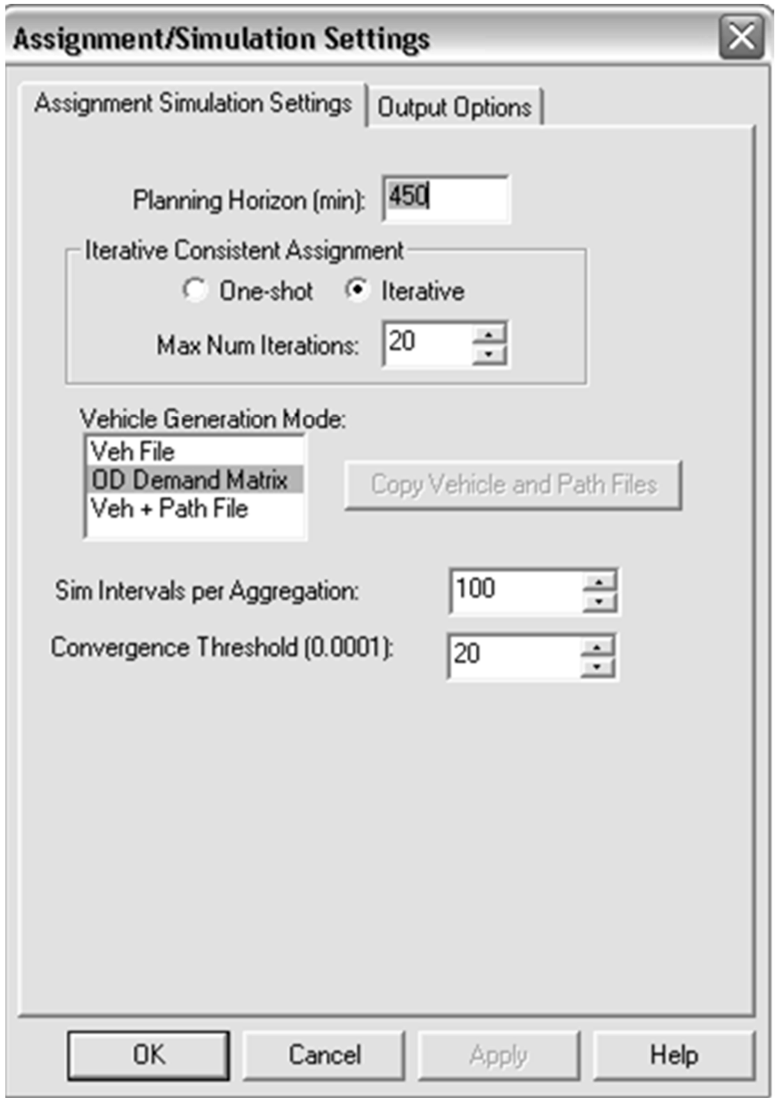


Figure 5.7. Assignment/Simulation Settings for the Baseline Network

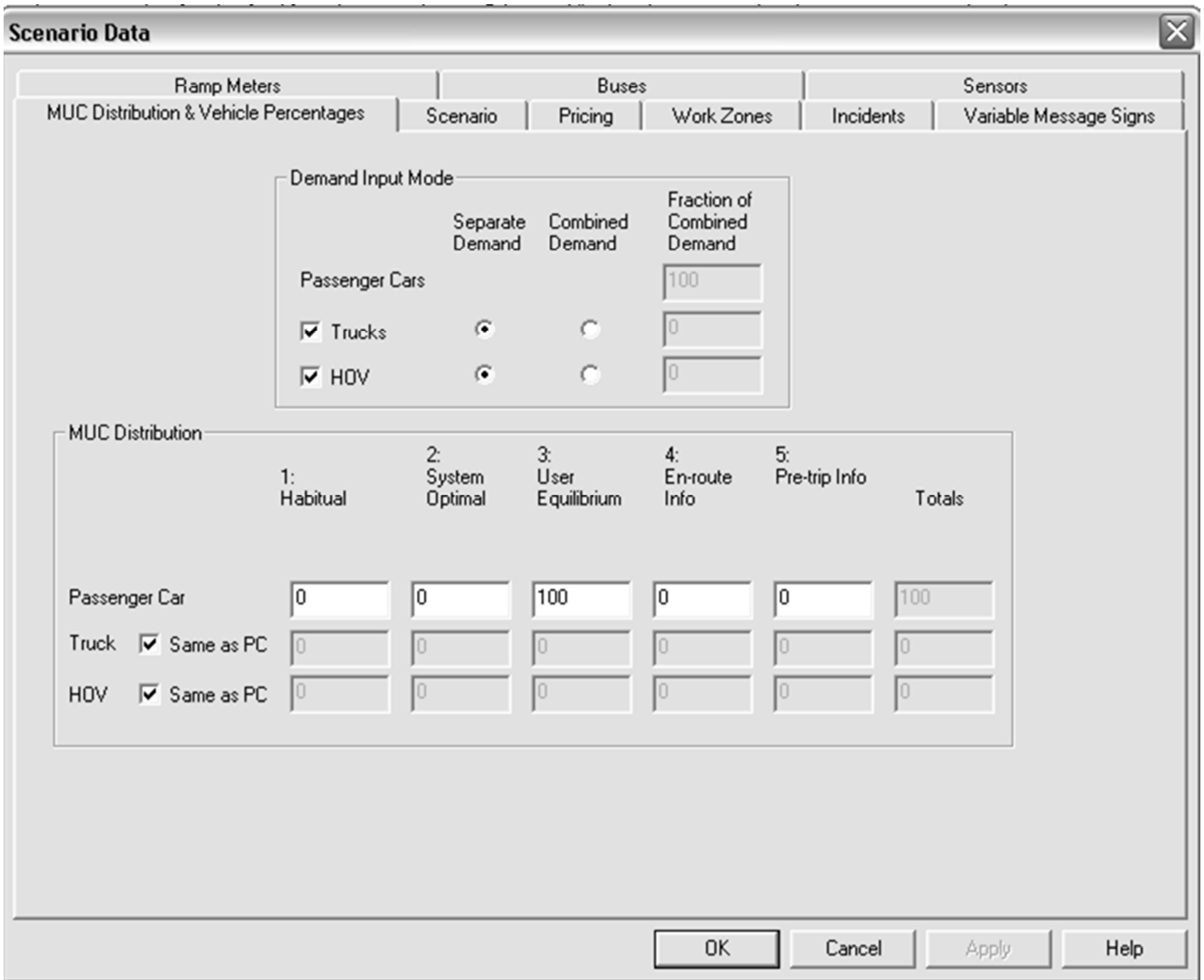


Figure 5.8. User Class Settings for the Baseline Network

5.5 Baseline Network Run Results

Table 5.4 and Table 5.5 summarize the results from the baseline run for both the AM and PM periods, respectively.

Table 5.4 Network-wide Simulation Results for Baseline AM Peak

Total generated vehicles	SOV's	939,590 (85.99%)
	HOV's	94,338 (8.36%)
	Trucks	61,720 (5.65%)
	Total	1,095,648
Total number of vehicles of interest	1,095,648	
Un-served vehicles among total number of vehicles of interest	0	
Average trip travel time (min)	22.0558	
Average trip stop time (min)	5.8864	
Average trip distance (mile)	11.8815	
Average trip speed (mph)	32.3	
Average simulation run time/iteration	1 hour	

Table 5.5 Network-wide Simulation Results for Baseline PM Peak

Total generated vehicles	SOV's	1,724,875 (81.18%)
	HOV 's	44,674 (2.10%)
	Trucks	355,278 (16.72%)
	Total	2,124,827
Total number of vehicles of interest	2,124,827	
Un-served vehicles among total number of vehicles of interest	5,968	
Average trip travel time (min)	26.6013	
Average trip stop time (min)	11.3788	
Average trip distance (mile)	10.4895	
Average trip speed (mph)	25.7	
Average simulation run time/iteration	1.5 hour	

5.6 Discussion

Ideally, if the modeler could input the actual detailed link characteristics and actual traffic control plans at all intersections, the resulting DynusT network model would be more reflective of real-world conditions. However, because of the size of the TRM network, the team was limited in its ability to collect and input all the detailed real traffic network data given the limited time and resources available. An automated procedure to incorporate much of those data is lacking and is apparently limiting the utility of the mesoscopic models.

It is clear from a review of this chapter that the network data preparation was exceedingly time consuming. Following the importation of the network data from the travel demand model, many hours were spent specifying origin links and destination nodes, editing signal information, editing link geometry, and defining on-ramps and off-ramps in the network. However, any upfront effort put into coding a realistic baseline network is likely to pay dividends down the line, as networks can be readily updated after that first and significant initial coding effort. Of course, no network can be considered reliable until it is properly calibrated against empirical data. The challenge of model calibration is addressed in the next chapter.

CHAPTER 6. BASELINE MODEL CALIBRATION

Valid scenario analysis results require a reasonably accurate and valid baseline model representation. As mentioned above, the 2015 TRM regional network and OD tables were selected as the baseline conditions for scenario analysis. In a typical travel demand modeling effort, the calibration stage may include incremental adjustments to the OD tables in order to closely match measure link flows for existing year conditions. This type of "calibration" was deemed inappropriate for the current project for two primary reasons:

- The 2015 link flow conditions are, of course, unobservable
- The 2015 OD tables were taken as the most reasonable estimates of baseline year demand and therefore should be used in an unadjusted manner

The baseline model calibration undertaken for this project consisted of two primary steps:

- The freeway traffic flow models were calibrated to reflect measured traffic flow characteristics based on the Traffic.com side fire radar sensors
- Model flows on key network links that were identified as being unlikely to change considerably in terms of vehicular demand between 2009 and 2015 were compared to field measured flows

This calibration/validation methodology can be summarized as a calibration of embedded freeway traffic flow models followed by a validation of the resulting flows along temporally stable links with currently measure link flows. Detailed traffic flow model calibration was limited to freeway links because 1) modeled flow on the freeway links are likely to dominate trip distribution and dynamic traffic assignment, 2) link flow data were readily available only for freeway links, 3) non-freeway link flows are often dominated by delay at network intersections more so than by travel along the links, and 4) it would be prohibitively time consuming in terms of data collection and model fitting to extend detailed traffic flow model calibration beyond the regional network freeway links.

6.1 Freeway Traffic Flow Model Calibration

A significant set of Triangle freeway data was assembled for the traffic flow model calibration task. The Traffic.com detector network consists of 60 freeway detector stations, providing 120 directional freeway data observation locations. The stations used for traffic flow model calibration were selected in order to represent a variety of conditions in terms of number of travel lanes and speed limit. Nearly 30% of the available directional detector locations, 35 in total, were selected for the model calibration effort. Of these 35 data locations, two have two mainline travel lanes, sixteen have three mainline travel lanes, fourteen have four mainline travel lanes, and two have five mainline travel lanes.

For the selected locations, Traffic.com data were assembled for May 2009 and October 2009. These months were selected because they are widely recognized based on decades of traffic engineering research and practice as the two months that most closely match the average monthly demand over an entire year. In order to test the stability of the models across locations and lane configuration, individual traffic flow models were fit for each location and month. These models were then merged first into specific models for each lane configuration situation. These lane configuration specific models were tested in preliminary baseline runs. Adjustments to fitted minimum speed values were made in consultation with the software developers to prevent unrealistic freeway queuing and breakdown. Also, the preliminary tests and model modification test led to a determination by the project team that a single freeway model would be sufficient to properly model the freeway links. The parameters of this freeway model, as given in Figure 5.4a are as follows:

$$k_b = 30,\ v_i = 90,\ v_0 = 4,\ k_j = 185,\ \text{and}\ \alpha = 2.5$$

6.2 Link Flow Validation

The links used for model link flow validation were identified through a combination of expert knowledge of the project steering and implementation committee and the project team plus a specially designed analysis of TRM model output. The goal was to select locations that were unlikely to change significantly in link demand and flow from the present to the year 2015 baseline conditions. Members of the committee provided input on possible temporally stable links during the August 6, 2009 interim project meeting.

Subsequently, the project team conducted a link by link comparative analysis of the TRM 2005 model results with the TRM 2015 model results. The rationale for this comparison is that links which exhibited a small change in link flows between the 2005 and 2015 TRM model results would likely also exhibit a small change in link flow from 2009 to 2015. Links existing in both networks were ranked based on percentage change in link flow from TRM 2005 to TRM 2015.

After reviewing the comparative results and comparing the links identified as temporally stable, the project team selected +/-5% as the relative 2005 to2015 link flow change level as the means of identifying links for flow validation. Seven locations were finally selected for link flow validation. These validation links are illustrated in Figure 6.1.

The actual link volume comparisons are presented in Table 6.1. Although some of the DynusT values are significantly higher than the corresponding TRM and 2009 Traffic.com values, the project team considered the DynusT 2015 link volume estimates to be reasonable given the 2015 lane configuration and the network importance of the applicable links. Therefore, the calibrated baseline model was deemed sufficiently valid for comparative analysis of the candidate operational scenarios.

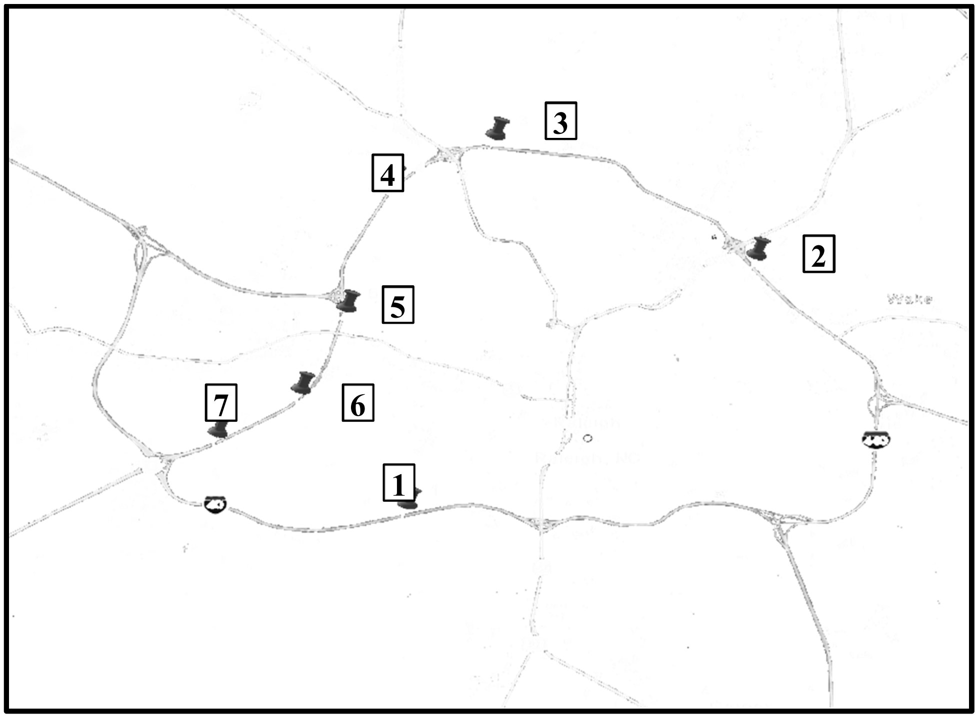


Figure 6.1. Link Locations for Flow Validation

Table 6.1 Average Peak Hour Link Volume Comparison

Location	Traffic.com Count	2015 TRM Model	2005 TRM Model	TRM Model Average	DynusT	DynusT vs. TRM Model	DynusT vs. TRAFFIC.com
1	2386	2596	2506	2551	2942	15%	23%
2	1859	1739	1698	1718	2631	53%	42%
3	3096	3046	3009	3028	3109	3%	0%
4	2576	2697	2625	2661	2683	1%	4%
5	2455	2768	2654	2711	3426	26%	40%
6	2378	2452	2283	2368	3180	34%	34%
7	1992	2355	2292	2323	2332	0%	17%

CHAPTER 7. OPERATIONAL SCENARIO ANALYSES

7.1 INTRODUCTION

The candidate operational scenarios defined earlier, in addition to the 2015 TRM baseline were analyzed on the calibrated TRM network (see Figure 5.3). The analyses were conducted with the goal of providing the clearest and most direct comparison between the performance impacts of the various scenarios.

The objective of this chapter is to demonstrate, through the detail of an actual application, the manner in which each step in the analysis procedure should be performed. Specifically, this chapter will illustrate:

1. How to build the strategy scenarios in the DynusT modeling environment;
2. How to evaluate and compare the scenarios; and
3. The results of case studies conducted on the TRM network.

7.2 DESCRIPTION OF SCENARIOS

Including the Baseline scenario, a total of six scenarios were evaluated in this study. It should be noted that each scenario was evaluated for in both the AM and PM peak periods. In the text below, each scenario is crisply defined, its corresponding information described, and the method of coding the information in DynusT detailed.

7.2.1 Scenario #1: Baseline

The baseline scenario is the TRM 2015 network based on projected traffic demands in the year 2015. The following statistics provide a detailed description of the baseline road network attributes in the test network:

- Network data
  - Number of Nodes: 9,527
  - Number of Links: 20,250
  - Number of OD demand Zones: 2,389
- Travel Demand Period and Characteristics (4-hour demand)
  - AM: 1,095,648 vehicles
  - PM: 2,124,827 vehicles
- Network Link Attributes
  - Number of Freeway Links: 1,165
  - Number of On/Off Ramps: 649
  - Number of Arterial Links: 15,792
  - Number of Highway (non-freeway) Links: 2,644

7.2.2 Scenario #2: Full Build

The Full-Build scenario assumes a cross section with five-lanes in each direction along the entire I-40 corridor. These are allocated as four general purpose lanes and one HOV lane throughout. It should be noted that DynusT treats HOV lanes as exclusive links. Thus the user must create the new HOV links parallel to the general purpose links.

7.2.3 Scenario #3: Low-Cost Bottleneck Improvements

As mentioned in Chapter 2 above, the I-40 "Brainstorming List" of candidate improvement strategies generated by the I-40 Regional Partnership working group provided the basis for developing the specific set of low cost improvements. Based on the baseline conditions in the TRM 2015 network (i.e. scenario #1), the research team identified twelve locations (Table 7.1) which can most benefit from the corresponding low-cost improvement. The team then made the appropriate adjustments on the baseline network to incorporate the improvement effects.

Table 7.1 Low Cost Improvement Candidates Selected for Scenario 3

EXIT #	EXIT NAMES OR ROUTES	IDEAS TO CONSIDER	COMMENTS
282	Page Rd	Dualize EB on-ramp loop	
285	Aviation Pkwy	Dual lane exit for WB I-40 to Aviation Pkwy	
285	Aviation Pkwy	Widen Aviation to 3 lanes over causeway (e.g. 2 lanes SB/WB), w/ reduced lane width	
290	NC 54 / E Cary / W Raleigh	Ramp metering	Only for PM
293	US 1 / US 64 W / End 440 W at Crossroads	I-40 EB - Auxiliary lane from Jones Franklin overpass to Gorman St	WB (not EB)
293	US 1 / US 64 W / End 440 W at Crossroads	Dual lefts from Jones Franklin offramp (Town of Cary suggestion)	
295	Gorman Street	Separte right turns allowing lefts and rights to move at same time	
297	Lake Wheeler	Dualize R-turn lane, WB offramp	
298	S Saunders	Dualize EB offramp	
303	Jones Sausage	Add Dual Left for Off ramps	Only for WB
303	Jones Sausage	Ramp metering	
312	NC 42	I-40 WB loop from EB 42	

7.2.4 Scenario #4: HOT Lanes

According to the *I-40 High Occupancy Vehicle/Congestion Management Study* (Parsons Brinkerhoff, 2003), the HOT lanes were added on two study corridors (one HOT lane for in each direction): I-40 corridor (between US-70 and NC-86) and I-540 corridor (between US-64 and NC50). Figure 7.1 demonstrates highlights the study corridors for the in Scenario #4, in which the red dots represent the terminal points for the HOT lanes.

Figure 7.1 Study Corridors for HOT Lane Scenario

The total length of the HOT lanes implemented in the TRM 2015 network is 128.9 miles (or 64.4 miles/direction). DynusT can only simulate a time-dependent toll rate for HOT lanes. In order to apply relatively reasonable toll rate (for SOV users) in the HOT lanes scenario, the following steps were undertaken. It should be noted that the objective of applying toll rate is to maintain a high level of service in the HOT lane, even after the allowance of SOV access. This LOS is assured by increasing the toll rate as speeds in the HOT lane begin to degrade.

- Step 1

  Set the toll rate as $999 (an extremely high toll rate) for SOVs and Trucks and $0 for HOVs. Simulate the network for 20 iterations.
- Step 2

  Get Extract the performance of the HOT lanes from DynusT for in the following time intervals (minutes): 61~120, 121~180, 181~240 and 240~300.
- Step 3

  Set the toll rate for the above four time intervals, based on the extracted corridor density in the HOT lanes. This logic is as follows:
    - If the corridor density is greater than 25 veh/mi, the toll rate is set at $1/mile, which is based on the maximum toll rates ($/mile) of the HOT applications in U.S. based on a scan of a readily available online information;
    - If the density is less than 25 veh/mi, the toll rate will be set based on multiple trials using toll rates of $0.1/mi, $0.25/mi, $0.5/mi and $0.75/mi. The minimum toll rates that will keep the corridor density below 25 veh/mi are selected.

7.2.5 Scenario #4: Ramp Metering (Short Term)

Based on the "Intelligent Transportation System Strategic Deployment Plan Update for the Triangle Region"*(3),* five locations were identified to implement in the "short term." Each location is modeled with two ramp meters, one for each on ramp. Figure 7.2 shows the short term ramp metering locations on the TRM network.

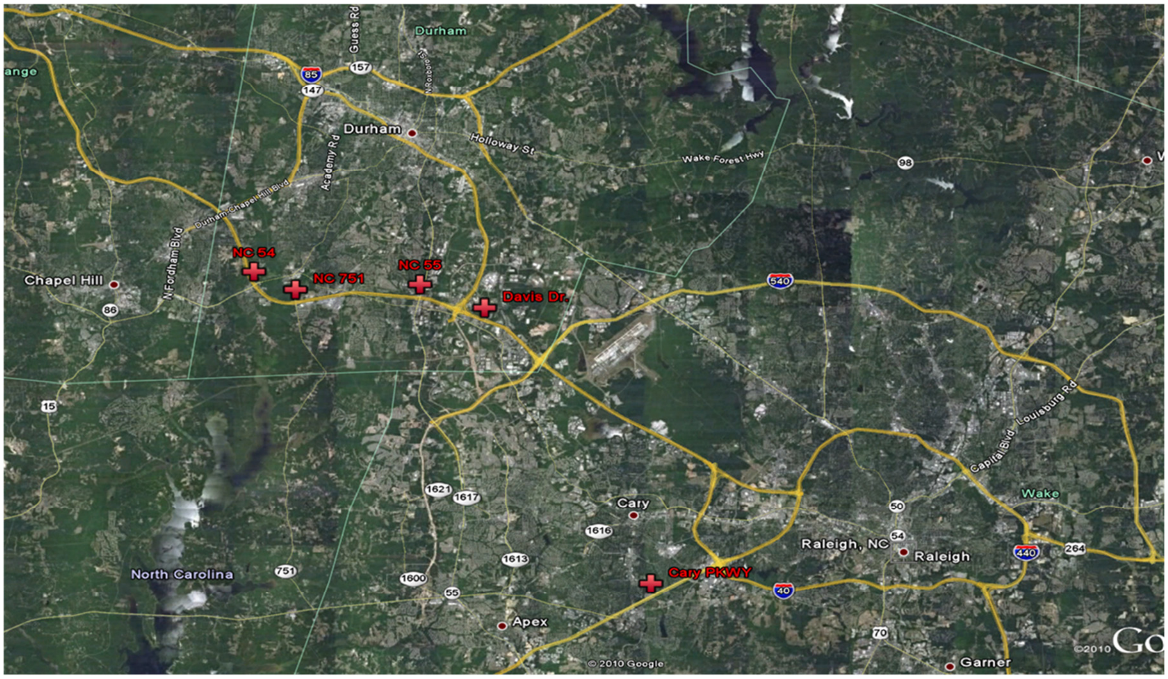


Figure 7.2 Short Term Ramp Metering Locations

7.2.6 Scenario #5: Ramp Metering (Short & Medium Term)

In addition to the five locations with short term ramp metering, three sites were identified to implement "medium term." Figure 7.3 shows the corresponding locations on the TRM network. Therefore, in scenario #5, ramp metering is implemented at a total of eight locations.

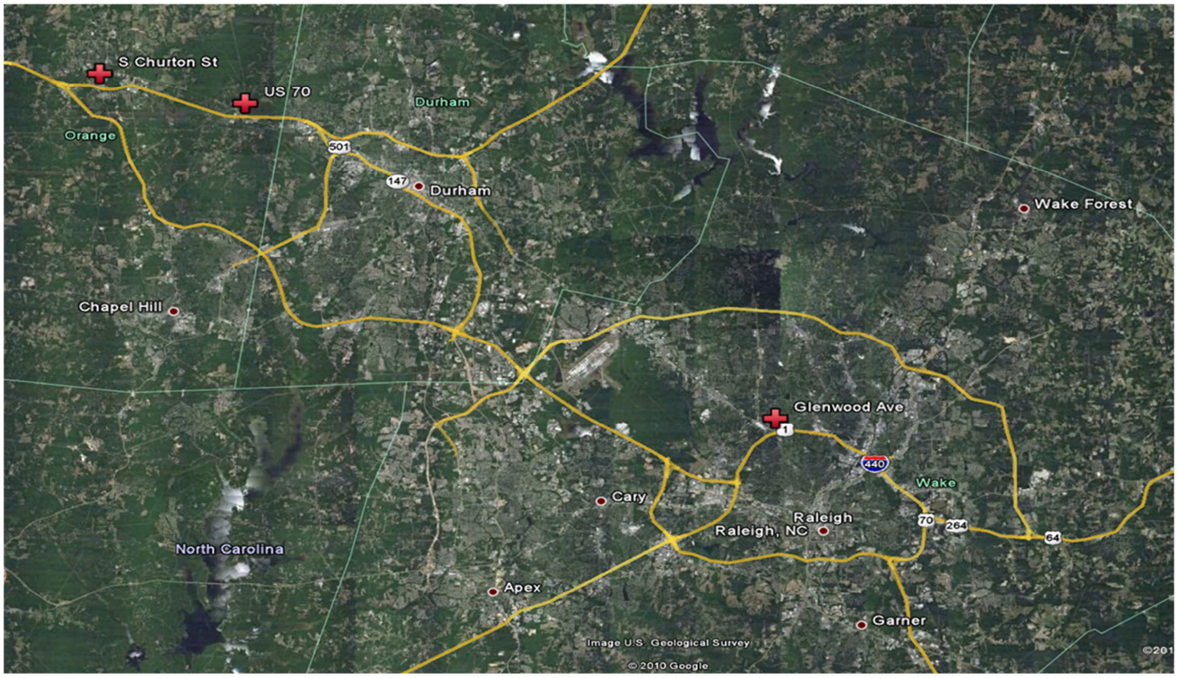


Figure 7.3 Medium Term Ramp Metering Locations

The interchange at I-440 and Glenwood Ave has four ramp metering plans implemented; while each of other two locations has two ramp metering plans.

Since the traffic-responsive ramp metering algorithm in the current version of DynusT does not yield reasonable results (the project team discovered this issue through software testing and notified the developer), the research team employed an analogous way to determine the metering rate by using the fixed metering rate function, as described below..

- Step 1
  Extract the downstream freeway link density profile for the baseline conditions of TRM 2015 network (i.e. scenario #1);

- Step 2

  Convert density to occupancy in each 15-min interval using the relationship:

$$OCC = 100 \times \frac{(L_{avg} + L_d) * D}{5280}$$

Where,

OCC = occupancy of downstream freeway link;

L_d = length of detector (assume $L_d = 6\ ft$);

D = density of downstream freeway link;

L_{avg} = average vehicle length

The average vehicle length is calculated as:

$$L_{avg} = (1 - p)L_P + pL_T$$

Where,

p = proportion of heavy vehicles;

L_P = length of passenger car (assume $L_P = 17\ ft$);

L_T = length of heavy vehicle (assume $L_T = 25\ ft$).

- Step 3

  Determine metering rate based on Table 7.2 taken directly from the *Freeway Management and Operations Handbook* (FHWA, 2003).

Table 7.2 Suggested Metering Rate based on Occupancy

Occupancy (%)	Metering Rate (Vehicles/Minute)
≤ 10	12
11 – 16	10
17 – 22	8
23 – 28	6
29 – 34	4
> 34	3

Source: Freeway Management and Operations Handbook

As an illustration of this process, Figure 7.4 demonstrates how the metering rate was determined for one study site (US-1 NB @ Cary PKWY).

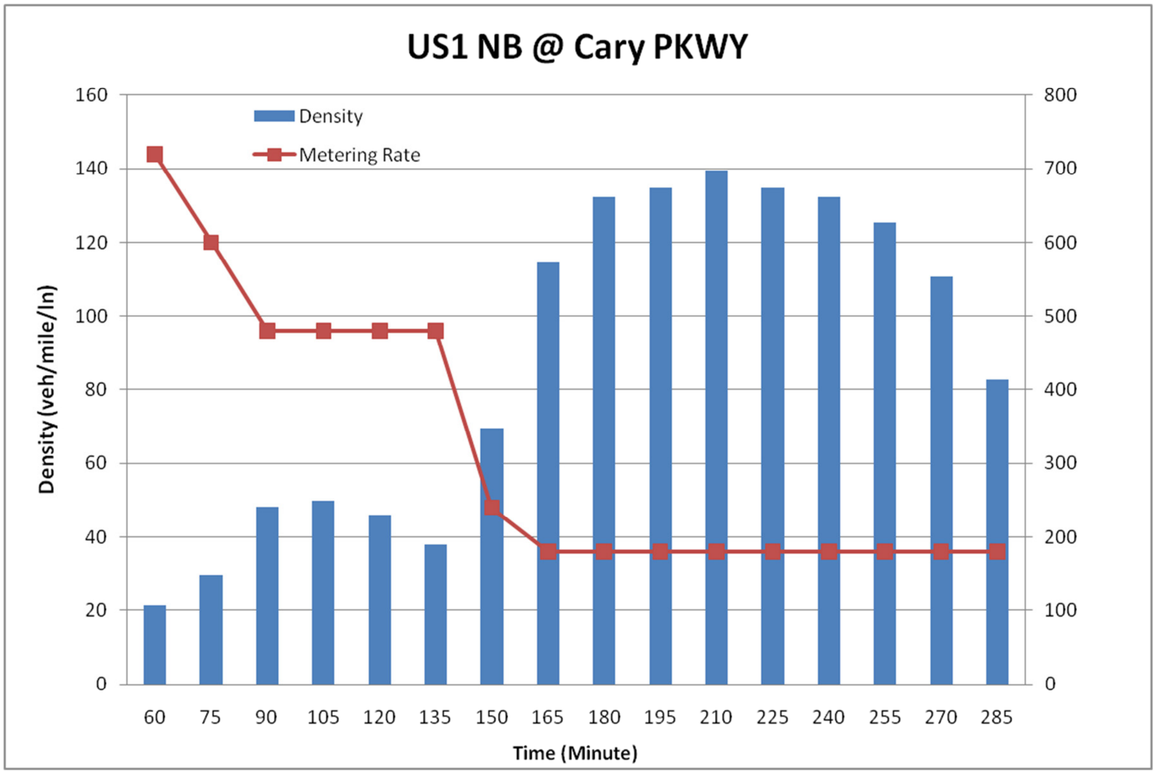


Figure 7.4 Example of Metering Rate Determination

7.3 PERFORMANCE MEASURES

Advancements in mesoscopic and microscopic traffic models enable more focused analyses of traffic conditions and performance at various temporal and spatial levels. Spatial analyses can be extended from a single node or link to an entire corridor, origin-destination pair, or the full network. Likewise, the time period for analysis can be extended from a traditional 15-minute (HCM-style) or one-hour analysis period to multiple hours, an entire day, or time periods across multiple days. In this section, different levels of performance measures, which could be used to evaluate the effectiveness of the various scenarios, are discussed.

7.3.1 Link-Level Performance Measures

For each link (*i*) in DynusT, the following MOEs are reported for any user-specified time interval:

- link vehicle count (veh/time interval), v_i
- average travel time (minutes), t_i
- space mean speed (mph), s_i
- link vehicle density (veh/mi/ln), d_i
- queue length, q_i, (in DynusT, q_i is defined as the ratio of the vehicle queue to the link length)

7.3.2 Corridor-Level Performance Measures

DynusT output does not directly produce measures of effectiveness (MOEs) for a roadway corridor of interest. However, MOEs for the user-specified corridor can be generated by aggregating one or more link-based MOEs.

Since the corridor-level MOEs are aggregated based on link-level MOEs, they should be reported for the same time interval as the link-level MOEs discussed above. These equations are not currently integrated within the mesoscopic simulator but are easily applied in a post-processing mode (in this case, using Excel functions).

Thus, overall density (veh/mi/ln) for a linear corridor encompassing multiple links (i) each with different length and number of lanes can be estimated as: –

$$D_c = \frac{\sum_i (d_i \times n_i \times l_i)}{\sum_i (n_i \times l_i)}$$

Where,

D_c: Density for the user specified linear corridor

d_i: Density for link i in the corridor

l_i: Link length (miles)

n_i: Link number of lanes

The space mean speed (mph) for a linear corridor encompassing multiple links (i) –

$$S_c = \frac{VMT}{VHT} = \frac{\sum_i (v_i \times l_i)}{\sum_i \left(v_i \times \frac{l_i}{s_i} \right)}$$

Where,

S_c : Space mean speed for the user specified corridor

VMT: Total distance traveled on the user specified corridor;

VHT: Total travel time on the user specified corridor;

v_i: Vehicle count for link i

l_i: Link length (miles)

s_i: Space mean speed on link i

Queue length for a linear corridor encompassing multiple links:

$$Q_c = \frac{\sum_i (n_i \times q_i \times l_i)}{\sum_i (n_i \times l_i)}$$

Where,

Q_c: Queue Length on user specified corridor, expressed as a fraction of corridor length

n_i: Number of lanes for link i

q_i: Queue length for link i

l_i: Link length (miles)

And finally, corridor travel time for a linear corridor encompassing multiple links:

$$T_c = \sum_i t_i$$

Where,

T_c: Corridor travel time

t_i: Travel time for link i

7.3.3 Origin-Destination Pair Performance Measures

For an origin-destination pair, the average travel time (minutes/veh) across all paths is the only MOE produced by DynusT, and is reported only for the entire simulation period. After running the simulation, the user may define multiple critical origin-destination pairs, which could be an O-D pair with the highest travel demand or an O-D pair of particular interest to the user.

7.3.4 Network-Level Performance Measures

At the network level, DynusT generates the average overall travel time (minutes/veh.) for each of the vehicle/ user subgroups listed below:

- Full fleet (all vehicles)
- Low Occupancy Vehicle (LOV) Group
- High Occupancy Vehicle (HOV) Group

The average travel time for each vehicle is reported for the entire simulation period.

7.3.5 Performance Measures Summary

Table 7.3 summarizes the performance measures at the various spatial resolutions.

Table 7.3 Reported Performance Measures by Spatial Resolution in DynusT

MOEs	Node/Link	Corridor	Origin-Destination Pair	Network
Volume Count	X			
Speed	X	X		
Density	X	X		
Queuing	X	X		
Average Travel Time	X	X (end-to-end only)	X	X

7.4 EVALUATION OF SCENARIOS

Each of the six scenarios, including the baseline scenario, was analyzed using DynusT. Performance measures were evaluated at different spatial and temporal levels as discussed above.

7.4.1 Network Level Performance

The average network trip travel time (in minutes) for both the AM and PM peak periods is shown in Figure 7.5.

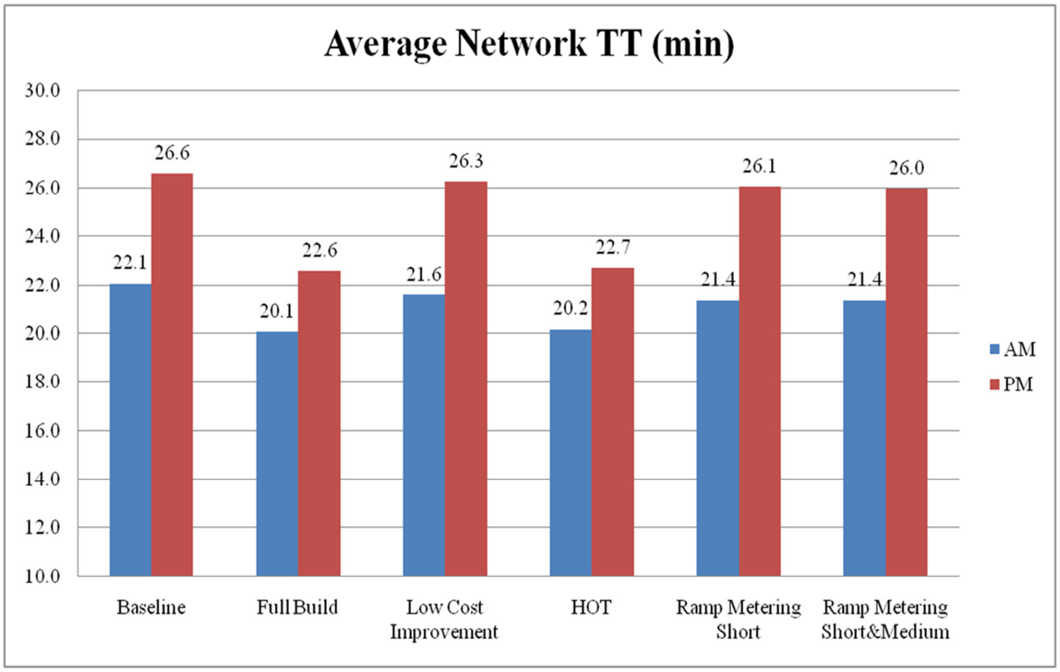


Figure 7.5 Average Network TT

The average trip length was estimated at 11.9 miles in the AM period and 10.5 miles in the PM period. As expected, the average travel time during the PM period is significantly greater than its AM counterpart due to the much higher traffic demand during that period. Compared with the baseline condition, the full build scenario provides the most significant improvement in terms of average travel time, followed by the HOT lane scenarios. All other scenarios only provide marginal improvements at the network level.

7.4.2 Corridor Level Performance

For the corridor level performance, the entire I-40 freeway facility (highlighted in Figure 7.6) was selected for analysis. The length of the I-40 facility in the TRM network is 78.8 miles.

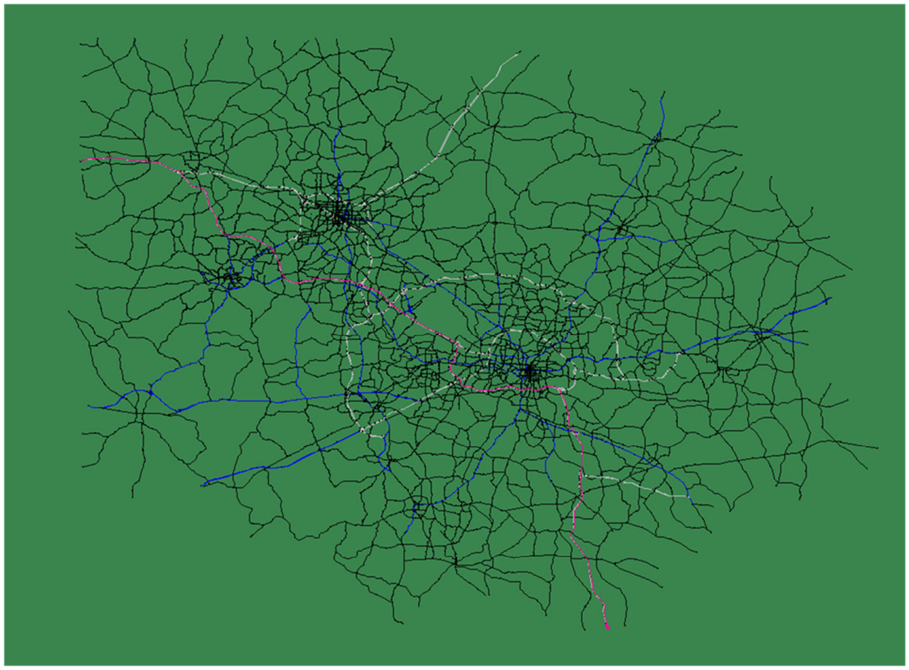


Figure 7.6 I-40 Facility for Corridor Level Analysis

As discussed before, average density, speed, and travel time are important performance measures for corridor level analysis. Figure 7.7 through Figure 7.9 summarize the results across all performance measures for Eastbound I-40 during both AM and PM periods. Figure 7.10 through Figure 7.12 summarize the results for Westbound I-40. An examination of these diagrams reveals the same patterns of measures of effectiveness at the corridor level: both the full build and HOT lane scenarios show the highest promise in terms of reduced density and travel time, and conversely in terms of increased travel speed. The degree of effectiveness is also much more pronounced during the PM peak period as it represents the most congested portion of the day for the I-40 corridor.

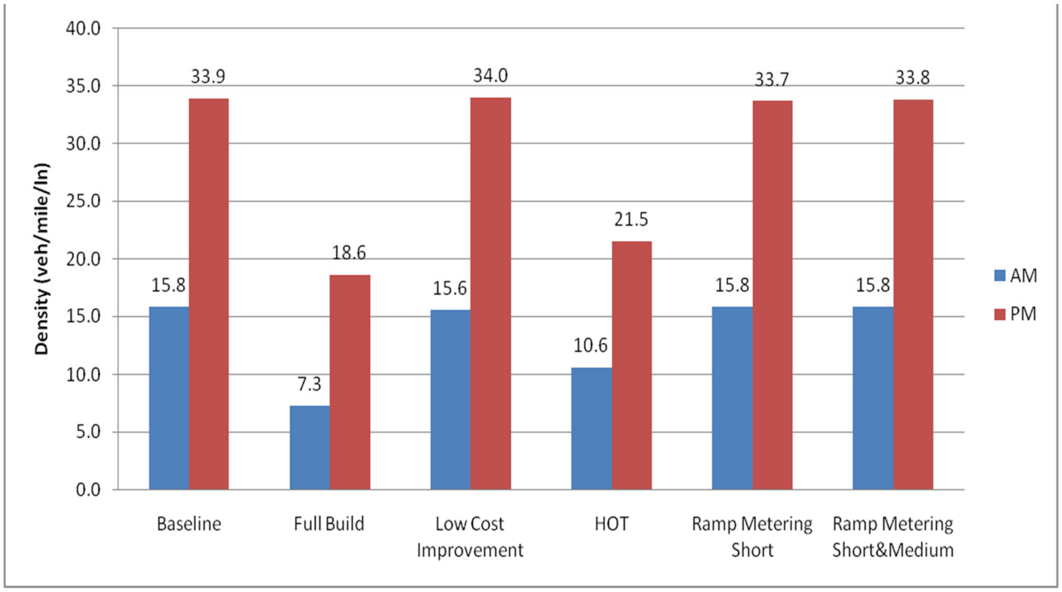


Figure 7.7 Average Corridor Density on I-40 EB

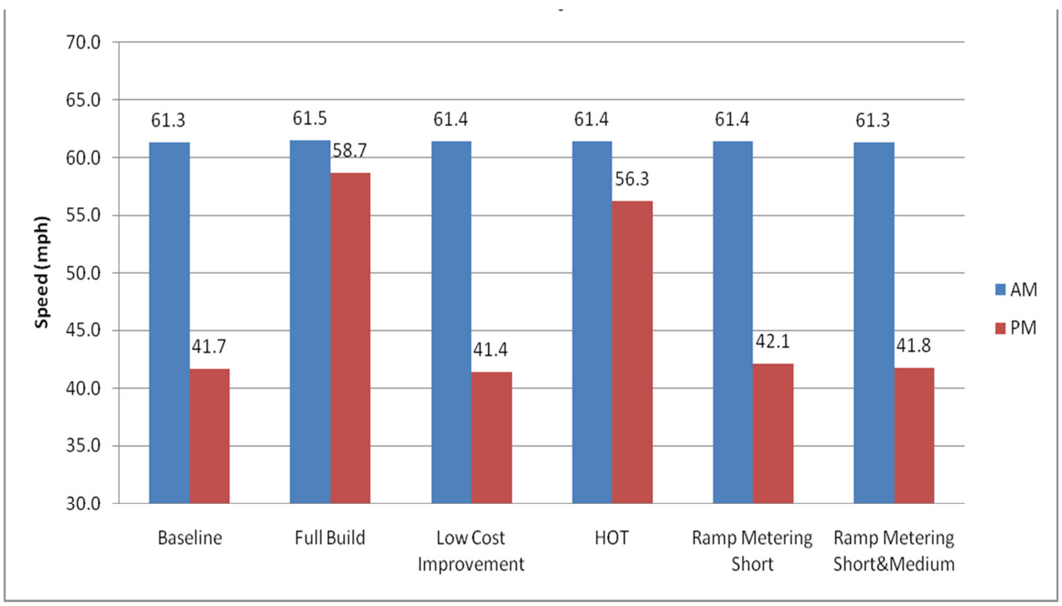


Figure 7.8 Average Corridor Speed on I-40 EB

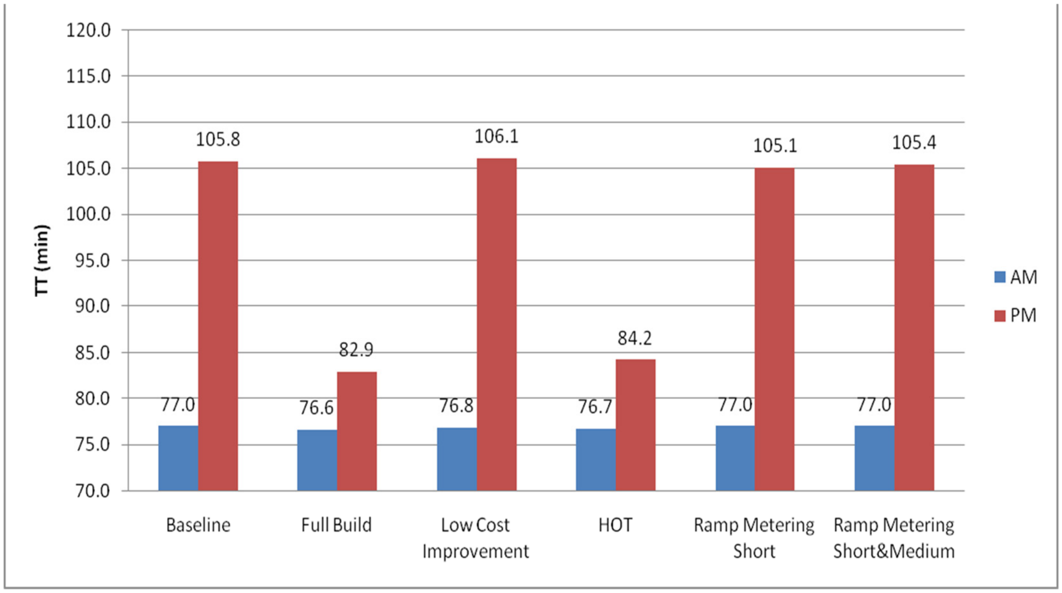


Figure 7.9 Average Corridor Travel Time on I-40 EB

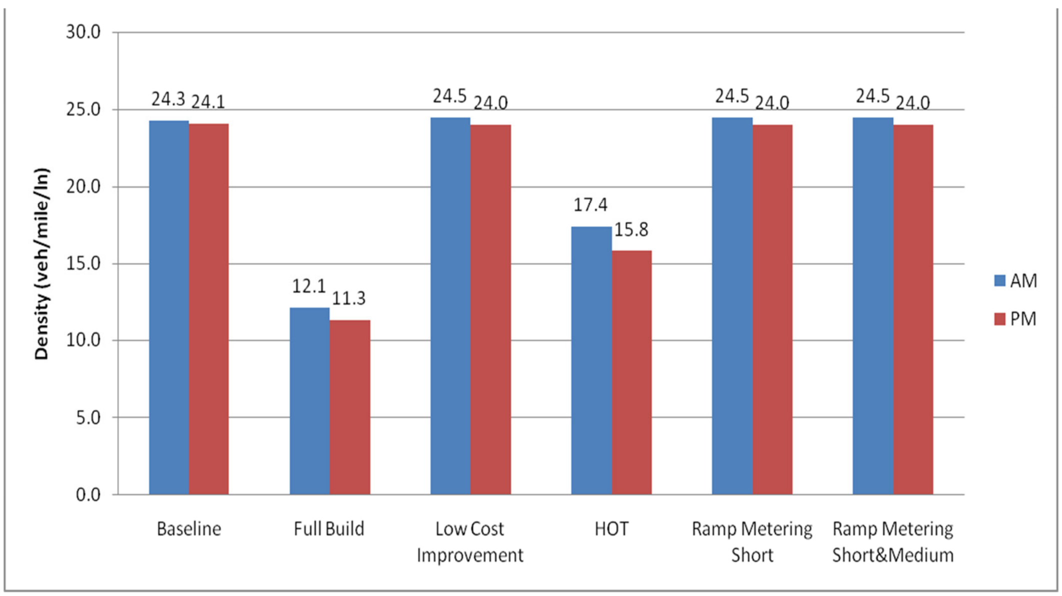


Figure 7.10 Average Corridor Density on I-40 WB

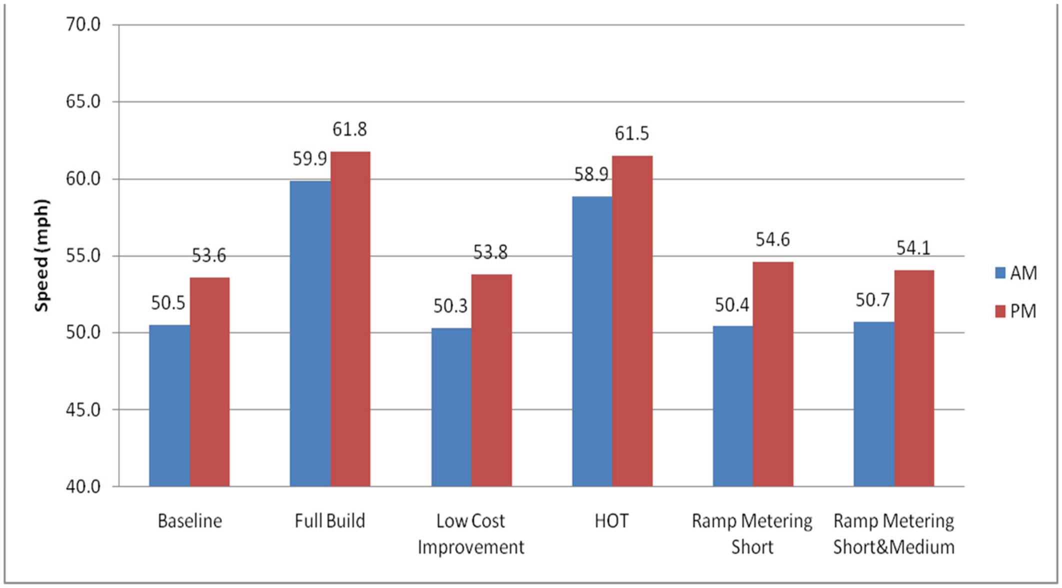


Figure 7.11 Average Corridor Speed on I-40 WB

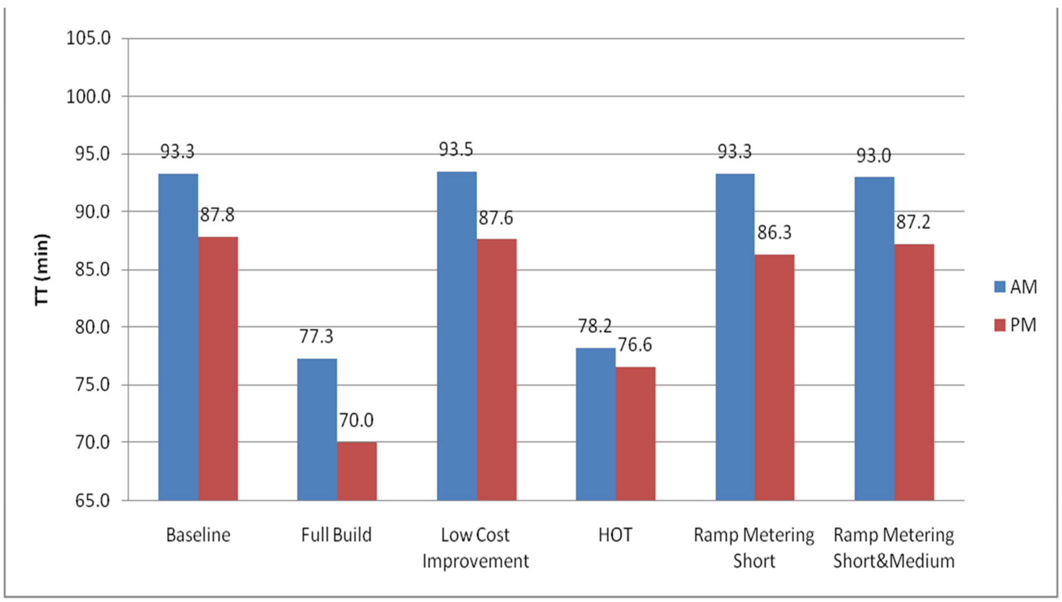


Figure 7.12 Average Corridor Travel Time on I-40 WB

7.4.3 Key OD Performance

In this study, the OD pair with the highest traffic demand along I-40 (highlighted in Figure 7.13) was selected to evaluate the effect of different scenarios. This OD represents travel to and from I40-85 in Hillsborough, NC and Benson, NC near I-95. The average OD travel time (minutes) is shown in Figure 7.14 for both the AM and PM periods.

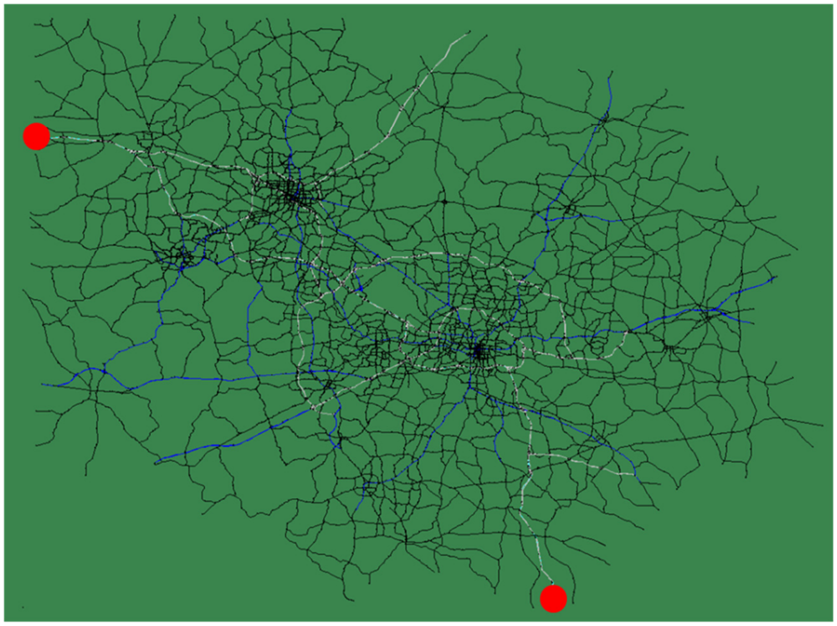


Figure 7.13 Key I-40 OD Pair in TRM Network

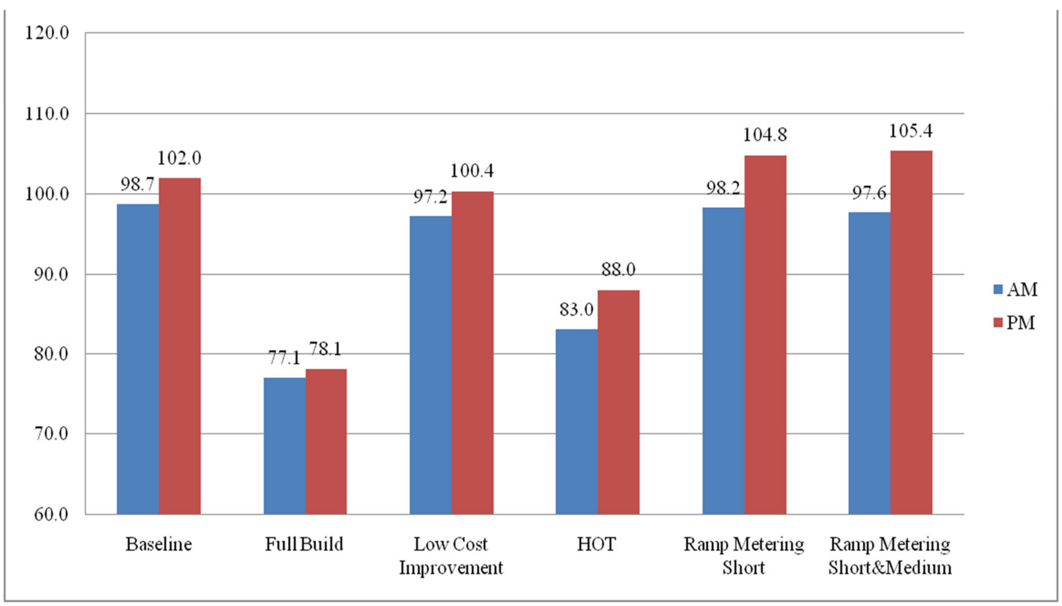


Figure 7.14 Average Travel Time for Key OD

7.4.4 Critical Link Performance

The critical network link is defined as the link with the highest density in the Baseline Scenario #1 during the AM or PM peak periods, respectively (could be a different link between the two cases). Figure 7.15 (a) and (b) show the location of critical links during the AM and PM peak periods. During the AM peak period, the critical link is on I-40 WB just east of the interchange with US70 Bypass. While during the PM peak period, the critical link is on I-40 EB just west of the on-ramp from US70 EB to I-40 EB.

(a) Critical Link for AM Period **(b) Critical Link for PM Period**

Figure 7.15 Critical I-40 Link Locations

Figure 7.16 and Figure 7.17 summarize the performance measures for the critical link during the AM peak period.

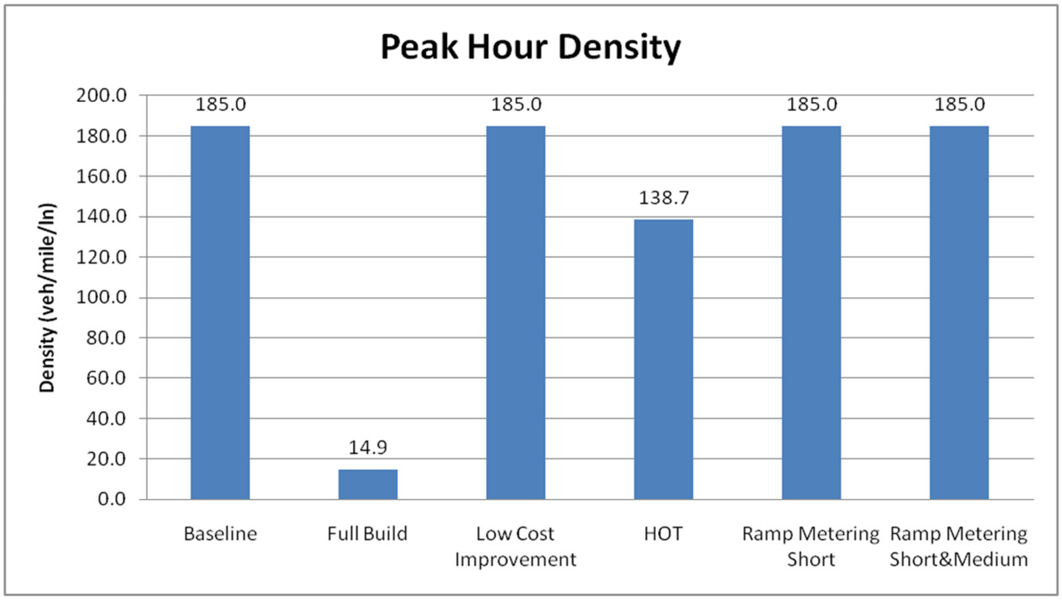


Figure 7.16 Critical Link Density during the AM Peak Period

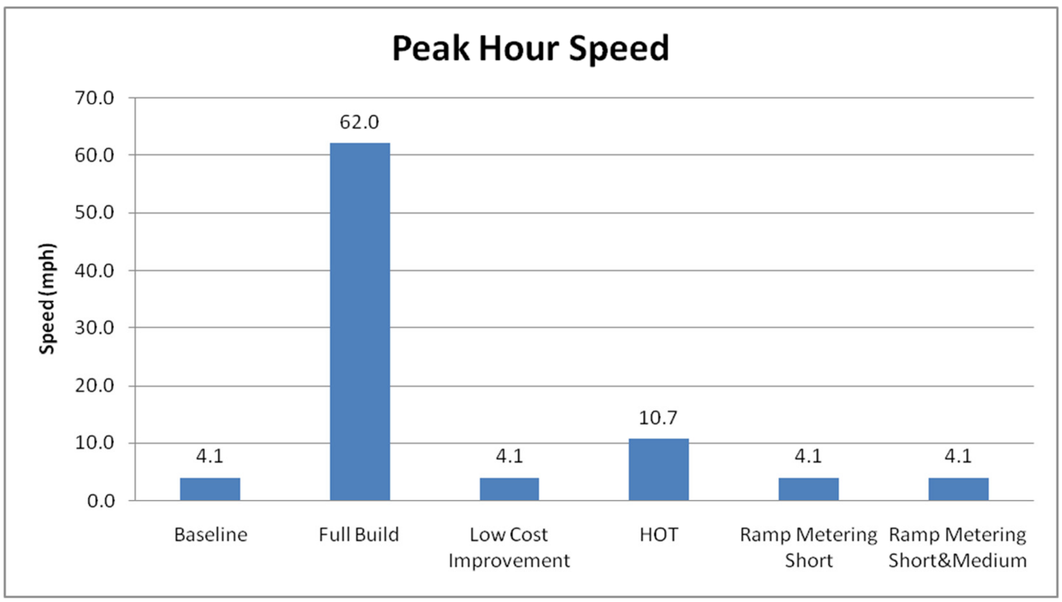


Figure 7.17 Critical Link Speed during the AM Peak Period

Figure 7.18 and Figure 7.19 show the performance measures for the critical link during the PM peak period.

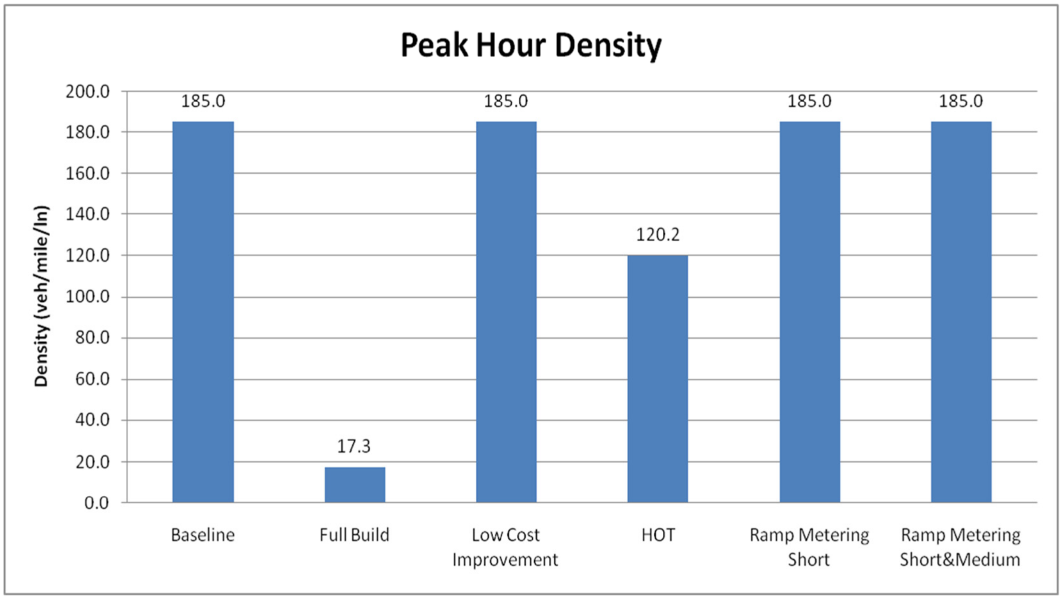


Figure 7.18 Critical Link Density during the PM Peak Period

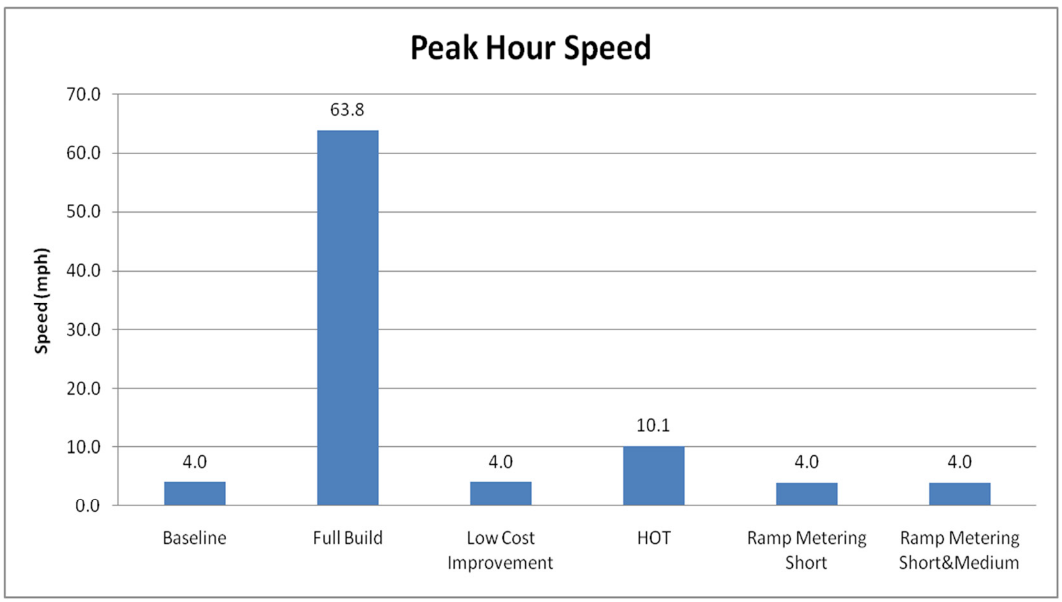


Figure 7.19 Critical Link Speed during the PM Peak Period

It is clear that at the link level, only the full build scenario resulted in meaningful improvements in link performance, followed by the HOT lane, although the latter effect is far from satisfactory. This is to be expected, since the full build scenario is a capacity addition on all segments of I-40, and therefore is likely to improve performance across the board.

The analysis above also reveals that performance measures should be selected to reflect link, corridor, and network characteristics. It was shown that alternative improvement strategies may have markedly differently effects at the link, corridor, and network levels.

CHAPTER 8. NC-511 SURVEY – DESIGN AND ANALYSIS

8.1 Survey Instrument Design

8.1.1 Introduction

Traffic congestion in North Carolina results in wasted resources as well as adverse economic and environmental impacts. To combat congestion and support travelers' decisions, NCDOT disseminates dynamic travel information to help travelers decide on whether to use alternative routes, times, or modes. The state of North Carolina has the capability to monitor traffic and travel conditions on major roadways and share the information through various sources. The objective of behavioral research was to develop and implement surveys that will assess the efficacy of the travel information provided by NCDOT.

8.1.2 Preliminary Survey Designs

The project team initially developed two draft surveys. The first was a short call back survey designed for voluntary participation by NC 511 users who would express their willingness to participate in the survey by leaving their name and number in response to a recorded verbal request delivered during NC 511 calls. The second survey was designed to a richer set of user response data. It was envisioned that this more detailed survey instrument could be made available on the NCDOT Traveler Information Management System (TIMS) website.

The draft survey instruments were presented to the project steering and implementation committee during an interim project meeting held on August 6, 2009. The committee provided feedback and critique on the survey instruments during and after the meeting. Two critical decisions were also made regarding the survey efforts that would be undertaken on the project. First, the committee decided that the project team would finalize the short call-back survey for implementation and that the survey would be implemented by statewide traffic operations center operators. Second, the committee decided that implementation of the longer survey would not be prudent during the course of the project, primarily due to the level of approval and clearance that would be required to publish a broadly available web-based survey. Therefore, the committee instructed the project team to revise the detailed survey based on committee input and include the revised detailed survey in the project final report for possible future implementation.

The final versions of the short call-back survey and the detailed survey are provided in Appendix B.

8.2 Implementation and Analysis

8.2.1 Call-Back Survey Implementation

As discussed above, the survey that was implemented for the project is a brief instrument designed as a call-back telephone interview. The NC 511 callers were the target audience, and they were asked if they are willing to participate in a brief survey, when they called NC 511. Callers who were willing to participate were asked to provide their contact information. The call-back interviews were conducted by the Triangle TMC operators. Survey questions requested information about the respondents' use of NC 511 and their satisfaction with the service.

The call-back survey was successfully implemented from December 2009 through May 2010. The first participant name and phone number recordings and the first call-backs occurred on December 15, 2009. The survey ended on May 24, 2010 just prior to the 2010 Memorial Day Weekend. A total of 480 responses were received, coded, and analyzed. The number of unique NC 511 callers by month during the survey period was approximately 320,000 (calculated by summing the "Unique Callers this Month" values for the period of December 2009 to May 2010 in Table 8-1). It is not possible to calculate a precise response rate, because the 320,000 is the sum of unique callers by month and is not the number of unique callers over the survey period.

However, the project team set a target of 500 responses. The total of 480 responses is very close to the target number, and therefore, the analysis results should be considered to have a reasonable level of statistical validity. Nevertheless, we recognize the potential for non-response and non-coverage bias in the survey results.

8.2.2 Methodology and Results

The NC 511 call-back survey collected behavioral data on travel information usage and perceptions of people who called 511 in North Carolina. The survey relies on the willingness of individuals to (1) provide their calling preferences, (2) perceptions about the usefulness of 511, (3) the desired content of travel information, and (4) how they responded to the acquired information, e.g., changing their travel decisions. As mentioned above, 480 respondents participated in the call-back survey, and their responses constitute the final data set. During the survey implementation period, the North Carolina 511 service was reasonably active, as indicated by the monthly calling volumes, shown in Figure 8-1 and Table 8-1.

The call-back interviews were conducted by the NCDOT Statewide Traffic Management Center operators. As noted above, NC 511 callers were the target audience, and callers who were willing to participate were asked to provide their contact information. Notably, this is a non-probability self-selected convenience sample and as such it may not be representative of the NC 511 callers or the region's driving population nor the region's attitudes, perceptions, and behaviors.

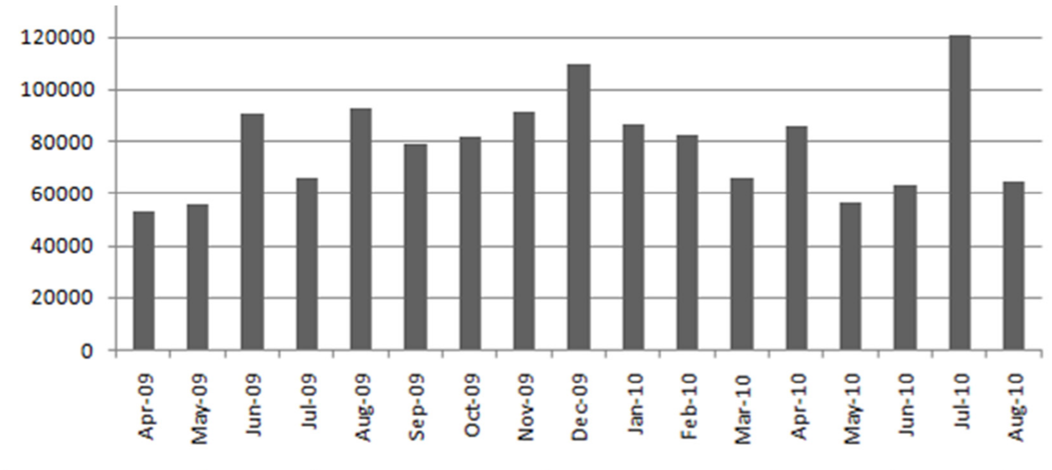


Figure 8-1: Total Calls by Month

Table 8-1: Calling Volumes by Month

	Unique Callers this Month	New Callers	Repeat Callers	No. of regular callers	Unique callers since 5/1/2005	Total calls for month
Apr-09	53010	20074	32926	889	1364126	53010
May-09	55561	21370	34191	861	1385496	55561
Jun-09	90883	42773	48060	890	1428269	90833
Jul-09	66062	28003	38059	978	1456272	66062
Aug-09	92853	42892	49961	1039	1499164	92853
Sep-09	78811	33341	45470	802	1532505	78811
Oct-09	81662	34063	47599	928	1566568	81662
Nov-09	91370	38504	52866	1519	1605072	91370
Dec-09	68982	49128	19854	1773	1654200	109539
Jan-10	56553	38579	17974	1265	1692779	86318
Feb-10	54673	35419	19254	1225	1728198	82482
Mar-10	42312	25753	16559	927	1753951	65814
Apr-10	59884	40566	19318	1037	1794517	85987
May-10	37840	22644	15196	725	1817161	56478
Jun-10	42407	27373	15034	888	1844534	63251
Jul-10	85884	57790	28094	1323	1902324	121007
Aug-10	42037	25571	16466	897	1927895	64472

8.2.2.1 How often do people call NC 511?

The survey first asked respondents about how often they called the NC 511 service. As shown in Figure 8-2, more than one-half (53%) of the respondents indicated that they called NC 511 less than once per month. Nearly one-third (32%) called 511 two times to five times per month. About 11% of the respondents called NC 511 frequently, i.e., more than once per week (4% of the respondents did not answer this question). Thus there is substantial variation in calling frequency of the people who use NC 511.

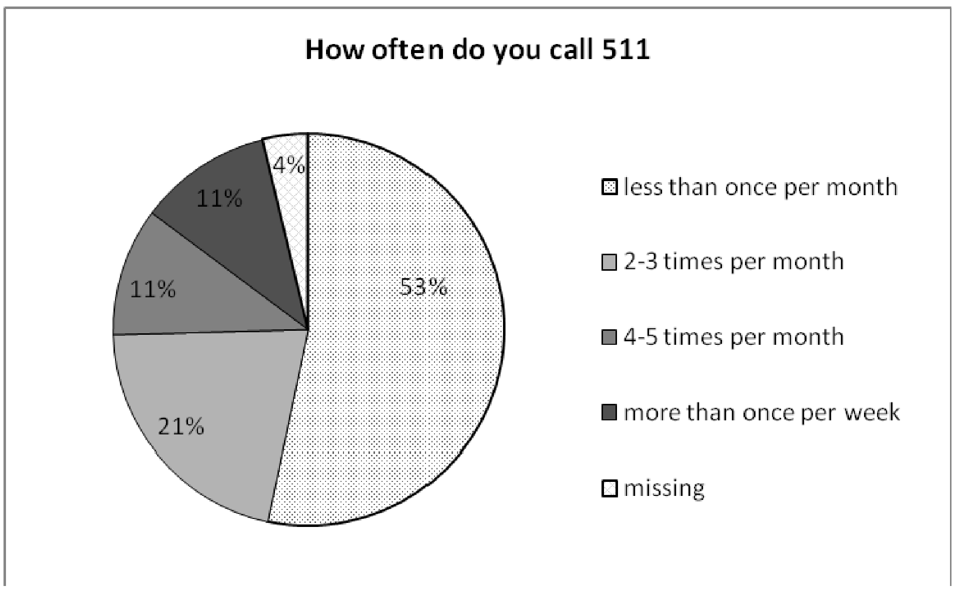


Figure 8-2: How often do people typically call NC 511? (N=480)

8.2.2.2 When do people call NC 511?

The weekly distribution of NC 511 calls is shown in Figure 8-3. Respondents' calls were not evenly distributed among weekdays. The sample shows that relatively more individuals called during the latter half of the week, especially on Fridays. Nearly 20% of the calls were placed on Fridays, perhaps reflecting the diversity of travel at the end of the work week. Fewer calls were placed during weekends. Only 10% of the calls were placed on Saturdays and 12% on Sundays, based on the sample.

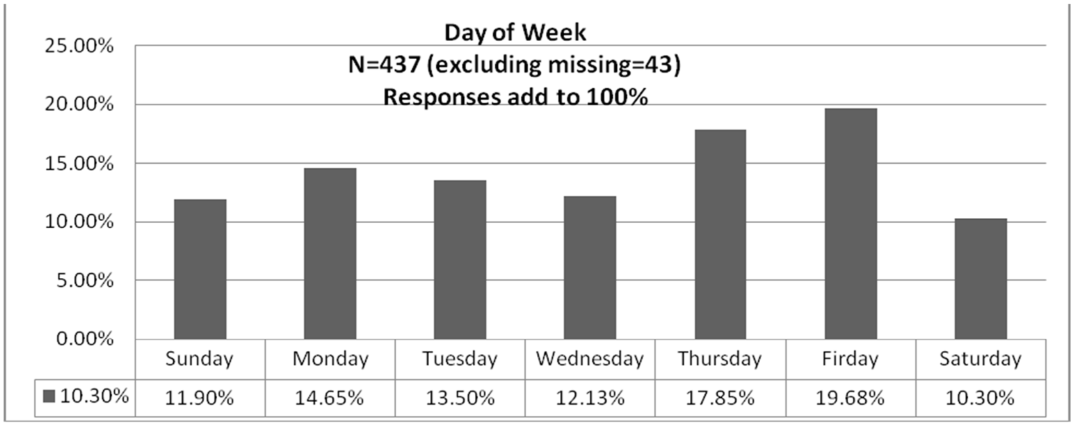


Figure 8-3: Weekly distribution of NC 511 calls

A distribution of calling hours is shown in Figure 8-4. Generally, a majority of the calls by survey respondents were reported during daytime (8:00 AM to 5:00 PM), especially during the afternoon peak hours. Calls by respondents dropped during the evening (6:00 PM to 9:00 PM), as expected, and increased slightly after 10:00 PM till midnight.

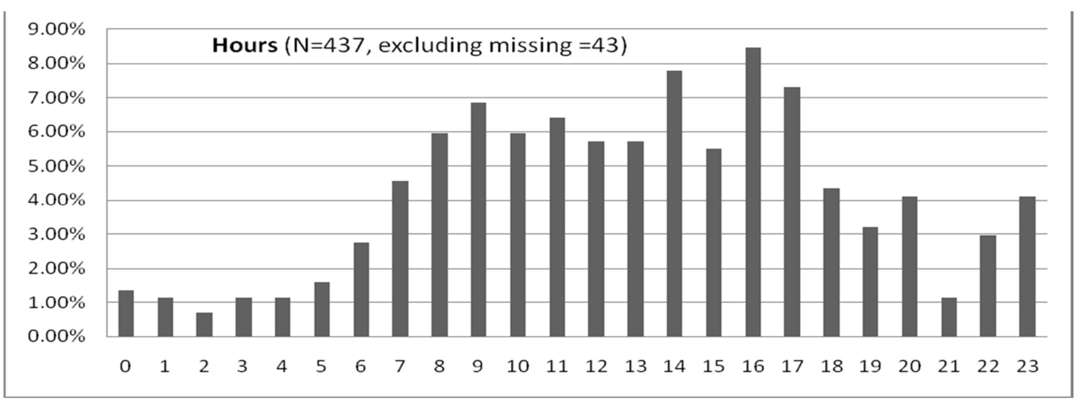
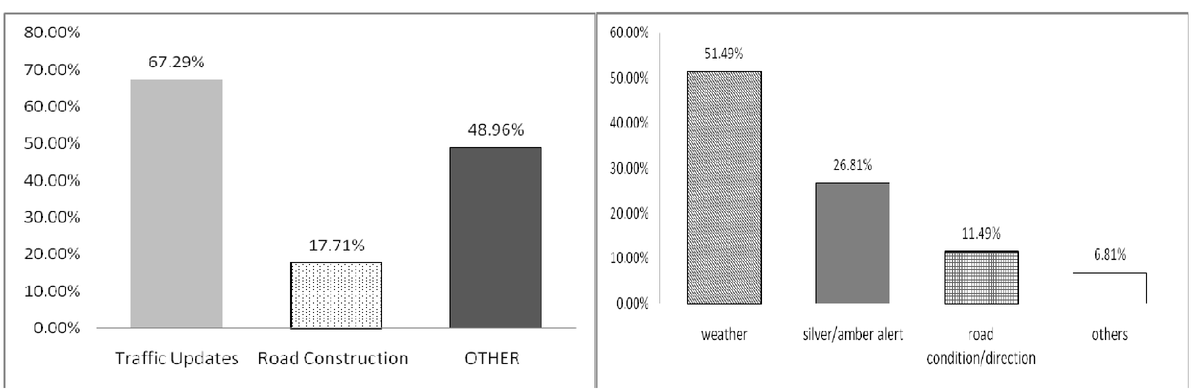


Figure 8-4: Hourly distribution of NC 511 survey respondent calls (0=Midnight)

8.2.2.3 What information do people request?

The content of travel information available on 511 nationwide varies substantially. The study team did not investigate what information content may be desired, other than the information that was available on through NC 511. Figure 8-5 shows the information content requested by respondents. A higher proportion of respondents requested information about traffic updates. More than two-thirds (67%) of the respondents reported calling about traffic updates (multiple responses were permitted to this question, so the total percentage exceeds 100). Nearly 18% of the sample called about road construction information. Furthermore, one-half of the respondents reported calling for other information. Analysis of the descriptive data showed that the other calls included requests for weather conditions, silver/amber alerts, road conditions, and directions to a destination.

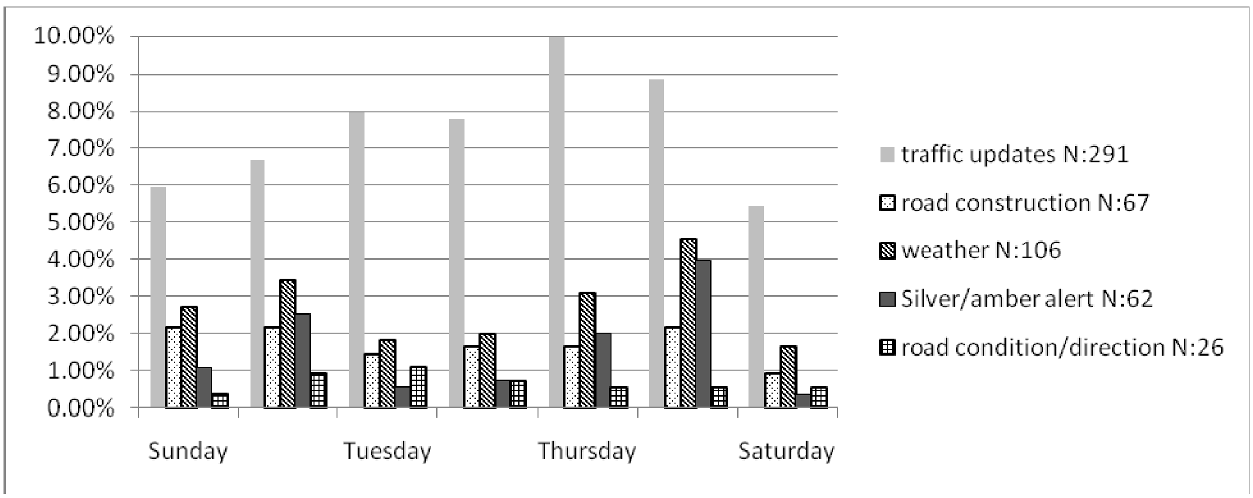


(a) Information types (b) Other information

Note: Multiple responses permitted; therefore, the total percentage exceeds 100%

Figure 8-5: Information content desired by NC 511 survey respondents (N=480)

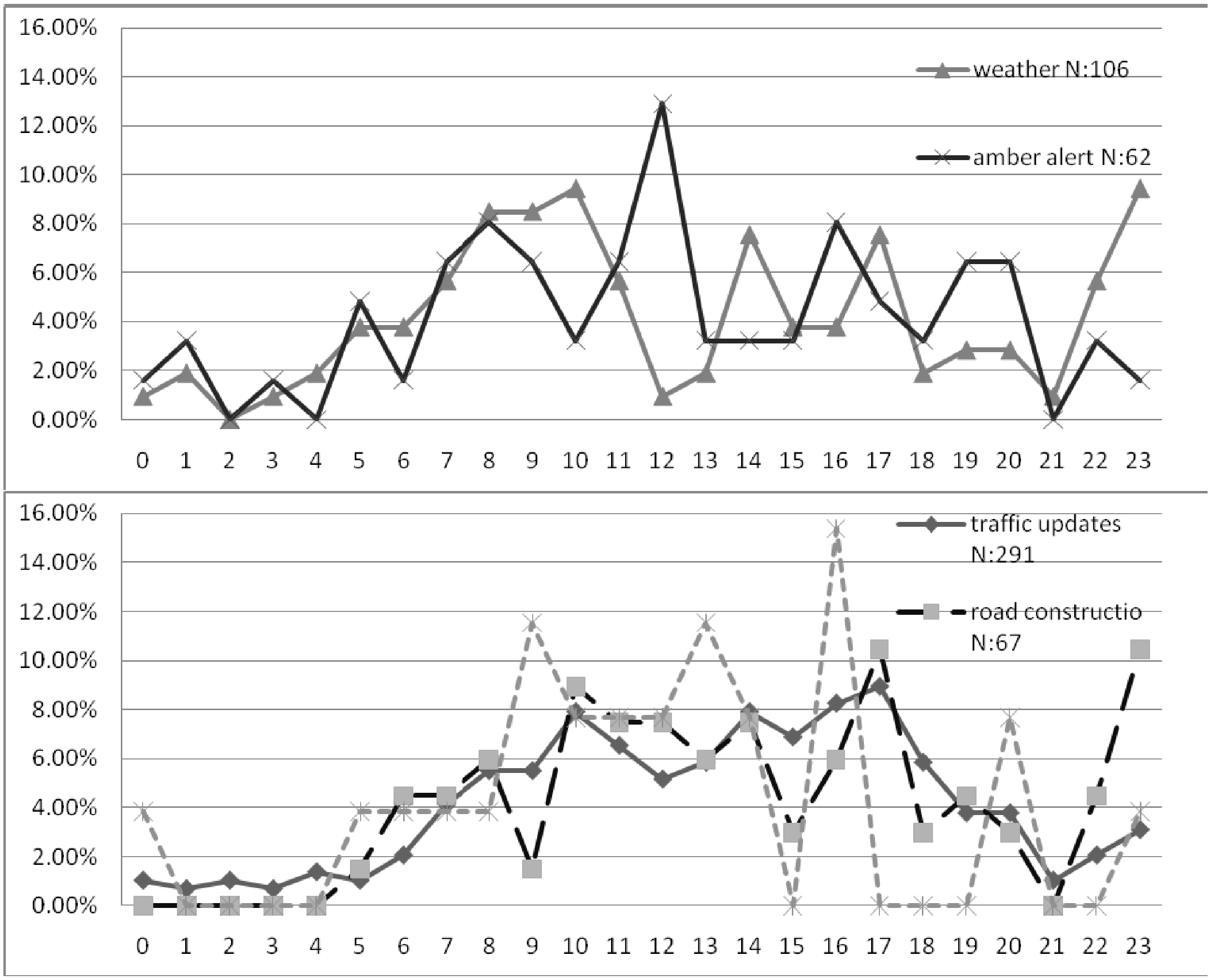
The variations in requested information content by day of the week are analyzed further—see Figure 8-6. The bars in the figure represent the percentage of traffic information content category that respondents accessed by day of the week. Among the nearly 12% of calls placed on Sunday (shown in Figure 8-3), 6% were about traffic updates, and about 2% were calls for road construction information, another 2.5% were about weather conditions, 1% were calls for silver/amber alert and 0.5% were calls about roadway condition and directions. Between 9% to 10% of the calls on Thursday and Friday are for traffic updates. Clearly, a large number of respondents seek information on traffic updates, especially during the work week. Furthermore, the percentage of respondents accessing weather and silver/amber alert information is slightly higher on Fridays compared with other days of the week.



Note: Multiple responses permitted; therefore, the total percentage exceeds 100%

Figure 8-6: Information types by day of the week

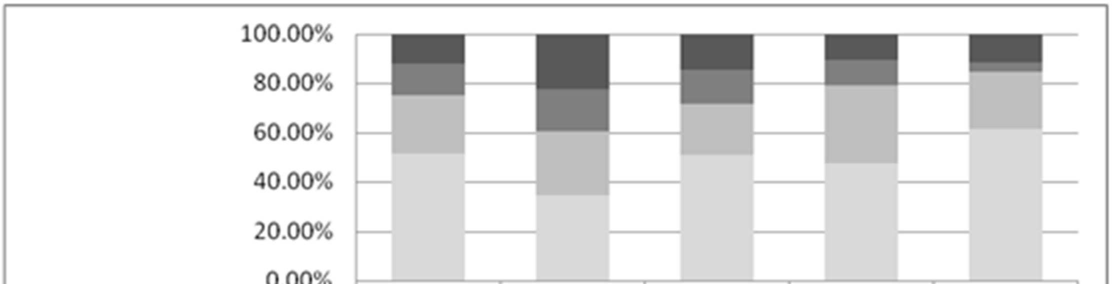
The hour-by-hour information acquisition distributions are provided in Figure 8-7. As expected, there are more calls for traffic updates, road construction, and road condition during the peak hours, especially during afternoon peak hours. Calls for weather condition are more likely to be placed during the morning peak hours, and silver/amber alert information is more likely to be accessed during the mid-day. Overall, respondents were more likely to call during the day and they were slightly more likely to call during the peak hours.



Note: Multiple responses for information category are permitted.

Figure 8-7: Hourly distribution of requested information content

The kind of information accessed by frequent vs. infrequent callers was analyzed as shown in Figure 8-8. Noting that about 11% of the respondents are frequent NC 511 callers (calling more than once per week), they are more likely to call about roadway construction (23% of the calls were received for this purpose), and weather information (15% of the calls were received for this purpose). The infrequent callers are more likely to call about roadway condition information and to get directions.



	traffic updates	road construction	weather	Silver/amber alert	road condition/ direction
more than once per week	11.86%	22.62%	14.53%	10.53%	11.54%
4-5 times per month	13.14%	16.67%	13.68%	10.53%	3.85%
2-3 times per month	23.40%	26.19%	20.51%	31.58%	23.08%
less than once per month	51.60%	34.52%	51.28%	47.37%	61.54%
Sum=596	N=312	N=84	N=117	N=57	N=26

Note: Multiple responses for information content are permitted.

Figure 8-8: Calling frequencies by information content (N=437, 43 missing)

8.2.2.4 How useful is NC 511 information?

Whether NC 511 information was useful is another important aspect of assessing the efficacy of NC 511 system. Usefulness of NC 511 information was rated on a three-point scale ranging from not useful to somewhat useful to very useful. The survey results are provided in Figure 8-9, indicating that 61% of the users rated the information provided by NC 511 as very useful, 26% rated it as somewhat useful, and 11% rated the information as not useful. About 2% of the respondents did not answer this question. Given these numbers, there seems to be room for improvement of the NC 511 service.

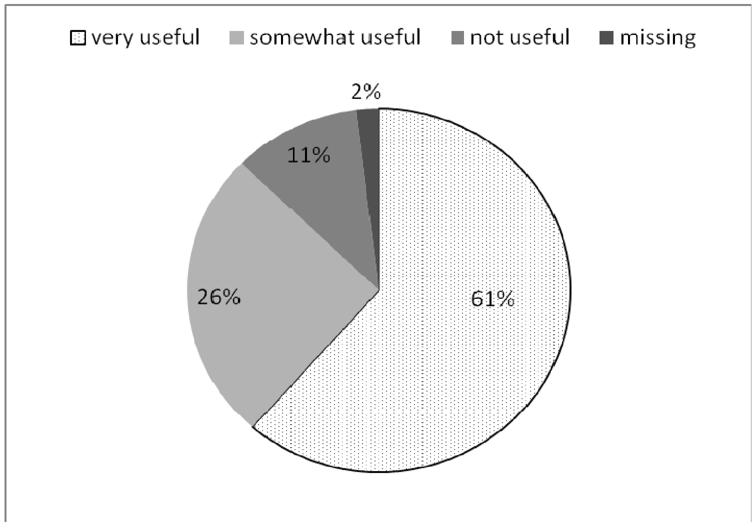
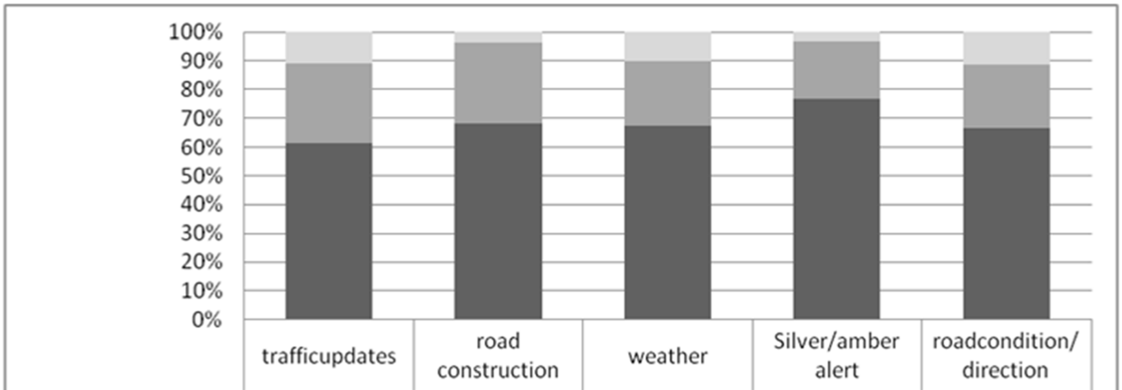


Figure 8-9: How useful is the information provided by NC 511 (N=480)

To explore what types of information provided was found most and least useful, further analysis of the data was conducted (see Figure 8-10). Respondents who accessed silver/amber alerts were more likely to find the information to be useful. Specifically, 76.6% of the respondents who accessed silver/amber alert stated that NC 511 information was very useful; while only 3.1% of them stated NC 511 information was not useful. Similarly, 68% of the users who accessed roadway construction information rated the service as very useful and only 3.5% rated NC 511 as not useful. Notably, about 10% of the users who accessed traffic updates, road conditions, and weather information stated that information provided by NC 511 was not useful. Therefore, these aspects of the service can potentially see improvements in the future. A more detailed study of ease of using the system and how improvements in traffic updates, road conditions, and weather information can be made, if needed.



	trafficupdates	road construction	weather	Silver/amber alert	roadcondition/ direction
not useful	10.63%	3.53%	10.00%	3.13%	11.11%
somewhat useful	28.13%	28.24%	22.50%	20.31%	22.22%
very useful	61.25%	68.24%	67.50%	76.56%	66.67%
Sum= 616	N=320	N=85	N=120	N=64	N=27

Note: Multiple responses for information category are permitted.

Figure 8-10: Usefulness level by information content

Those who call more frequently were expected to find the service more useful. Figure 8-11 provides the level of usefulness rated by frequent vs. infrequent users. As expected, infrequent callers found the service to be less useful compared with frequent callers. For example, 54% of infrequent callers found the service to be very useful compared with 72% of the frequent callers. Furthermore, infrequent callers were more likely (compared with frequent callers) to report that the service was not useful at all (17% vs. 6%, respectively).

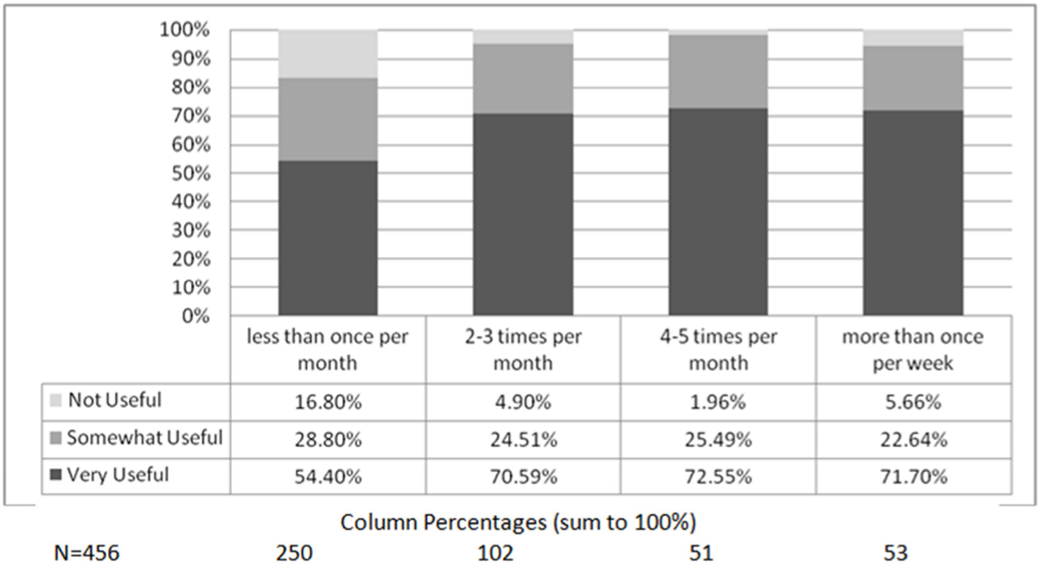
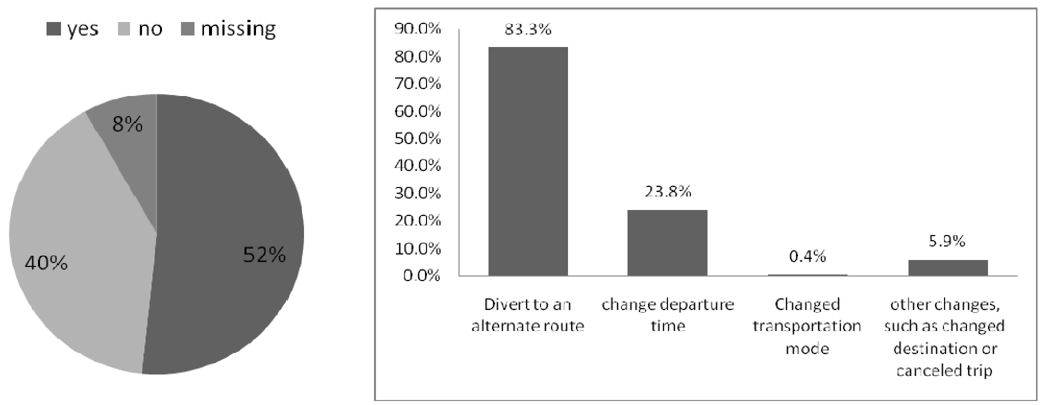


Figure 8-11: Usefulness level by frequency of access

8.2.2.5 Do travelers change their travel plans, after obtaining travel information?

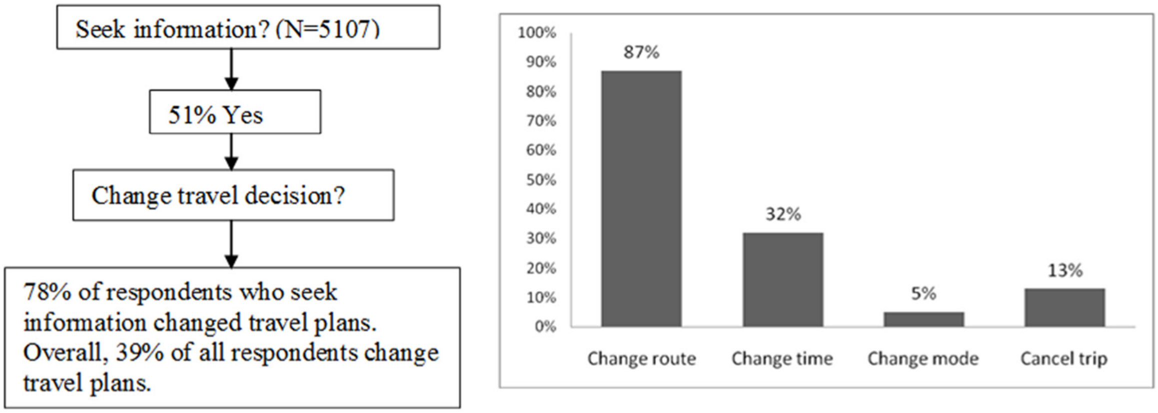
Figure 8-12 shows whether respondents changed their travel plans, and if so, how they changed them based on the information received from NC 511. A total of 248 out of 480 respondents (52%) reported that they changed their travel plans. Moreover, 239 among these 248 respondents provided information about how they changed their travel plans, based on the information received (multiple responses were permitted). Diverting to alternate routes and changing departure times are the two most common changes implemented in response to receiving information, as expected. Dynamic information about unexpected congestion typically motivates travelers to take alternate routes or change departure times. More than 80% of the respondents who changed their travel plans diverted to alternative routes, followed by 24% of respondents who reported changing their time of trip departure. Nearly 6% of the respondents made other changes to their travel plans, including changing their destinations or cancelling their trips altogether. Only a few respondents (0.4%) changed their transportation mode based on the information they received. This is likely due to the limited number of mode choice options available to NC 511 callers.



Note: Multiple responses for reported changes in travel decisions are permitted.

Figure 8-12: Changes in travel decisions based on travel information received (N=480)

The results of this survey can be compared and cross-checked with earlier surveys. A 511 Virginia evaluation study by Swan et al. (2004)[1] showed that the 511 telephone system provided travel information that allowed 49% of the callers to change their travel plans (versus 52% in this NC 511 survey). Further, 78% (N=166 of 212) of the responding callers in Virginia reported that they have changed their routes, which is consistent with 83% in the NC 511 survey. According to the Virginia study, 90% of the survey respondents felt that 511 Virginia was somewhat useful or very useful (this is close to 87% of the survey respondents in NC finding the service useful). Thus the results of the NC 511 survey are consistent with those of the Virginia 511 survey, increasing the confidence in the results. Figure 8-13 shows the traveler information acquisition and changes of travel decisions in the Greater Triangle Area. The data used is from the regional travel survey dataset in the Greater Triangle Travel Study conducted in 2006. The survey utilized standard household travel survey methods, in which all the household members were asked to record their trips for a specified 24-hour period using a specially designed travel diary and provide household-level travel information usage data regarding traveler information sources, as well as the acquisition frequencies and travel choice changes. The information sources included Television, Internet, Radio, Telephone, Traveler Information Radio (TIR), and Variable Message Signs (VMS). The traveler information includes general pre-trip travel information such as commercial radio traffic reports, and television broadcasts of travel information, as well as en-route information available to travelers in the area such as the updates of traffic conditions and incidents, and travel advisories. The content of travel information available to travelers in the area was mostly qualitative traffic reports of congestion/delays, and real-time details of traffic incidents. The majority of respondents (51% of 5107 respondents) reported that they acquired travel information at least once a week. Among those who seek information, 78% of respondents changed their travel decisions, which means that 39% of all respondents changed their travel decisions. This percentage is lower than the NC 511 users (52% vs. 39%). However, if only information seekers in the Triangle survey are compared with NC 511 users, then the percentage is higher for the Triangle survey respondents (78% for the Triangle survey respondents vs. 52% for the NC 511 respondents). Similar to NC 511 users, a majority of respondents (87%) changed route, followed by changing time of trip departure, and other changes such as cancelling trips and changing modes.



Note: multiple responses for changes are permitted.

Figure 8-13: Changes of travel decisions in the 2006 Greater Triangle regional survey

Figure 8-14 shows the relationship between calling frequency and respondents who changed their travel plans. More frequent callers were expected to change their plans more frequently. While this relationship seems to be generally true, based on empirical evidence from the survey, the data shows that it is non-linear. That is, the proportion of individuals saying “yes” to travel plan changes does not increase substantially as the calling frequency increases.

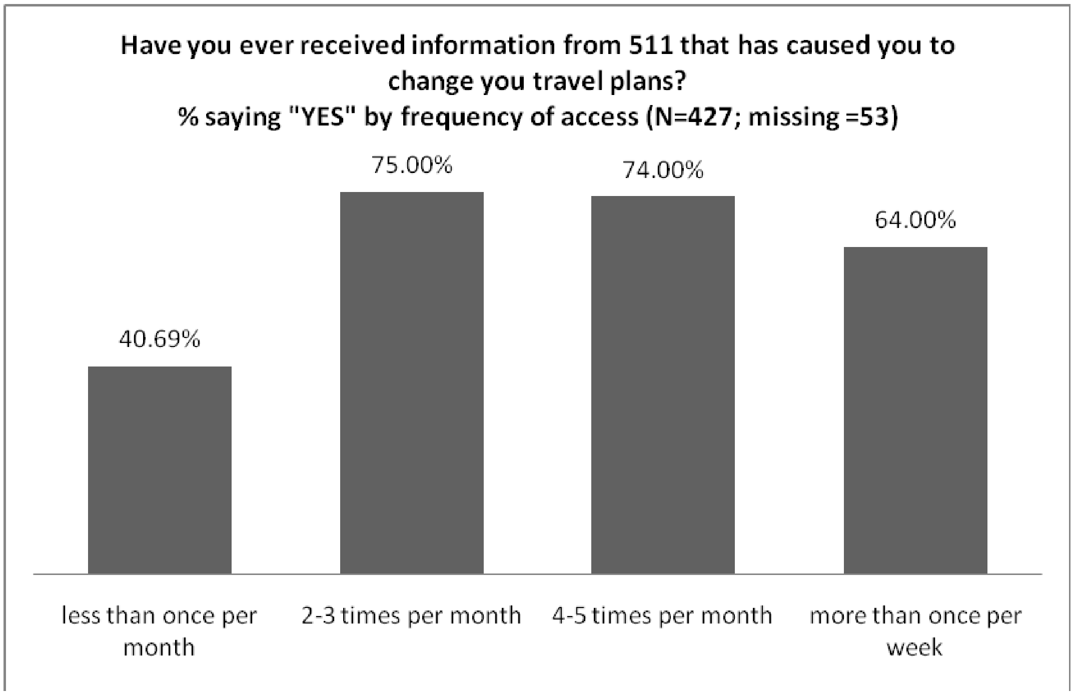


Figure 8-14: Percentage of changing plan by calling frequency by NC 511 callers

8.2.2.6 Open comments provided by NC 511 users

Open-ended comments were solicited in addition to the other information, already discussed in this chapter. Respondents were asked to provide comments on problems and potential improvements to NC 511 services. Their descriptive responses can be summarized as follows:

- More than 20 respondents indicated their displeasure with the system, especially mobile phone users and blue tooth technology users.
- Respondents were concerned about the interactive voice recognition and response system as it could not recognize speech properly and did not take commands very well.

Based on user responses, suggestions for improvement include:

- Providing the touch-tone option up front.
- Providing automated congestion texts.
- Adding more information about sequential alerts.
- Giving better and more detailed information about incidents and detours.

8.2.2.7 Limitations

The research results should be interpreted carefully. This is partly because the brief survey did not seek a probability sample and it was not conducted randomly. Instead it is a self-selected sample of NC 511 callers. The survey was conducted at a time of economic recession, relatively higher unemployment levels, and higher gasoline prices. These macro factors might influence daily travel, e.g., people may undertake fewer trips and therefore their behavior may be different from when there is no economic recession. The study is further limited by the use of cross-sectional data from NC 511 users. We recognize that the survey can have non-response and non-coverage biases. This investigation of NC 511 is also limited because it has only obtained and analyzed the acquisition and use of NC 511 travel information. A more detailed and comprehensive understanding of travelers' decision processes and information needs can be captured by conducting a more detailed behavioral survey, and perhaps combining the results with field observed travel data possibly collected through GPS enabled mobile devices and then analyzing the results. Special attention is needed to information needs and decision making in the face of travel time uncertainty caused by the occurrence of incidents, presence of work zones, traffic control devices, weather, and recurrent bottlenecks.

8.2.3 Summary and Recommendations

The NC 511 telephone survey was designed and implemented successfully. The sample obtained allows statistical analysis of NC 511 callers. This study has comprehensively explored and quantified NC 511 users' access to various types of information available and their propensity to change travel decisions in response to received information. The results are consistent with relevant studies and show that a large portion of respondents access NC 511 infrequently (one-half of respondents called NC 511 about once per month or less) but about

10% are frequent users (once or more per week). Furthermore, a large portion of the survey respondents who accessed NC 511 information (52%) changed their travel decisions based on the information received. When it comes to travel decision adjustments, travel routes and departure times are switched frequently by NC 511 callers who responded to the survey.

Higher information acquisition frequency is generally associated with higher likelihood of changing travel plans, as expected. However, the relationship seems non-linear, based on empirical evidence. While other traveler information technologies may be used for changing travel decisions, it seems that the NC 511 phone service is increasingly being used as an emerging and influential source of traffic information. There is clear evidence that acquisition of 511 travel information is related to the higher likelihood of adjusting planned travel by callers. Such adjustments are often made in response to uncertainty caused by traffic incidents, construction work zones, adverse weather, etc.

Improved travel time reliability may be achieved by distributing accurate travel information through NC 511, especially when unexpected events happen and traffic updates are desired. NC 511 is increasingly a key source of information for travelers. Serious consideration should be given to investments in improving the NC 511 service in terms of providing traffic updates, roadway condition information, and weather information, along with concomitant investments in data collection and data fusion. This will allow access to accurate 511 information and travelers' plan readjustments. Providing improved 511 travel information can result in a more dynamic readjustment of demand, potentially benefiting the transportation network performance. A more detailed study of ease of using the NC 511 system and improvements in traffic updates, road conditions, and weather information is needed.

Analysis of the survey data can be summarized as follows:

- Respondents were more likely to call on Thursdays and Fridays. As expected, more calls to NC 511 were made during traffic peak hours, especially to receive information about the traffic and roadway conditions.

- A substantial number of responding callers accessed traffic updates, weather conditions and road construction. Notably, road construction information is more likely to be acquired regularly. Road condition information is usually acquired on specific roadways when unexpected events occur, e.g., when there are rockslides.

- If respondents acquire information 2-3 times per month or more frequently, then they are more likely to change their travel decisions. Fifty-two percent of the users reported changing their travel decisions based on 511 information received. This indicates that the system is enhancing the mobility of users by allowing them to dynamically readjust their travel plans in response to traffic events and conditions.

- The callers found NC 511 service to be generally useful to them, and seemed to be satisfied with the service. Sixty-one percent of the respondents rated information provided by NC 511 as very useful. However, some of the callers did not find certain aspects of the service to be useful at all, pointing to potential improvements in the system.

The recommendations emerging out of the study are as follows:

- *Improving the NC 511 voice recognition system.* It will be worthwhile to look into upgrading the NC 511 telephone system so it can better recognize speech, and take commands well, and deal with background noise from callers. The telephone tree structure can be re-examined and reviewed to better reflect individuals' decision making sequence. Furthermore, a permanent feedback loop on the telephone system can be considered for continuous identification of problems and improvement suggestions from users.

- *Improving the content of information provided through NC 511.* Consideration should be given to investments in improving the NC 511 service in terms of providing traffic updates (e.g., exact location, duration, and details of traffic incidents and secondary incidents if they have occurred), roadway condition information, and weather information. This may require examining investments in traffic data collection and data fusion. Such investments can facilitate access to higher quality 511 information in the future.

- *Conduct a broader study in order to obtain substantive information about users and their travel behaviors.* A more detailed study of ease of using the travel information system and how improvements in traffic updates, road conditions, and weather information can be made is needed. Different user segments should be considered, including tourists, residents, and commercial vehicle drivers and operators. Several methods of collecting relevant assessment data should be considered, including focus groups to obtain information about traveler behavior of specific population segments, a detailed telephone survey, an Internet-based survey to obtain information about satisfaction with the service, and an awareness survey to gauge awareness of the travel information services, and using GPS to follow individuals travel locations. As discussed above, one example of an Internet-based behavioral survey that has already been designed as part of this project is available in Appendix B.

CHAPTER 9. SUMMARY FINDINGS AND CONCLUSIONS

This chapter will provide a high level summary of the project findings and conclusions. Recommendations based on these findings and conclusions are provided in Chapter 10. The summary recommendations will be organized in the following sections:

- Baseline model creation
- Baseline model calibration and validation
- Scenario modeling
- Scenario comparative analysis
- DynustT limitations

9.1 Baseline Model Creation

The DynusT software tool is clearly scalable to a regional model such as the TRM 2015 network and peak period demand tables. The basic network was created by direct import of the link-node structure and the AM and PM demand tables from the 2015 TRM TransCAD model. Significant effort was required to correct errors in network translation and to provide additional necessary network detail. The effort although significant was not unreasonable, and tools to support network translation are likely to be continually updated and improved.

9.2 Baseline Model Calibration and Validation

The process of calibrating the freeway traffic flow models is straightforward when appropriate detector data is available. The project team found that creating specific models for each level of number of mainline travel lanes was not necessary for reasonable results. It may in fact be inconstant to define traffic flow models to such a fine level of precision within a large-scale mesoscopic model. However, the DynusT tool does provide a nearly limitless capability to define situation specific traffic flow models. Therefore, it is an important avenue of future research to continue to investigate the effect of various levels of traffic flow model specification and whether there are cases where more detail provides valuable and valid improvement in model fidelity.

Validation based on network links identified by the expert opinion and analysis of the 2005 and 2015 TRM results as being relatively temporally stable appears to be an appropriate approach for providing a high-level check of reasonableness for a future year baseline model. However, although there was general agreement between the 2015 DynusT baseline model and year 2009 traffic count data, there were links where the DynusT model yielded significantly higher peak hour flows. Beyond verifying the accuracy of the network coding for these links, the project team decided there were no appropriate steps to address the differences. This decision was also based on the fact that the DynusT flow values for the links in question seemed reasonable for the number of lanes and the location for each link. The project team was not able to pursue this issue further under the scope of the research project, and the value of comparative results from the DynusT scenario modeling is are not likely to be significantly affected. Nonetheless, if DynusT becomes an important modeling tool in the future, it would be prudent to look more deeply at the issue of whether or not closer agreement between the base year travel demand model output and DynusT model output can be reasonably achieved.

9.3 Scenario Modeling

The selected operational scenarios could be effectively modeled in DynusT. However, the detail of the ramp metering software feature was not as fully developed as the project team had anticipated. The team had planned to develop custom ramp metering logic using an available application program interface (API). However, the API was not available in time for the team to implement this original plan. The second option pursued was to use the software's built-in traffic responsive ramp metering logic. However, initial tests showed that this imbedded ramp metering logic was not producing reasonable results. Therefore, as described in Chapter 7, a workaround was developed that allowed traffic responsive ramp metering control to be emulated using DynusT's fixed-rate ramp metering logic (which had been found to produce reasonable operational results).

Scenario coding for the HOT lane and Low Cost Bottleneck improvement scenarios was relatively straightforward and is described in detail in Chapter 7. However, the project team was not able to implement a proto-type transit scenario as planned. It was discovered during software testing that the "Bus Scenario" feature was not enabled in the version of the software that the project team was using for most of the project performance period. Although the bus feature was included in the new version of the software that was released near the end of the project, there was not time at that point to complete the planned transit scenario. However, the project team did use the bus scenario feature to code the Raleigh to Chapel Hill and Chapel Hill to Raleigh Triangle Transit Authority express routes. Through this effort, the project team verified that the ability to code fixed route bus service is available and working in the current version of the software. In the current implementation, the route coding process is tedious, and the team estimates on average about 2 hours per route are needed for route coding (of course dependent on route length and stop density). Also, although the ability to model fixed transit routes and the resulting operational impact of the transit vehicles on the roadway network does exist, DynusT does not include any mode choice capabilities. Therefore, if DynusT is used to evaluate the operational effect of major transit improvement scenarios, demand impacts will have to be estimated off line.

9.4 Scenario Comparative Analysis

The simulation output provided by DynusT enables scenario comparison at the link, corridor, origin-destination pair, and network levels. Based on complementary research under the federal SHRP2 program, the project team summarized these results in a manner that allows each scenario to be compared with the operational improvements provided by the full-build construction alternative (see Chapter 7).

9.4.1 Ramp Metering

The ramp metering results provide a preliminary indication that the level of congestion along the I-40 corridor and at non I-40 locations included in the ramp metering scenarios is not at a high enough level to yield significant improvement from ramp metering deployment. This result is somewhat at odds with the results derived from the ITS Deployment Analysis System (IDAS) tool and reported in the Triangle ITS strategic plan update (Kimley-Horn, 2010). As pointed out in the Day 1 workshop presentation (see Appendix D), this difference in result is not unexpected given the fundamental difference in how IDAS and DynusT model the effect of ramp metering. However, although these results should be taken into consideration, they are necessarily tentative because of the difficulties in coding the ramp metering strategy described above. Further modeling analyses of ramp metering projects under consideration are needed. For example, a limited microsimulation-based study could be undertaken to provide another assessment of the operational impact of ramp metering under project demand conditions.

9.4.2 Low Cost Bottleneck Improvements

The low cost bottleneck improvement scenario produced little measurable benefits in the DynusT results. This is not entirely unexpected because the 2015 network reflects years of carefully planned and executed projects to address bottlenecks along the I-40 corridor. No general conclusions can be drawn from these results. The impact of bottleneck improvements in the "low cost" category will be entirely network and local condition specific. The importance of this scenario is that it is relatively easy to implement in DynusT. Furthermore, if there were significant bottlenecks along I-40 remaining in the 2015 network that could be remedied with a low cost improvement, it would be valuable to assess the operational impact of such an improvement within the mesoscopic, dynamic traffic assignment environment provided by DynusT. The modeling value would arise from DynusT's ability to model the resulting network assignment impacts and to model the driver response of and operational benefit to travelers within the range of modeled user classes.

9.4.3 HOT Lanes

The results of the HOT lane scenario in essence confirmed the validity of the *I-40 High Occupancy Vehicle/Congestion Management Study* (Parson Brinkerhoff, 2003). As described in Chapter 7, this scenario involved adding HOT lanes to the links identified in the HOV study. What the results show is that a HOT system based on the boundaries identified in the HOV study would provide nearly the same benefits at the network, corridor, and critical origin-destination pair level as would build out of the entire I-40 corridor to the maximum feasible cross section.

9.5 DynusT Limitations

The project modeling efforts revealed two types of limitations to DynusT modeling capabilities. Limitations that the project team considers to be inherent to the mesoscopic, dynamic traffic assignment framework will be discussed first. This will be follow by a discussion of limitation that are correctible and therefore should be remedied in the future.

9.5.1 Inherent Limitations

The implementation vision assumed by the project team involves building the DynusT network and demand structure (zones and time-dependent demand table) from regional travel demand models. The resulting zone and network model is therefore limited in resolution to the resolution of the travel demand model. Therefore, modelers will need to take care that scenarios that must be modeled at a higher resolution in order to be effectively represented are not considered to be well-analyzed operationally within DynusT. Such a case would be an example where microsimulation may be necessary in order to effectively model the scenario under consideration.

In its current implementation, DynusT uses a 6 second simulation update interval. Although this interval may change in future versions, it is neither likely nor appropriate for a mesoscopic model such as DynusT to use a simulation interval that would provide high fidelity modeling of traffic signal operations. The signalized intersection modeling capabilities in DynusT are sufficient to model general operations along a signalized corridor within a larger network. However, similar to the caution regarding scenarios requiring a high level of network detail, scenarios that require detailed modeling of signal control will not be sufficiently modeled in mesoscopic models such as DynusT.

9.5.2 Correctible Limitations

In the course of model calibration, the project team concluded that the two-regime traffic flow modeled intended for freeway links in DynusT does not reflect actual freeway traffic flow as accurately as may be needed. With continued input from the user community, incorporation of improved traffic flow models is likely to be included in future editions of the software. The issues with the ramp metering logic should also be addressed in future versions. The most critical issue is the need to correct the traffic responsive ramp metering logic so that it will provide valid results. Beyond this correction, it would be very helpful to the user community if a richer set of ramp metering protocols were readily available within the software. Although the application programming interface (API) does exist for coding detailed ramp metering logic, it is likely that few users will have the knowledge and/or time to write custom ramp metering code. If not provided directly within the software, another possibility is that members of the open source user community will begin to contribute extensions such as ramp metering logic and improved transit modeling capabilities that can be used by other members.

CHAPTER 10. RECOMMENDATIONS AND IMPLEMENTATION CONSIDERATIONS

The project team recommends that NCDOT and North Carolina planning agencies further investigate the usefulness and practicality of incorporating DynusT into toolbox for analyzing the operational impacts of alternative mobility enhancement scenarios. The results of this research project have demonstrated that the mesoscopic, dynamic traffic assignment network modeling provided by the DynusT software tool is scalable to the regional network model level. Implementation considerations identified by the project research team can be categorized as software/hardware investment, training and support, and development of an overall modeling tool framework.

10.1 Software and Hardware Investment

In terms of software, cost is no longer an issue due to the fact that DynusT has moved into the open source software realm. The executable software is available for free download from the website identified in Chapter 11. The scenario file sets provided as digital deliverables for this research project can be immediately viewed, modified, and executed by any NCDOT or Triangle region planning professional with access to a computer with sufficient resources. As also mentioned in Chapter 11, the software is available in 32-bit and 64-bit versions.

In terms of computer hardware, the decision regarding whether a 32-bit platform is adequate or a 64-bit computer is necessary is solely dependent on the size of the network and traffic demand and the resulting computer memory (RAM) requirements. The TRM model developed for this project does require a 64-bit computer for interaction with previously generated simulation results, model modification, and/or model simulation. Details on specific hardware requirements and computer run time estimates are provided in Appendix C.

Although the requirement for a 64-bit computing platform as detailed in Appendix C may result in a short-term need for targeted hardware investment, the 64-bit specification is quickly emerging as the standard for new Windows-based systems, and costs are coming down as well. Therefore, the need for special computing investment to support DynusT modeling at the regional level is likely to be only a minor consideration in the short-term.

10.2 Training and Support

With computer software and hardware not a serious consideration, cost and effort required for training network modeling professional will likely be the most significant necessary investment. This research project provided a one-day, introductory, hands-on DynusT workshop. The PowerPoint presentations and DynusT files used in this workshop are provided as digital project deliverables. These materials can be used in the short-term to broaden the exposure to the NCDOT and Triangle region transportation planning community. This exposure will be important for informing the decisions that each constituent agency will make regarding the role of DynusT in future modeling and decision support efforts.

The ultimate level of training and ongoing user support needed will be dependent on the ultimate significance of DynusT's role in network modeling in the Triangle region and across North Carolina. The DynusT developers indicate that a "Plus" user category will be available (see Chapter 11). The details and cost of the support services that will be provided under this user category are not finalized. If NCDOT and/or regional planning agencies decide to move forward with incorporating DynusT into ongoing planning activities, appropriate support will need to be arranged. This support will likely come from the DynusT development team at least in the short-term. Training will also be provided by the DynusT development team to "Plus" users. In house training and/or specially designed training through the Institute of Transportation

Research and Education (ITRE) are longer term alternatives to fee-based training from the software developers.

10.3 Development of an Overall Modeling Framework

In clarifying the ultimate role for DynusT in ongoing planning activities, it will be important for NCDOT and regional planning agencies to develop an overall framework that defines a hierarchy of modeling approaches, the appropriate context for each approach, and how the approaches relate and interact within the framework. The mesoscopic, dynamic traffic assignment capabilities provided by DynusT has the potential to provide the missing link between planning activities that have relied on static and deterministic macroscopic travel demand modeling and detailed operational modeling with microsimulation. The decision support effectiveness of overall modeling activities will be in large measure dependent on a clear definition of the unique and complementary role played by each level of modeling within the hierarchical framework.

CHAPTER 11. IMPLEMENTATION AND TECHNOLOGY TRANSFER PLAN

This chapter is organized in two sections. The first section will describe the two workshop sessions that were held in January 2011 as part of the project scope. The second section will describe recommended future activities that will foster implementation of the project research.

11.1 Project Training Workshop

Training workshop activities were called for in Task 11 of the project scope. These workshops were planned in conjunction with the steering implementation committee chair and the project research engineer during the fall of 2010. Ultimately, a two-day format was selected with Day 1 being a one-half day session designed for the members of the steering and implementation committee and other interested NCDOT and regional planning managers. Day 2 was designed as an introductory level hands-on workshop to provide an opportunity for attendees to interact with the DynusT software and gain initial familiarity with the basics steps in developing baseline models and analysis scenarios. The agendas and PowerPoint presentations for these workshops are provided in Appendix D.

11.2 Future Activities

The project team recommends that appropriate NCDOT and Triangle region planning professionals use the DynusT project files provided along with this final report to conduct informal analyses to continue the process of building familiarity with and confidence in the DynusT software tool. This informal use will provide the basis for an ultimate decision of whether or not and if so how extensively the NCDOT and regional planning agencies will use DynusT.

The transition of DynusT from license-fee based to open source software that began during the latter half of the project is now complete. DynusT is freely available for download at –

http://www.dynust.net

As pointed at in Appendix C, a 64-bit computer with at least 8 GB running a 64-bit Windows operating system (either Windows XP or Windows 7; Windows Vista is not supported) is required to run the TRM baseline model and scenarios. The 64-bit version of DynusT is available for download along with the 32-bit version.

As an open-source software tool, both the executable install files and the source code files are freely available. The DynusT developers are also offering a user level that includes training and support resources for fee. The fee structure for the DynusT Plus users has not been finalized. Whether or not NCDOT or other North Carolina planning agencies will need to become DynusT Plus users will depend on how extensively DynusT is used in the future. The open source user community for DynusT will also drive the future development and enhancement of DynusT features, such as improvement in the ramp metering and transit capabilities. Figure 11-1 below is taken from the DynusT website and provides a summary of the resources available to "Standard" and "Plus" users.

	DynusT Standard	DynusT Plus
Source Code	✓	✓
Online Manual	✓	✓
User Forums	✓	✓
Technical Support	✗	✓
Programmer's Guide	✗	✓
Training Videos	✗	✓
Course Materials	✗	✓
Online Videos	✗	✓
Example Datasets	✗	✓
DynusT Utilities	✗	✓

(Source: www.dynust.net "Become a DynusT User")

Figure 11-1: DynusT User Scheme

CITED REFERENCES

DynusT Online User's Manual, http://dynust.net/wikibin/doku.php

Kimley-Horn and Associates, Inc. (2010) "Intelligent Transportation System Strategic Deployment Plan Update, Triangle Region: FINAL Project Evaluation and Prioritization Report." Raleigh, NC.

NUSTATS. (2006) "Greater Triangle Travel Study-Household Travel Survey Final Report," Austin, Texas.

Parsons Brinckerhoff. (2002). "I-40 High Occupancy Vehicle/Congestion Management Study: Bottleneck Analysis Report," Raleigh, NC.

Parsons Brinckerhoff. (2003). "I-40 High Occupancy Vehicle/Congestion Management Study: Final Report," Raleigh, NC.

Swan, N., S. Baker, R. Hintz, T. Trimble. (2004). "511 Virginia Evaluation, Virginia Department of Transportation: Final Report," Virginia Tech Transportation Institute.

APPENDICES

APPENDIX A. NETWORK CREATION PROCEDURES

Chapter 5 presents an overview of the network preparation procedures applied for this project. As mentioned in Chapter 5, the TRM 2015 TransCAD network provided the network geometry and demand data for the DynusT simulation network. This appendix explains how the project team prepared the TRM DynusT simulation network from the TRM TransCAD network in detail.

Data conversion methods can vary slightly for different users. The method presented here provides one example. This appendix discussion is organized into following sections.

- DynusT import file example and descriptions of required data fields
- The TRM 2015 TransCAD network data views and exporting the TransCAD data into Excel sheets and text files
- Editing the exported data into the import file format for DynusT network
- Importing the network and modifying the DynusT network for fine tuning

A.1 DynusT Import File and Required Data

Network EXplorer for Traffic Analysis (**NEXTA**) is a graphical user interface system for simulation-based dynamic traffic assignment models DYNASMART-P and DynusT. NEXTA allows users to create new networks and datasets, modify existing datasets, import datasets from other planning models, specify traffic analysis scenarios, specify simulation run-time parameters, and execute the simulation engine. For outputs, NEXTA allows users to load existing datasets and simulation results, and conduct extensive post-simulation analysis. It also has simulation animation features. Figure A.1 is a screen capture to show the import tool of NEXTA. This tool has a capability of importing GIS data set, TRF network, or GNU Network files. Because the TRM TransCAD network is a GIS based network, GIS data set option was selected.

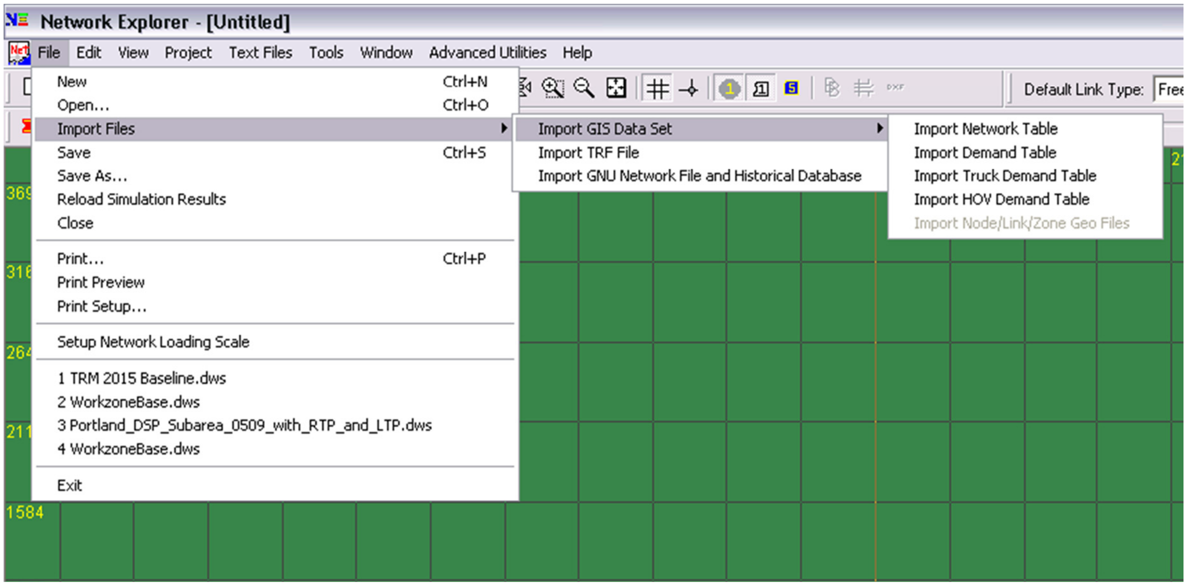
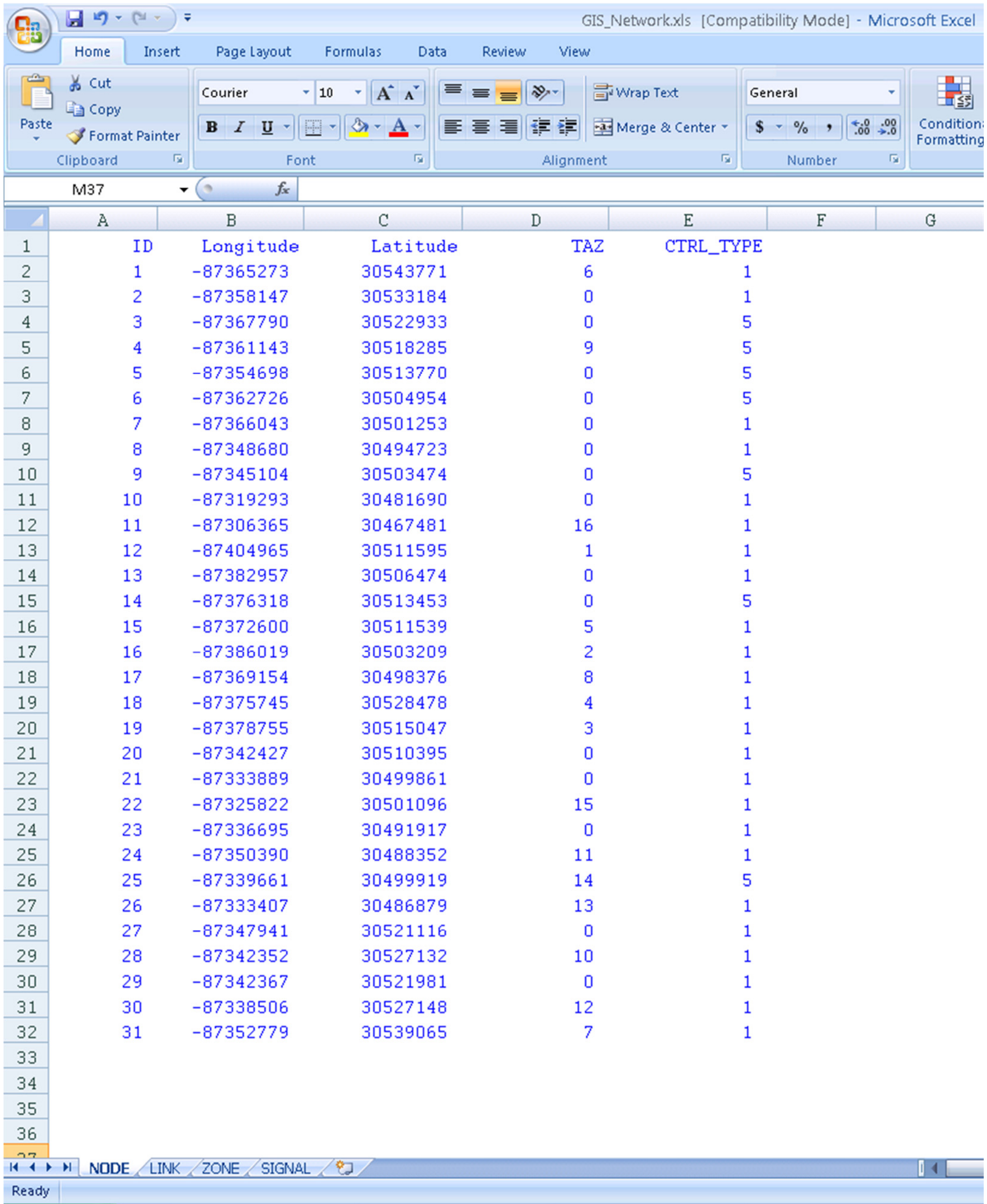


Figure A.1 Import Tool of NEXTA

Sample GIS network import file, "GIS_network.xls" can be found in "C:\Program Files (x86)\FHWA\DynusT (Dynamic Urban Systems in Transportation) x64\3.0x64 Beta". The excel file contains four worksheets, i.e. node, link, zone, signal. Below sections show the example sheets and descriptions of the required data fields.

a. Node

The column headings of the sheet must be ID, Longitude, Latitude, TAZ, and CTRL_Type. These headings must be in this exact form as shown in Figure A.2.



ID	Longitude	Latitude	TAZ	CTRL_TYPE
1	-87365273	30543771	6	1
2	-87358147	30533184	0	1
3	-87367790	30522933	0	5
4	-87361143	30518285	9	5
5	-87354698	30513770	0	5
6	-87362726	30504954	0	5
7	-87366043	30501253	0	1
8	-87348680	30494723	0	1
9	-87345104	30503474	0	5
10	-87319293	30481690	0	1
11	-87306365	30467481	16	1
12	-87404965	30511595	1	1
13	-87382957	30506474	0	1
14	-87376318	30513453	0	5
15	-87372600	30511539	5	1
16	-87386019	30503209	2	1
17	-87369154	30498376	8	1
18	-87375745	30528478	4	1
19	-87378755	30515047	3	1
20	-87342427	30510395	0	1
21	-87333889	30499861	0	1
22	-87325822	30501096	15	1
23	-87336695	30491917	0	1
24	-87350390	30488352	11	1
25	-87339661	30499919	14	5
26	-87333407	30486879	13	1
27	-87347941	30521116	0	1
28	-87342352	30527132	10	1
29	-87342367	30521981	0	1
30	-87338506	30527148	12	1
31	-87352779	30539065	7	1

Figure A.2 GIS_Network.xls-Node Sheet

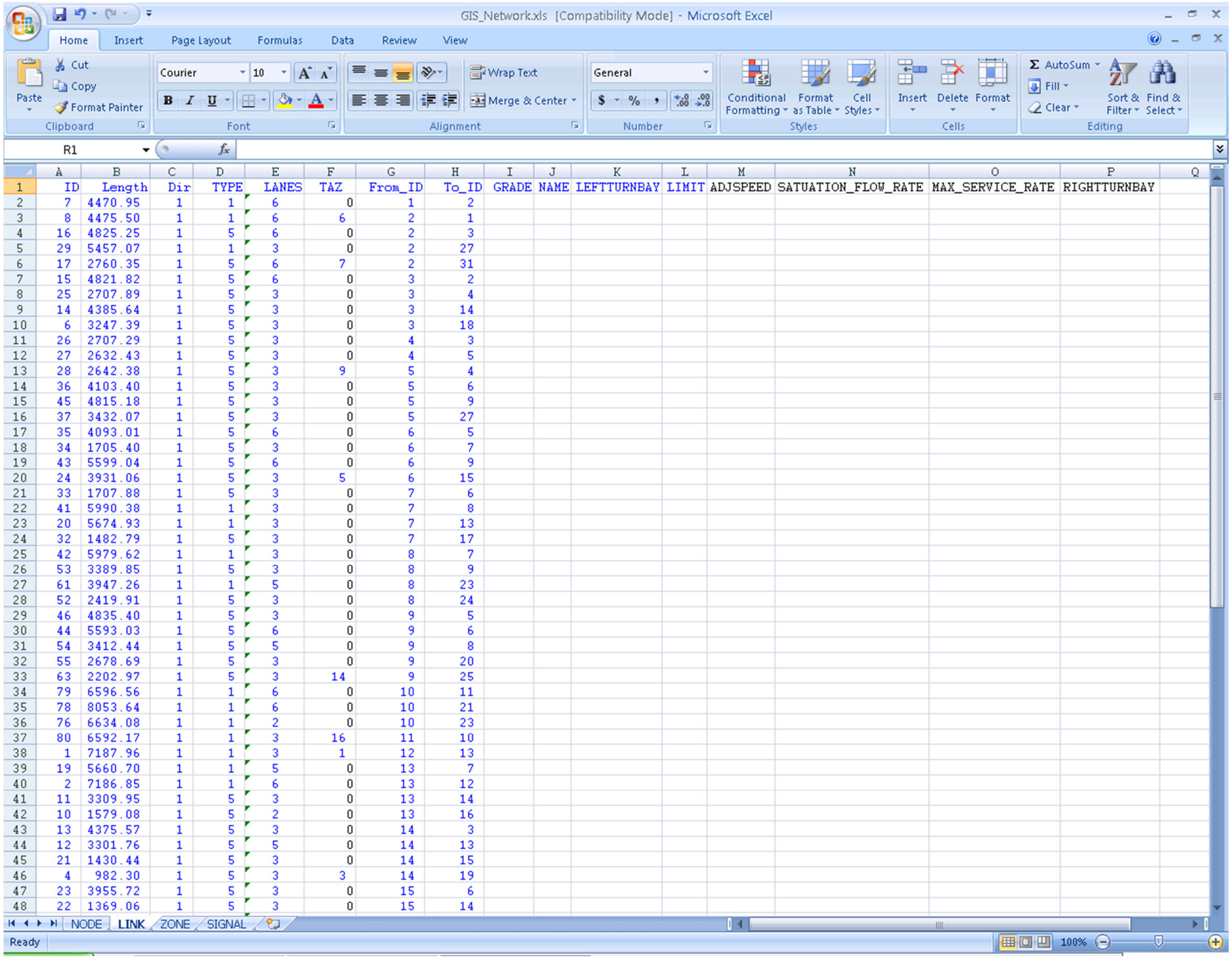
Table A.1 summarizes the definitions of each field in Node sheet. ID, longitude, and latitude are easily transferable from TransCAD. The TAZ and CTRL_Type can be left blank, but if user can fill these columns, post works (mostly need manual work) after importing the data set will be significantly reduced.

Table A.1 Definitions of Each Column in Node Sheet

Field Name	Data Type	Description
ID	Integer	Node ID assigned by GIS software
LONGITUDE	Float / Double	Longitude coordinate of the node
LATITUDE	Float / Double	Latitude coordinate of the node
TAZ	Integer	If the node is a destination node for a zone, then this field is supplied with the corresponding zone TAZ number; otherwise, put it as 0.
CTRL_TYPE	Integer	Defined for signal control type of the node with the following values: 1. No control 2. Yield sign 3. 4-way stop sign 4. Pre-timed control 5. Actuated signal control 6. 2-way stop sign

b. Link

These headings must be in this exact form as shown in Figure A.3. The column heading should be ID, Length, Dir, TYPE, LANES, TAZ, From_ID, To_ID, GRADE, NAME, LEFTTURNBAY, LIMIT, ADJSPEED, SATUATION_FLOW_RATE, MAX_SERVICE_RATE, RIGHTTURNBAY. Table A.2 summarizes the definitions of each field in Link sheet. Most of field can be transferred from TransCAD. The “TAZ” column is for defining generation links and can be left blank, but if user can fill these columns at this stage, post works (mostly need manual work) will be significantly reduced.



ID	Length	Dir	TYPE	LANES	TAZ	From_ID	To_ID	GRADE	NAME	LEFTTURNBAY	LIMIT	ADJSPEED	SATUATION_FLOW_RATE	MAX_SERVICE_RATE	RIGHTTURNBAY
7	4470.95	1	1	6	0	1	2								
8	4475.50	1	1	6	6	2	1								
16	4825.25	1	5	6	0	2	3								
29	5457.07	1	1	3	0	2	27								
17	2760.35	1	5	6	7	2	31								
15	4821.82	1	5	6	0	3	2								
25	2707.89	1	5	3	0	3	4								
14	4385.64	1	5	3	0	3	14								
6	3247.39	1	5	3	0	3	18								
26	2707.29	1	5	3	0	4	3								
27	2632.43	1	5	3	0	4	5								
28	2642.38	1	5	3	9	5	4								
36	4103.40	1	5	3	0	5	6								
45	4815.18	1	5	3	0	5	9								
37	3432.07	1	5	3	0	5	27								
35	4093.01	1	5	6	0	6	5								
34	1705.40	1	5	3	0	6	7								
43	5599.04	1	5	6	0	6	9								
24	3931.06	1	5	3	5	6	15								
33	1707.88	1	5	3	0	7	6								
41	5990.38	1	1	3	0	7	8								
20	5674.93	1	1	3	0	7	13								
32	1482.79	1	5	3	0	7	17								
42	5979.62	1	1	3	0	8	7								
53	3389.85	1	5	3	0	8	9								
61	3947.26	1	1	5	0	8	23								
52	2419.91	1	5	3	0	8	24								
46	4835.40	1	5	3	0	9	5								
44	5593.03	1	5	6	0	9	6								
54	3412.44	1	5	5	0	9	8								
55	2678.69	1	5	3	0	9	20								
63	2202.97	1	5	3	14	9	25								
79	6596.56	1	1	6	0	10	11								
78	8053.64	1	1	6	0	10	21								
76	6634.08	1	1	2	0	10	23								
80	6592.17	1	1	3	16	11	10								
1	7187.96	1	1	3	1	12	13								
19	5660.70	1	1	5	0	13	7								
2	7186.85	1	1	6	0	13	12								
11	3309.95	1	5	3	0	13	14								
10	1579.08	1	5	2	0	13	16								
13	4375.57	1	5	3	0	14	3								
12	3301.76	1	5	5	0	14	13								
21	1430.44	1	5	3	0	14	15								
4	982.30	1	5	3	3	14	19								
23	3955.72	1	5	3	0	15	6								
22	1369.06	1	5	3	0	15	14								

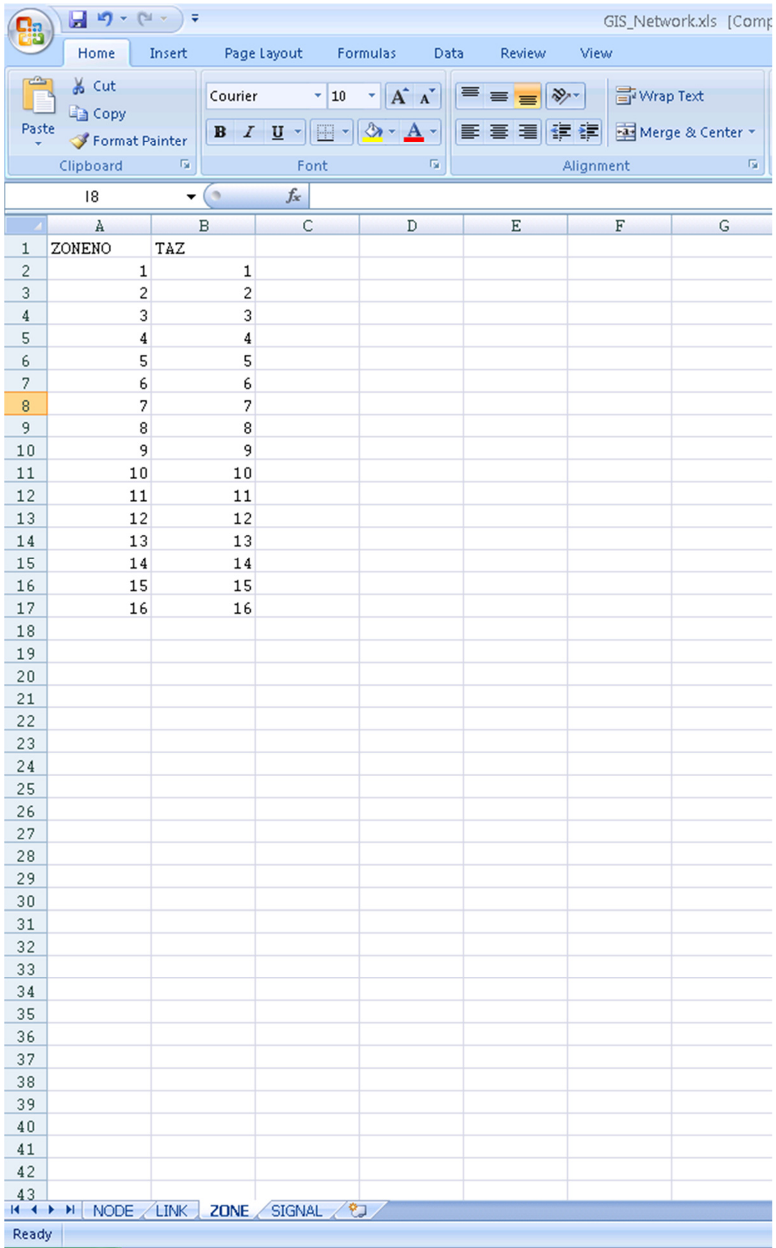
Figure A.3 GIS_Network.xls-Link

Table A.2 Definitions of Each Column in Link Sheet

Field Name	Data Type	Description
ID	Integer	Link ID assigned by GIS software
LENGTH	Float / Double	Length of the link (feet).
DIR	Integer	Defined as the direction of a link, with the following values: 1. from FromID to ToID -1. from ToID to FromID 0. two way
TYPE	Integer	Defined as the type of link, with the following value: 1. Freeway 2. Freeway segment with detector 3. On-ramp 4. Off-ramp 5. Arterial 6. Non-freeway HOT link 7. Highway 8. Non-freeway HOV link 9. Freeway HOT link 10. Freeway HOV link
LANES	Integer	Number of lanes of the link
TAZ	Integer	If this link is a generation link for a zone, then supply with the corresponding zone TAZ number; otherwise, put it as 0.
FROM_ID	Integer	From node ID, which should be consistent with the node ID given in NODEINFO
TO_ID	Integer	To node ID, which should be consistent with the node ID given in NODEINFO
GRADE	Integer	Road grade
NAME	Character	Road name
LEFTTURNBAY	Integer	Number of right turn bay
LIMIT	Integer	Speed limit
ADJSPEED	Integer	Free flow speed adjustment value Free flow speed= LIMIT+ADJSPEED
SATUATION_FLOW_RATE	Integer	Default value 1900
MAX_SERVICE_RATE	Integer	Default value - 2400, if type=1 - 1900, others
RIGHTTURNBAY	Integer	1: if right turn bay exist 0: if right turn bay does not exist

c. Zone

The column headings of the sheet must be ZONENO and TAZ. These headings must be in this exact form as shown in Figure A.4. Table A.3 summarizes the definitions of each field in Zone sheet. “ZONENO” assigns a unique numerical ID to each zone that can be exported from TransCAD. These values need to be in consecutive order starting at 1. The second column is “TAZ”. The values in the column are the actual TAZ values that were exported from TransCAD and they do not have to be in consecutive order however they obviously must correspond to the correct Zone.



ZONENO	TAZ
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16

Figure A.4 GIS_Network.xls-Zone

Table A.3 Definitions of Each Column in Zone Sheet

Filed Name	Data Type	Description
ZONENO	Integer	Zone ID assigned by GIS software
TAZ	Integer	Transportation Analysis Zone ID provided by users for planning purpose

d. Signal

The column headings of the sheet must be MaxGreen, MinGreen, and Amber as shown in Figure A.5. These are input values for actuated traffic controllers. If user left blank cell, the default values are MaxGreen=100sec, MinGreen=25sec, and Amber=0sec.

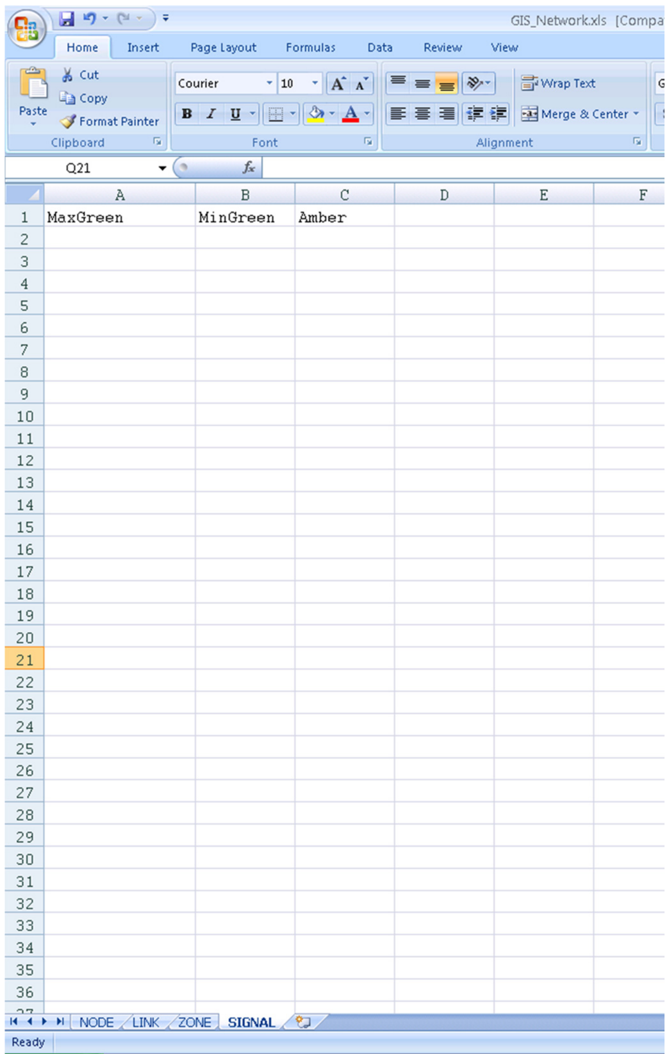


Figure A.5 GIS_Network.xls-Signal

e. Demand

The demand input for DynusT is an Origin-Destination (OD) matrix. A sample demand import file, “demand.txt” can be found in the DynusT program directory. The data should be in this exact format as shown in Figure A.6. In this file, the number “16" is the number of zones that are in the traffic network. The “8" is the number of demand intervals that this file represents, the “5" is the length of each demand interval in minutes, and the “0.1" is the proportion of the demand table that is applied to each interval.

```
//# of OD demand zones
16

//# of demand intervals
8
// length of demand interval
5

0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1
1,1,0
1,2,0
1,3,0
1,4,0
1,5,0
1,6,0
1,7,0
1,8,0
1,9,0
1,10,0
```

```
1,11,0
1,12,0
1,13,0
1,14,0
1,15,0
1,16,0
….
16,1,1200.1667
16,2,80.3333
16,3,16.4167
16,4,1705.3333
16,5,57.75
16,6,23.1667
16,7,36.0833
16,8,69.75
16,9,1
16,10,22.5833
16,11,6.9167
16,12,208.5
16,13,100.75
16,14,60.5833
16,15,67.3333
16,16,0
```

Figure A.6 Sample demand.txt File

A.2 TransCAD file – TRM 2015 data views and exporting network data

The TransCAD network (links, nodes, and zone) data can be exported into comma separated values (*.csv) files which can be opened and edited in Excel. Using the Excel template (GIS_network.xls) in the DynusT installation files and referring to the descriptions which are explained in this section of Appendix A, the required information for DynusT from raw TransCAD files was excerpted. The OD demand matrix from TransCAD was exported into a *.txt file format for demand file input to DynusT.

A.1.1. Open map and show node layer

In the TRM2015 TransCAD network, the "Highway_line.dbd" file contains nodes, links, and zones information. This file was opened in the file open menu of TransCAD. File open panel is presented in Figure A.7. Figure A.8 shows road network map.

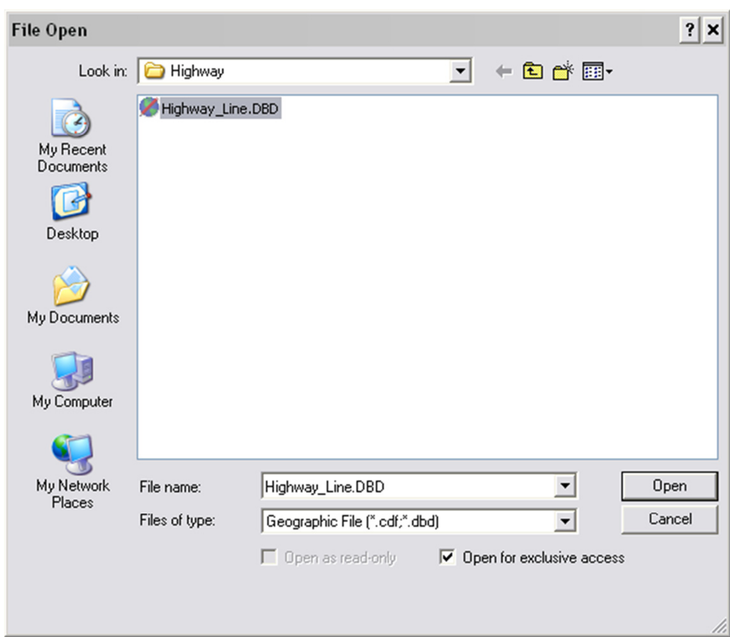


Figure A.7 TRM TransCAD File Open

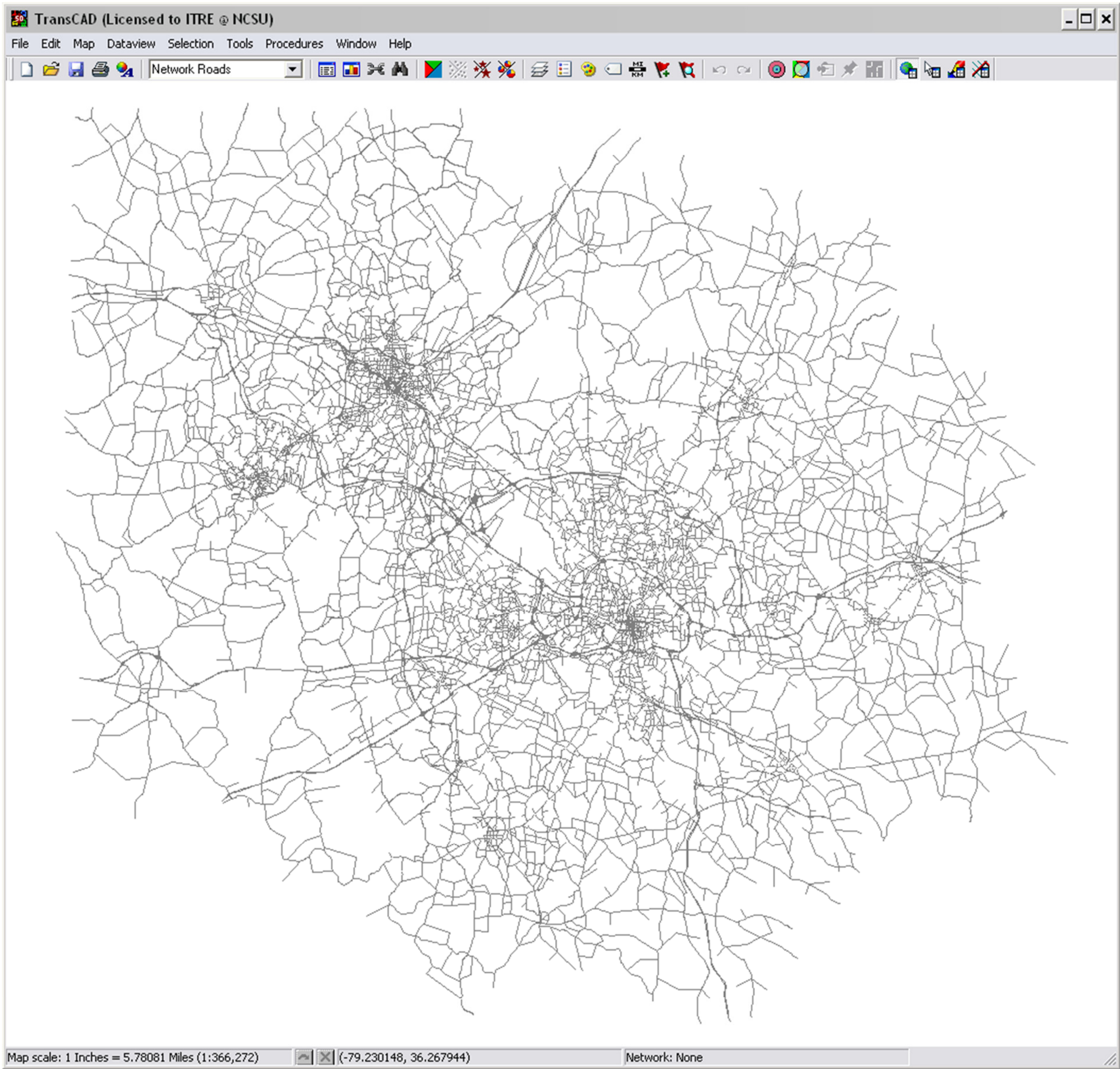


Figure A.8 TRM 2015 highway_line Map

To open the data table, select "Network Roads" as the active layer and then click the "new dataview" button as illustrated in Figure A.9. The link data for the network appears in a dataview table as shown in Figure A.10.

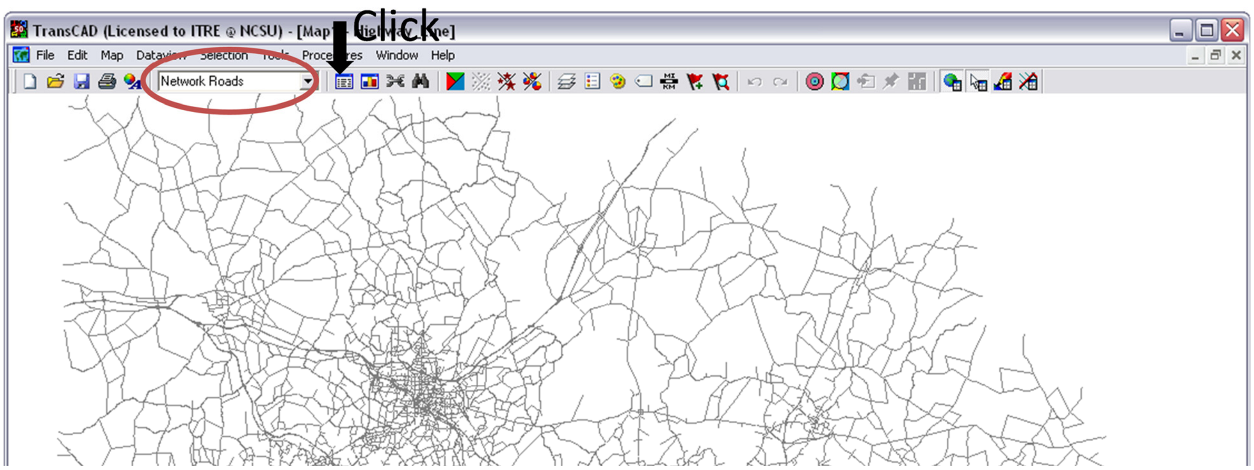
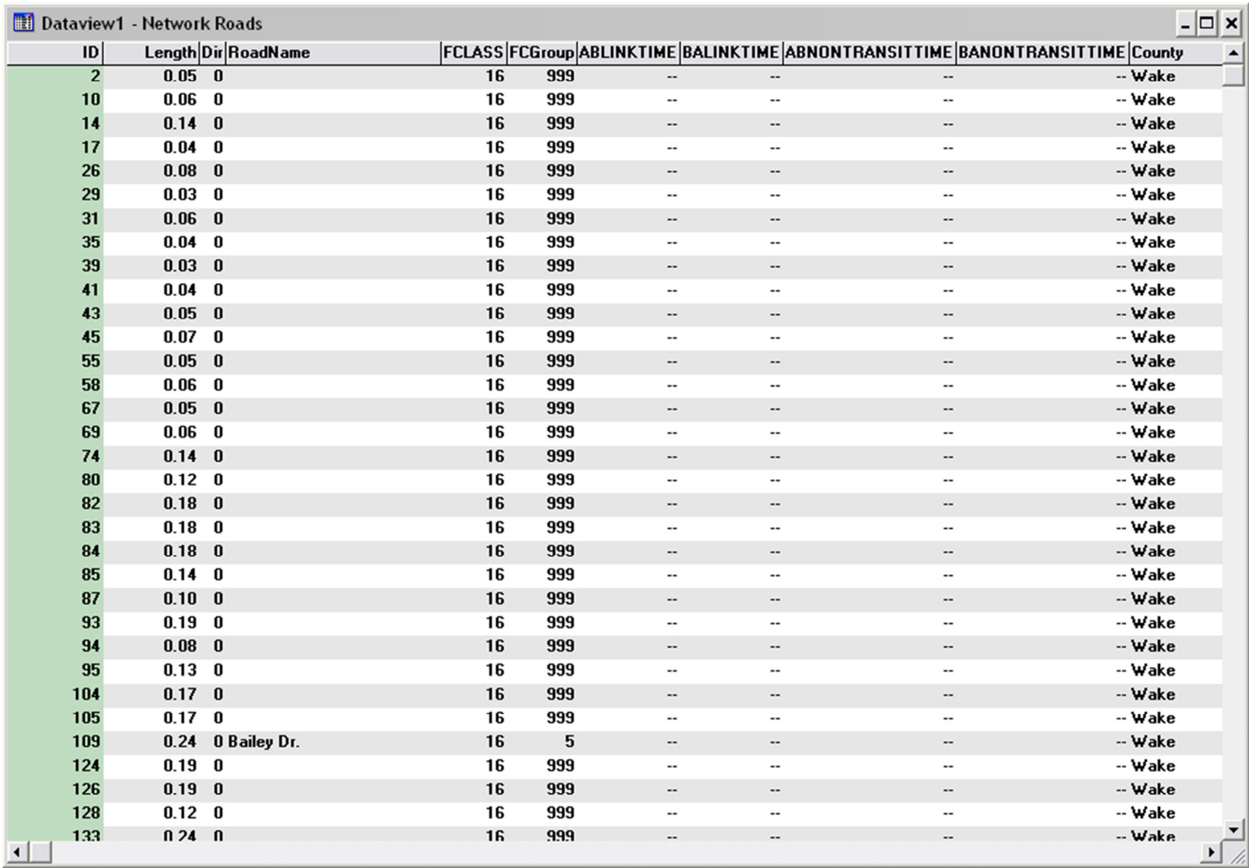


Figure A.9 Select Layer for Data Table View



Dataview1 - Network Roads

ID	Length	Dir	RoadName	FCLASS	FCGroup	ABLINKTIME	BALINKTIME	ABNONTRANSITTIME	BANONTRANSITTIME	County
2	0.05	0		16	999	--	--	--	--	Wake
10	0.06	0		16	999	--	--	--	--	Wake
14	0.14	0		16	999	--	--	--	--	Wake
17	0.04	0		16	999	--	--	--	--	Wake
26	0.08	0		16	999	--	--	--	--	Wake
29	0.03	0		16	999	--	--	--	--	Wake
31	0.06	0		16	999	--	--	--	--	Wake
35	0.04	0		16	999	--	--	--	--	Wake
39	0.03	0		16	999	--	--	--	--	Wake
41	0.04	0		16	999	--	--	--	--	Wake
43	0.05	0		16	999	--	--	--	--	Wake
45	0.07	0		16	999	--	--	--	--	Wake
55	0.05	0		16	999	--	--	--	--	Wake
58	0.06	0		16	999	--	--	--	--	Wake
67	0.05	0		16	999	--	--	--	--	Wake
69	0.06	0		16	999	--	--	--	--	Wake
74	0.14	0		16	999	--	--	--	--	Wake
80	0.12	0		16	999	--	--	--	--	Wake
82	0.18	0		16	999	--	--	--	--	Wake
83	0.18	0		16	999	--	--	--	--	Wake
84	0.18	0		16	999	--	--	--	--	Wake
85	0.14	0		16	999	--	--	--	--	Wake
87	0.10	0		16	999	--	--	--	--	Wake
93	0.19	0		16	999	--	--	--	--	Wake
94	0.08	0		16	999	--	--	--	--	Wake
95	0.13	0		16	999	--	--	--	--	Wake
104	0.17	0		16	999	--	--	--	--	Wake
105	0.17	0		16	999	--	--	--	--	Wake
109	0.24	0	Bailey Dr.	16	5	--	--	--	--	Wake
124	0.19	0		16	999	--	--	--	--	Wake
126	0.19	0		16	999	--	--	--	--	Wake
128	0.12	0		16	999	--	--	--	--	Wake
133	0.24	0		16	999	--	--	--	--	Wake

Figure A.10 Dataview of Network Roads

To see the nodes in the TRM TransCAD map, the node layer should be selected as the display layer. To do this, click “Map” menu and select “layers” resulting in the presentation of the dialog shown in Figure A.11.

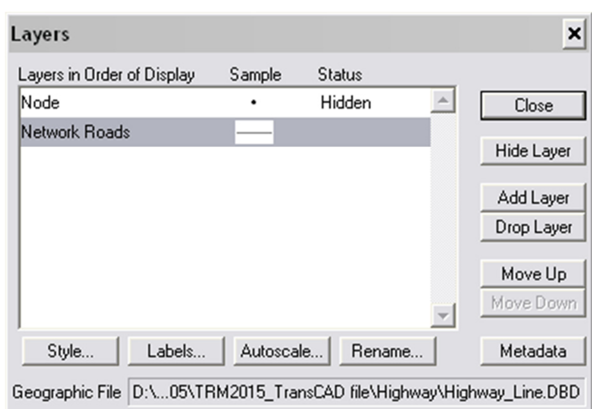


Figure A.11 Layer Edit Panel

Next, select the node layer and click “show layer”, and then click “close” as shown in Figure A.12. These steps result in display of the network map as shown in Figure A.13. Dots at the ends of links represent nodes.

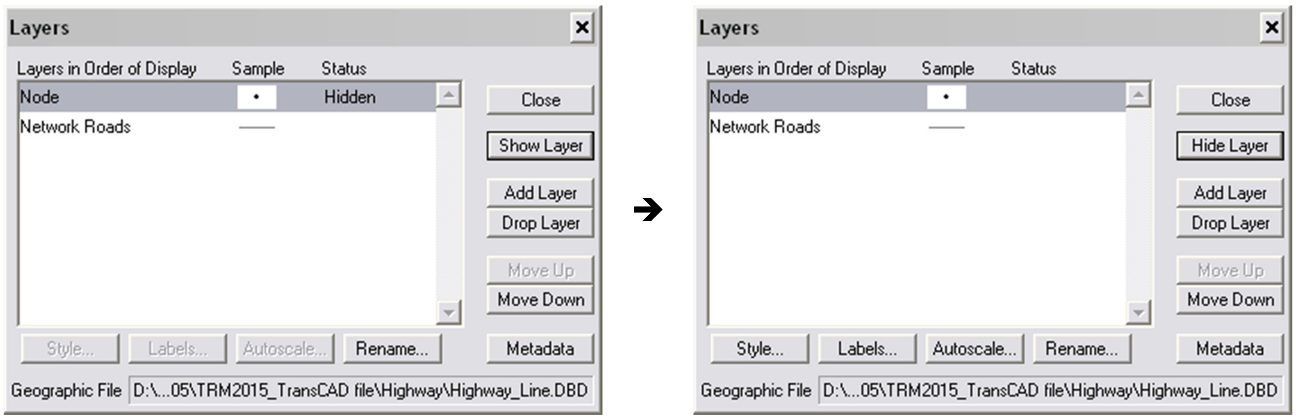


Figure A.12 Steps for Displaying Node Layer

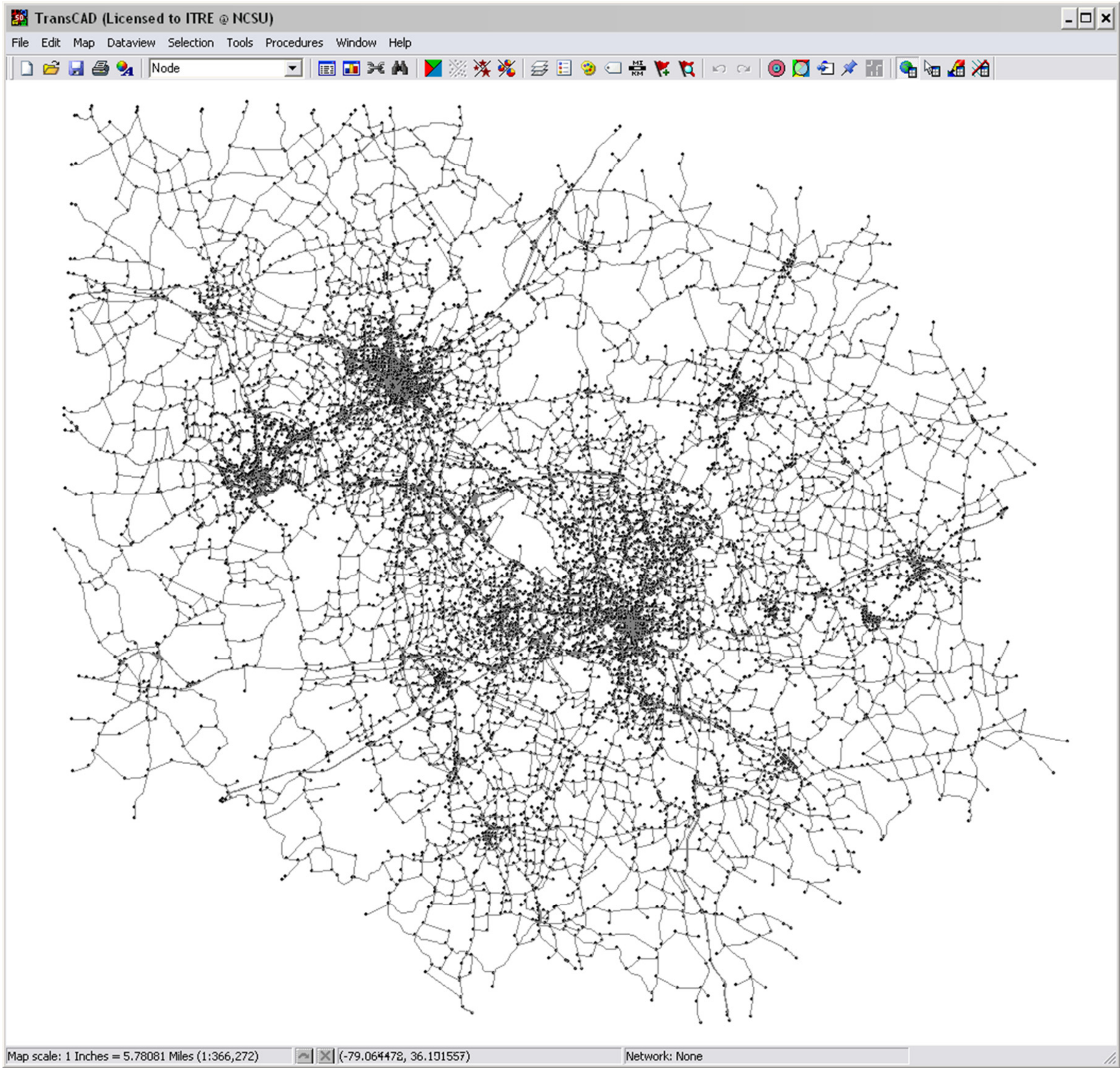


Figure A.13 TRM 2015 TransCAD Map with Nodes

To open the data table, select "Node" as the active layer and click "new dataview" button as shown in Figure A.14. Figure A.15, the Dataview for nodes, shows the network node and zone data.

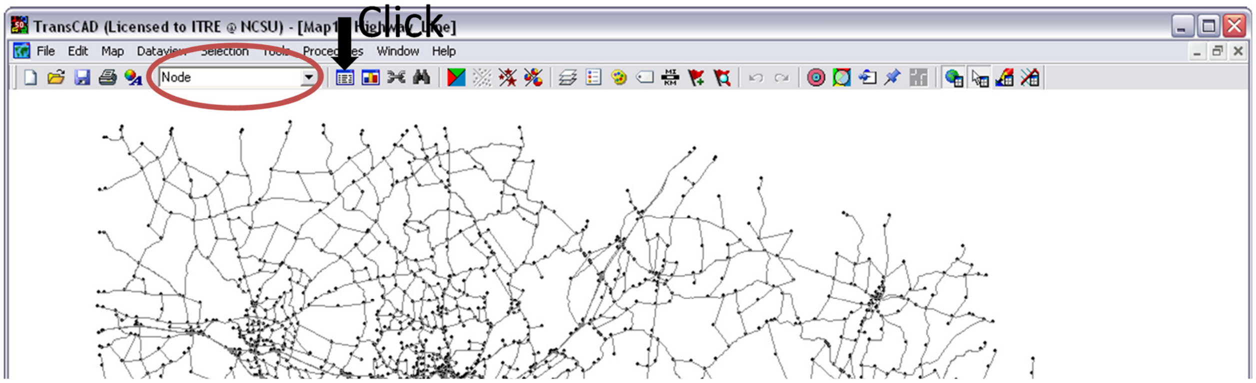
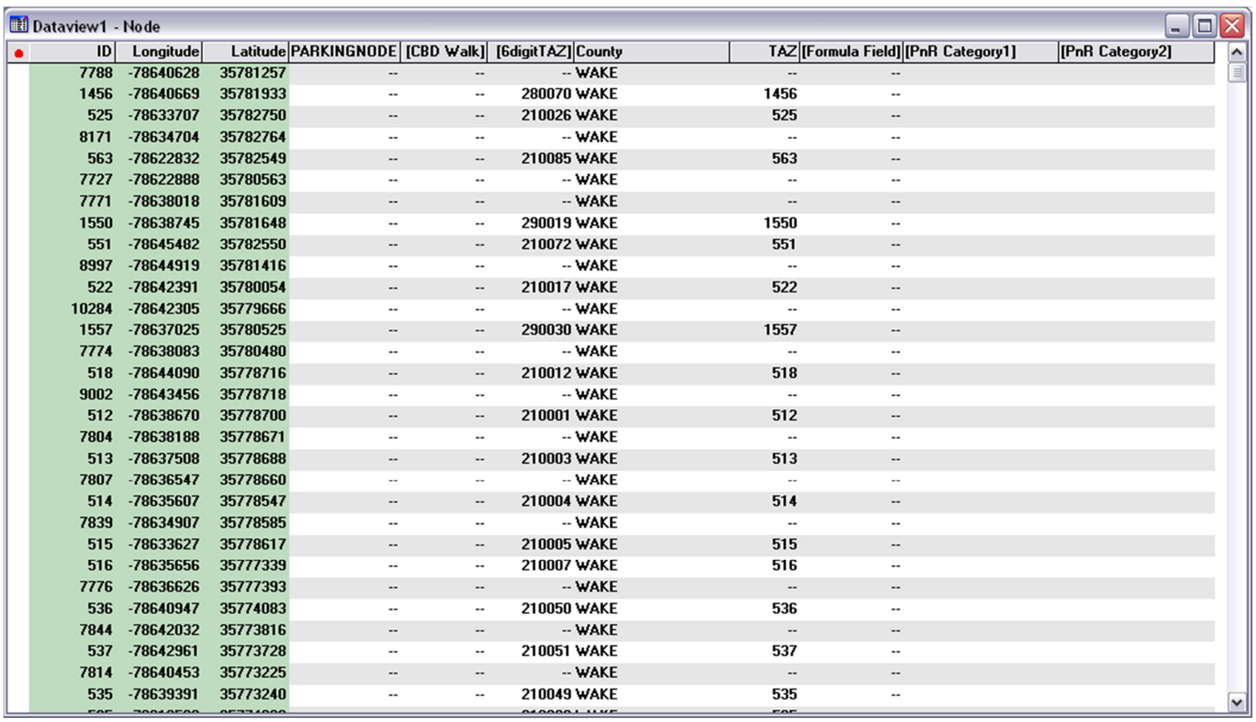


Figure A.14 Select Node Layer for Dataview Table



Dataview1 - Node

ID	Longitude	Latitude	PARKINGNODE	[CBD Walk]	[6digitTAZ]	County	TAZ	[Formula Field]	[PnR Category1]	[PnR Category2]
7788	-78640628	35781257	--	--	--	WAKE	--	--		
1456	-78640669	35781933	--	--	280070	WAKE	1456	--		
525	-78633707	35782750	--	--	210026	WAKE	525	--		
8171	-78634704	35782764	--	--	--	WAKE	--	--		
563	-78622832	35782549	--	--	210085	WAKE	563	--		
7727	-78622888	35780563	--	--	--	WAKE	--	--		
7771	-78638018	35781609	--	--	--	WAKE	--	--		
1550	-78638745	35781648	--	--	290019	WAKE	1550	--		
551	-78645482	35782550	--	--	210072	WAKE	551	--		
8997	-78644919	35781416	--	--	--	WAKE	--	--		
522	-78642391	35780054	--	--	210017	WAKE	522	--		
10284	-78642305	35779666	--	--	--	WAKE	--	--		
1557	-78637025	35780525	--	--	290030	WAKE	1557	--		
7774	-78638083	35780480	--	--	--	WAKE	--	--		
518	-78644090	35778716	--	--	210012	WAKE	518	--		
9002	-78643456	35778718	--	--	--	WAKE	--	--		
512	-78638670	35778700	--	--	210001	WAKE	512	--		
7804	-78638188	35778671	--	--	--	WAKE	--	--		
513	-78637508	35778688	--	--	210003	WAKE	513	--		
7807	-78636547	35778660	--	--	--	WAKE	--	--		
514	-78635607	35778547	--	--	210004	WAKE	514	--		
7839	-78634907	35778585	--	--	--	WAKE	--	--		
515	-78633627	35778617	--	--	210005	WAKE	515	--		
516	-78635656	35777339	--	--	210007	WAKE	516	--		
7776	-78636626	35777393	--	--	--	WAKE	--	--		
536	-78640947	35774083	--	--	210050	WAKE	536	--		
7844	-78642032	35773816	--	--	--	WAKE	--	--		
537	-78642961	35773728	--	--	210051	WAKE	537	--		
7814	-78640453	35773225	--	--	--	WAKE	--	--		
535	-78639391	35773240	--	--	210049	WAKE	535	--		

Figure A.15 Dataview of Nodes

A.1.2. Centroids and Centroid connectors

In TransCAD, Centroids and Centroid connectors are virtual nodes and links for trip generation or trip destination. Since these are not real network components, they create incorrect simulation results in DynusT. Therefore, Centroids and Centroid connectors be removed. The centroid and centroid connectors can be removed before exporting the network data. If not removed before exporting, the centroids and centroid connectors can be remove using Excel before importing or using NEXTA after importing. Explanation of the method used for the project follows. It is important to note that Centroid and Centroid connector data provide zone information and origin and destination link information that must be stored before the network elements are deleted.

In TRM2015, Centroids (TAZ) information can be founded in Nodes Dataview. TAZ 1~2389 are Centroids in TRM 2015. Set "node" as the active layer, then click "selection menu" and click the "select by condition" option. Next enter the condition "TAZ<=2389 as shown in Figure A.16. The selected nodes, the centroid nodes, change to red color as presented in Figure A.17.

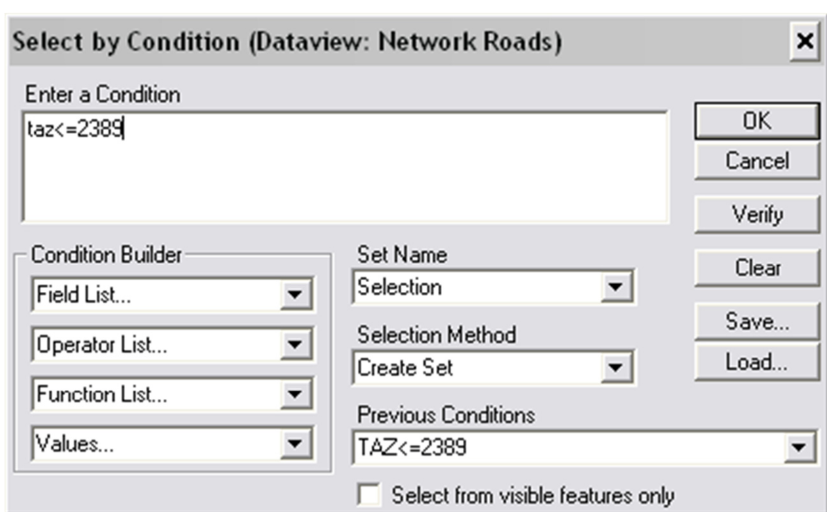


Figure A.16 Centroids Selection

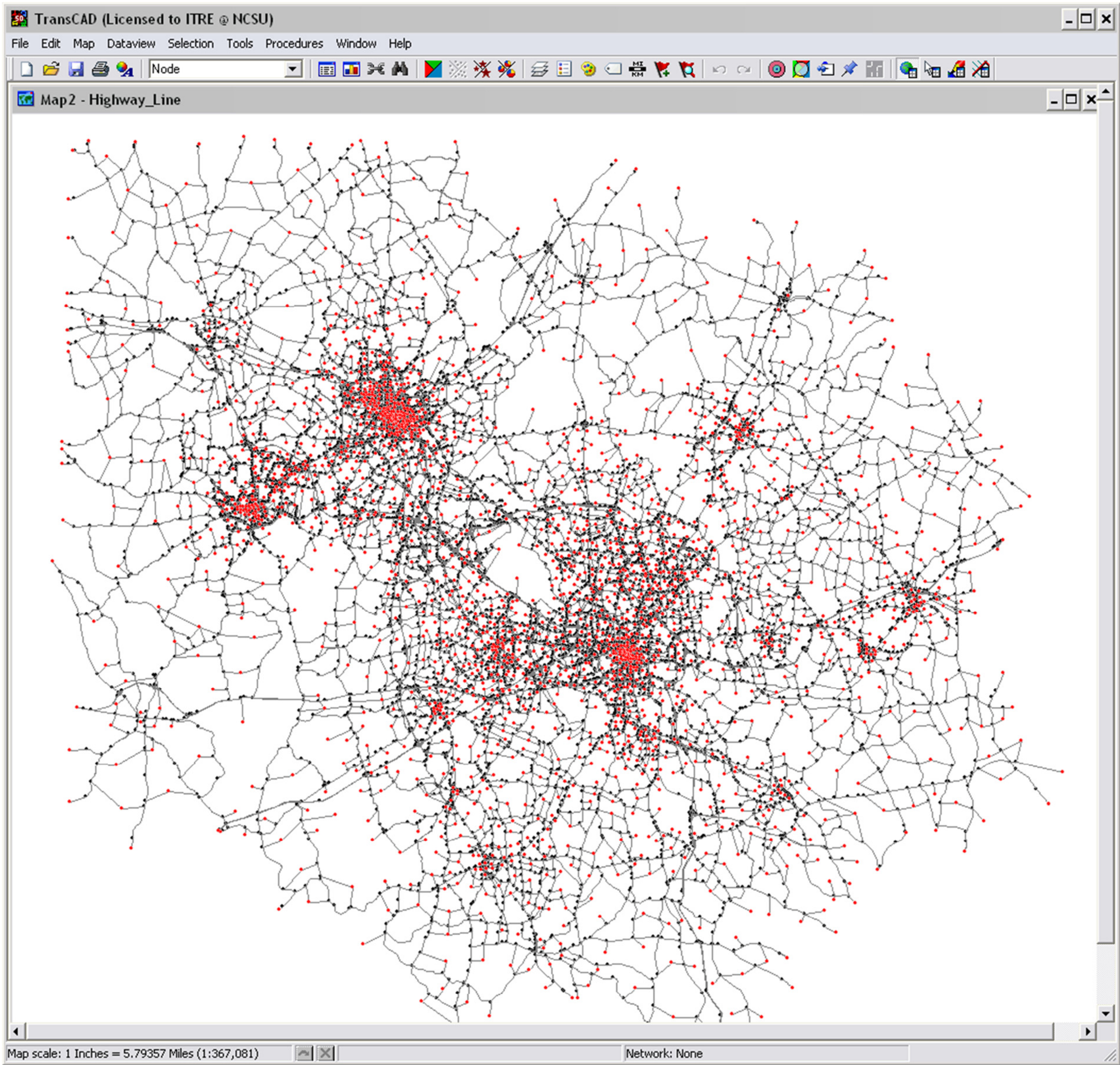


Figure A.17 Map Showing Centroids

In TRM2015, “Special” field value “31” for link represents Centroid connectors. Therefore, to select Centroid connectors, make “link” the active layer, then clicked “selection menu” and clicked “select by condition”, then entered the condition

“Special=31” as shown in Figure A.18. The selected links, the centroid connectors are shown in red color lines in Figure A.19.

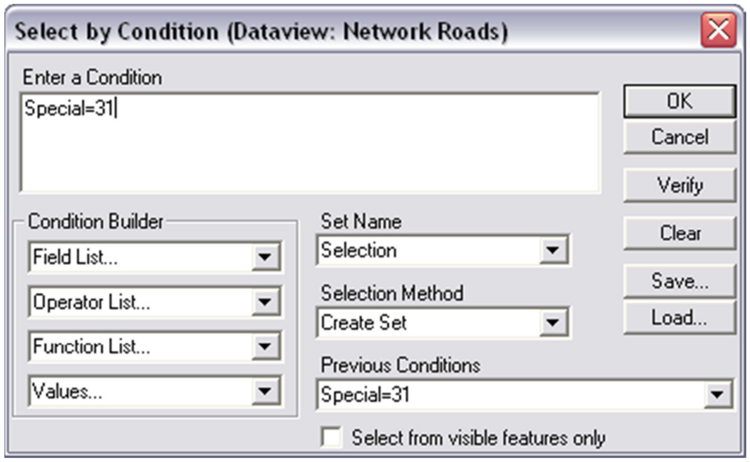


Figure A.18 Centroid Connectors Selection

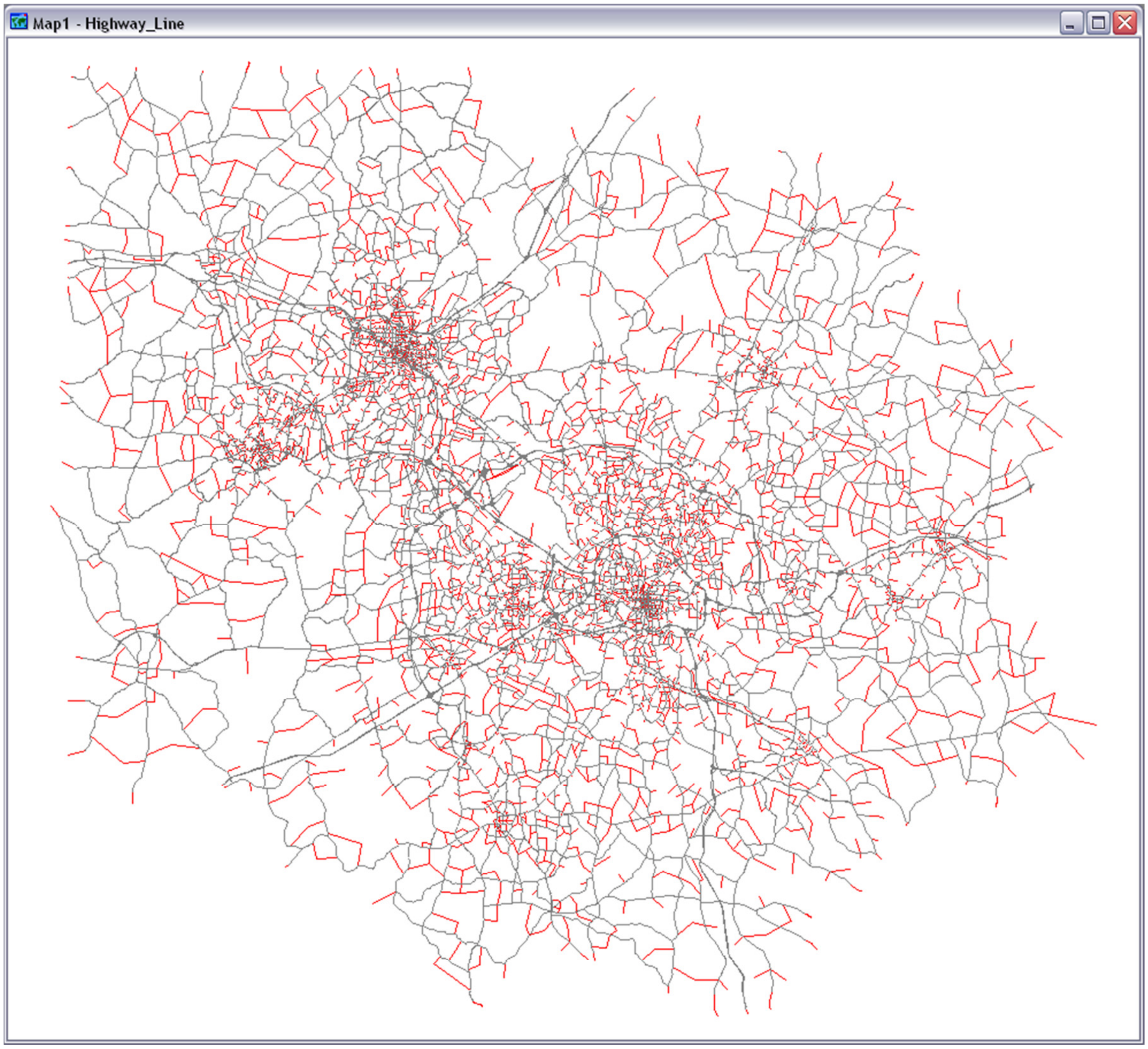


Figure A.19 Map Showing Centroid Connectors

Before removing these centroid connectors from network, to get destination node and generation link data for DynusT network, export the dataview for the selected links. As shown in Figure A.20, click dataview and chose selection as active dataset to display records only for the selected centroid connectors.

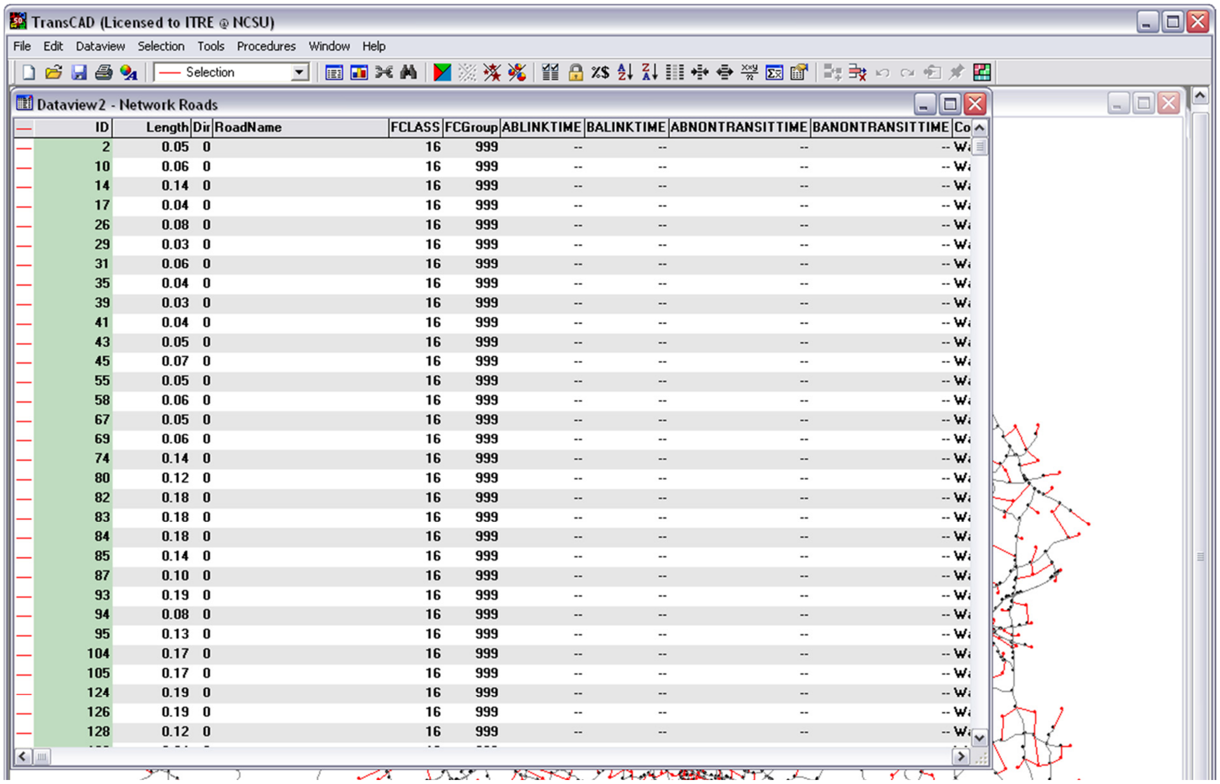


Figure A.20 Dataview for Centroid Connectors

The dataview does not contain “From node” and “To node” information for links. To bring this information into the dataview as shown in Figure A.22, click “Dataview” menu, then click “Formula Fields, then click “Node Fields”, and then select ID and mark the “both” option. These steps are shown in Figure A.21.

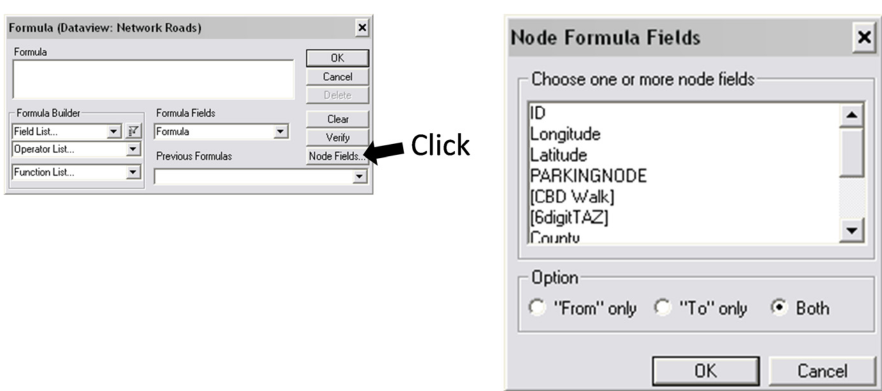
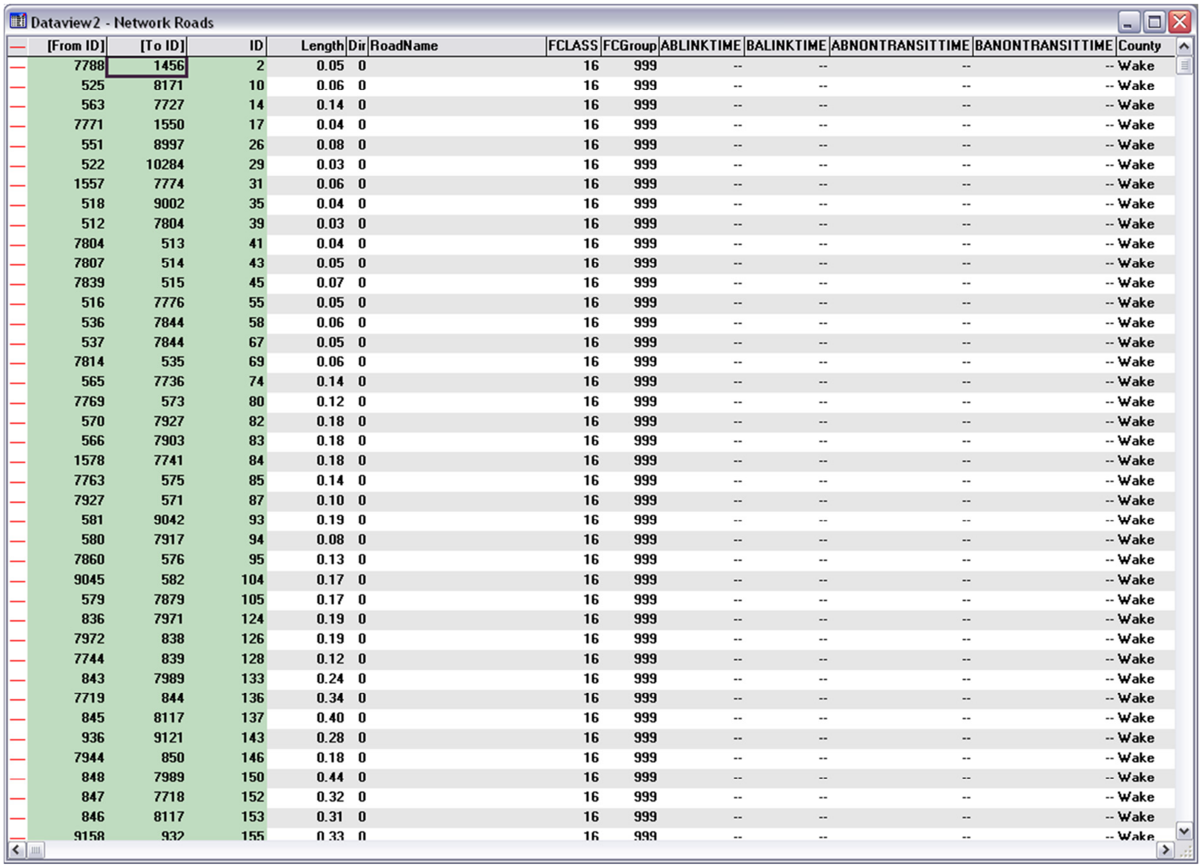


Figure A.21 Procedure to Get Node Information in Link Dataview



Dataview2 - Network Roads

[From ID]	[To ID]	ID	Length	Dir	RoadName	FCLASS	FCGroup	ABLINKTIME	BALINKTIME	ABNONTRANSITTIME	BANONTRANSITTIME	County
7788	1456	2	0.05	0		16	999	--	--	--	--	Wake
525	8171	10	0.06	0		16	999	--	--	--	--	Wake
563	7727	14	0.14	0		16	999	--	--	--	--	Wake
7771	1550	17	0.04	0		16	999	--	--	--	--	Wake
551	8997	26	0.08	0		16	999	--	--	--	--	Wake
522	10284	29	0.03	0		16	999	--	--	--	--	Wake
1557	7774	31	0.06	0		16	999	--	--	--	--	Wake
518	9002	35	0.04	0		16	999	--	--	--	--	Wake
512	7804	39	0.03	0		16	999	--	--	--	--	Wake
7804	513	41	0.04	0		16	999	--	--	--	--	Wake
7807	514	43	0.05	0		16	999	--	--	--	--	Wake
7839	515	45	0.07	0		16	999	--	--	--	--	Wake
516	7776	55	0.05	0		16	999	--	--	--	--	Wake
536	7844	58	0.06	0		16	999	--	--	--	--	Wake
537	7844	67	0.05	0		16	999	--	--	--	--	Wake
7814	535	69	0.06	0		16	999	--	--	--	--	Wake
565	7736	74	0.14	0		16	999	--	--	--	--	Wake
7769	573	80	0.12	0		16	999	--	--	--	--	Wake
570	7927	82	0.18	0		16	999	--	--	--	--	Wake
566	7903	83	0.18	0		16	999	--	--	--	--	Wake
1578	7741	84	0.18	0		16	999	--	--	--	--	Wake
7763	575	85	0.14	0		16	999	--	--	--	--	Wake
7927	571	87	0.10	0		16	999	--	--	--	--	Wake
581	9042	93	0.19	0		16	999	--	--	--	--	Wake
580	7917	94	0.08	0		16	999	--	--	--	--	Wake
7860	576	95	0.13	0		16	999	--	--	--	--	Wake
9045	582	104	0.17	0		16	999	--	--	--	--	Wake
579	7879	105	0.17	0		16	999	--	--	--	--	Wake
836	7971	124	0.19	0		16	999	--	--	--	--	Wake
7972	838	126	0.19	0		16	999	--	--	--	--	Wake
7744	839	128	0.12	0		16	999	--	--	--	--	Wake
843	7989	133	0.24	0		16	999	--	--	--	--	Wake
7719	844	136	0.34	0		16	999	--	--	--	--	Wake
845	8117	137	0.40	0		16	999	--	--	--	--	Wake
936	9121	143	0.28	0		16	999	--	--	--	--	Wake
7944	850	146	0.18	0		16	999	--	--	--	--	Wake
848	7989	150	0.44	0		16	999	--	--	--	--	Wake
847	7718	152	0.32	0		16	999	--	--	--	--	Wake
846	8117	153	0.31	0		16	999	--	--	--	--	Wake
9158	932	155	0.33	0		16	999	--	--	--	--	Wake

Figure A.22 Dataview for Centroid Connectors with FROM and TO Node Information

This table for centroid connector was used for filling the TAZ field of “Node” table (to specify destination nodes) and the TAZ field of “Link” table (to define origin links) in the DynusT import file. To export the dataview, click “File’ menu, then choose “Save as” option, enter the file name, and then save the file as a *.csv file as shown in Figure A.23.

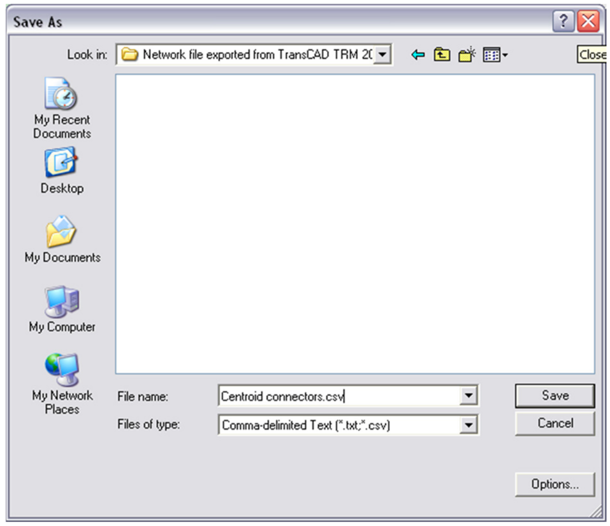


Figure A.23 Export Dataview for Centroid Connectors

To remove all the centroids and centroid connectors from the TransCAD map, select the "Edit" menu and click "delete set". After completing this step, the centroid nodes and centroid connectors are deleted as shown in Figure A.24.

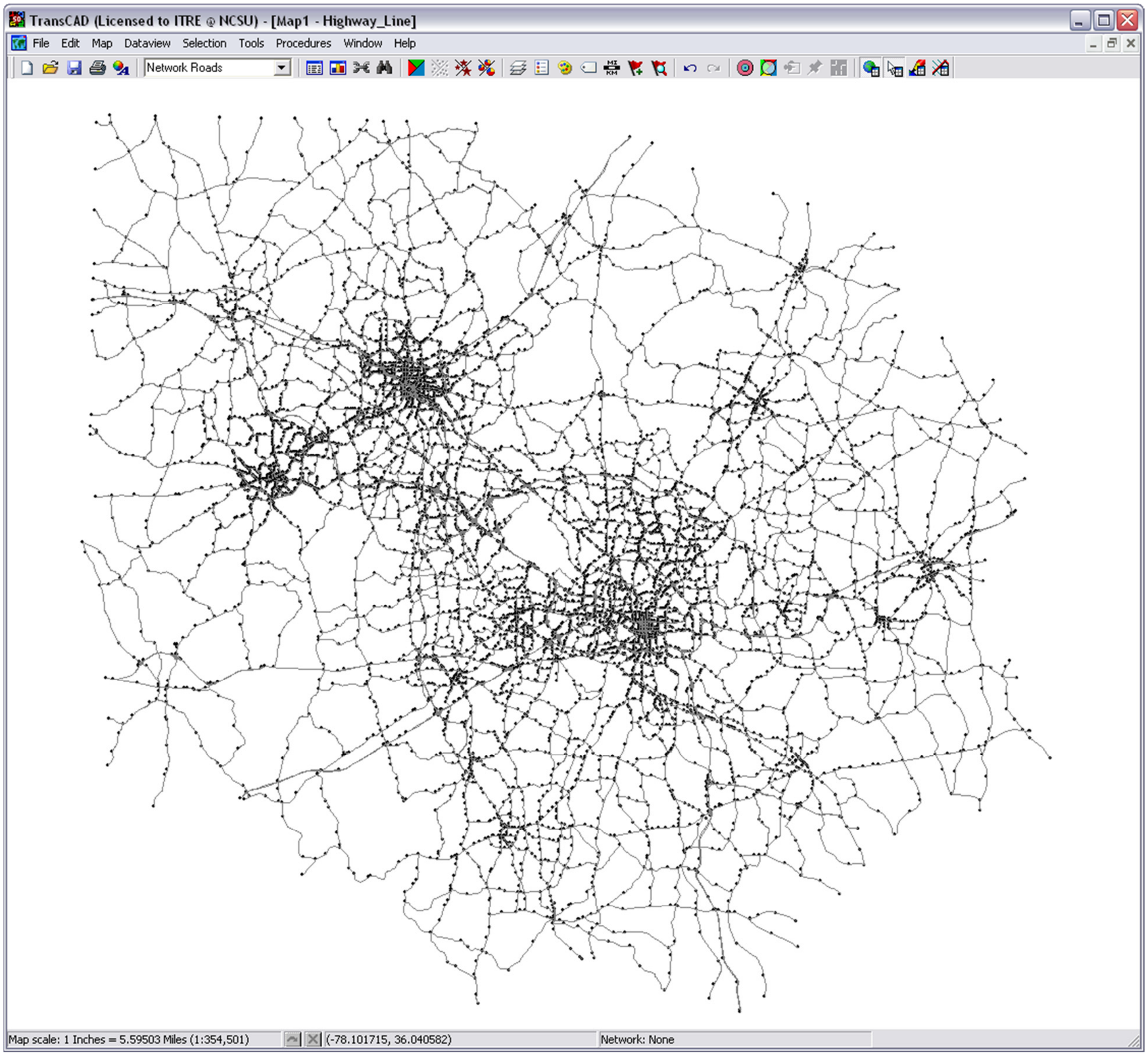


Figure A.24 Map after Removing Centroid and Centroid Connectors

A.1.3. Node data view and export

Opening the node dataview by making "node" the active layer and clicking "new dataview" button reveals all required data for DynusT import file except for "node control type". This information does not exist in the TRM 2015 TransCAD model. The solution used for the project involved setting "Actuated Signal Control" for all the arterial nodes and "No Control" for freeway links.

The "Signal density of links" field in the TRM 2015 TransCAD network can be a good indicator for node control type (Actuated Signal Control or No Control). To bring this information into the node dataview, add a new field into the node table and name it SignalDensity then fill the new field with following Tag option (using layer: Network, Tag with: SignDns) shown in Figure A.25.

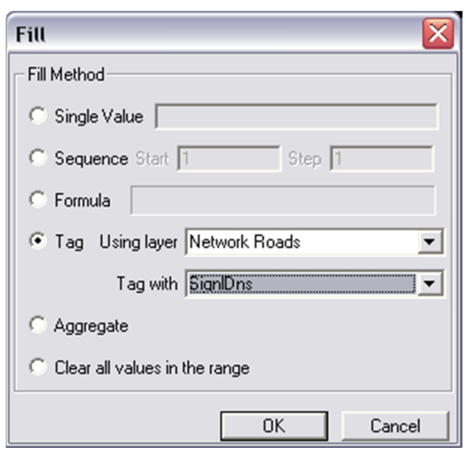


Figure A.25 Link Signal Density Information of Link Data to Node Data

As another clue, we brought "FClass (Facility class)" into the node dataview. The Tag option (using layer: Network, Tag with: FCLASS) shown in Figure A.26 was selected for filling the newly inserted FCLASS field in the node table view.

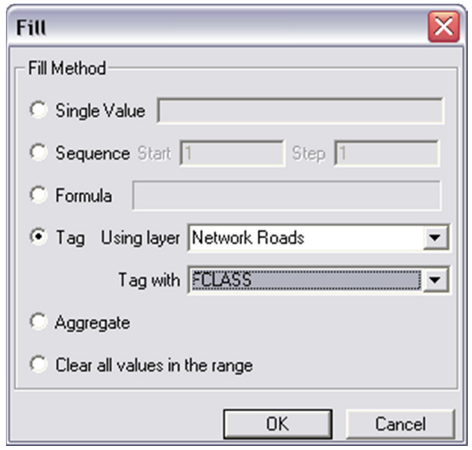
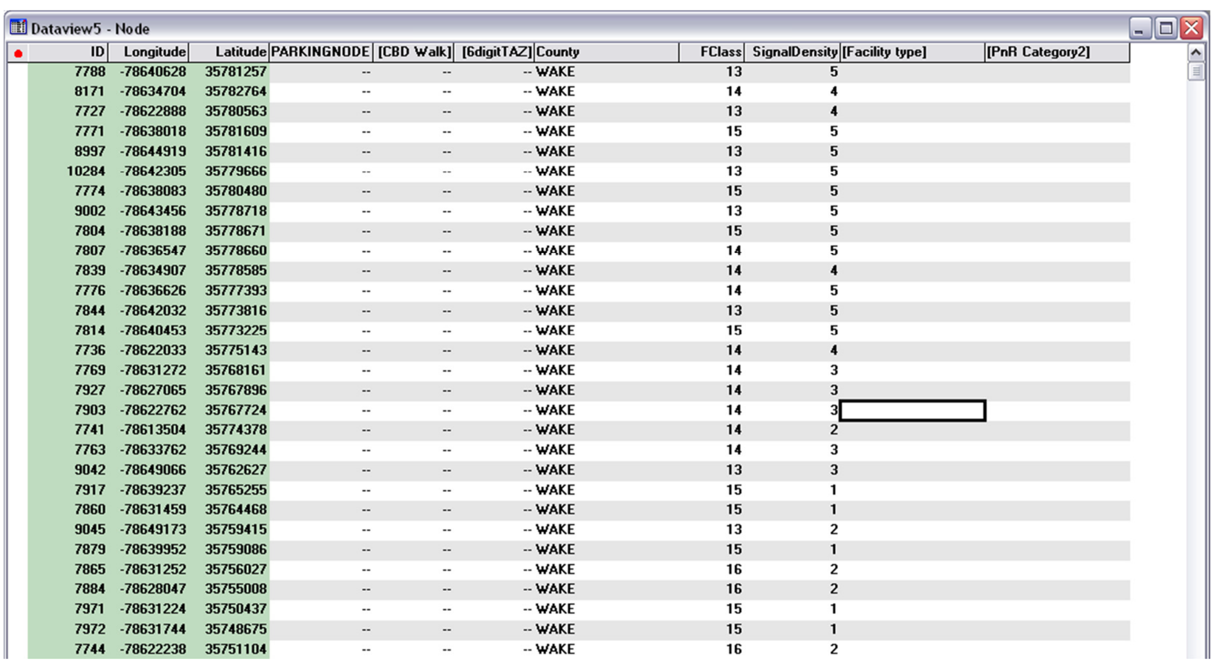


Figure A.26 Link Facility Class Information of Link Data to Node Data

With this new information in place a node table with Signal density and facility type information can be displayed as shown in Figure A.27. Table A.4 explains meanings of SignDns and FCLASS fields.


Dataview5 - Node

ID	Longitude	Latitude	PARKINGNODE	[CBD Walk]	[6digitTAZ]	County	FClass	SignalDensity	[Facility type]	[PnR Category2]
7788	-78640628	35781257	--	--	--	WAKE	13	5		
8171	-78634704	35782764	--	--	--	WAKE	14	4		
7727	-78622888	35780563	--	--	--	WAKE	13	4		
7771	-78638018	35781609	--	--	--	WAKE	15	5		
8997	-78644919	35781416	--	--	--	WAKE	13	5		
10284	-78642305	35779666	--	--	--	WAKE	13	5		
7774	-78638083	35780480	--	--	--	WAKE	15	5		
9002	-78643456	35778718	--	--	--	WAKE	13	5		
7804	-78638188	35778671	--	--	--	WAKE	15	5		
7807	-78636547	35778660	--	--	--	WAKE	14	5		
7839	-78634907	35778585	--	--	--	WAKE	14	4		
7776	-78636626	35777393	--	--	--	WAKE	14	5		
7844	-78642032	35773816	--	--	--	WAKE	13	5		
7814	-78640453	35773225	--	--	--	WAKE	15	5		
7736	-78622033	35775143	--	--	--	WAKE	14	4		
7769	-78631272	35768161	--	--	--	WAKE	14	3		
7927	-78627065	35767896	--	--	--	WAKE	14	3		
7903	-78622762	35767724	--	--	--	WAKE	14	3		
7741	-78613504	35774378	--	--	--	WAKE	14	2		
7763	-78633762	35769244	--	--	--	WAKE	14	3		
9042	-78649066	35762627	--	--	--	WAKE	13	3		
7917	-78639237	35765255	--	--	--	WAKE	15	1		
7860	-78631459	35764468	--	--	--	WAKE	15	1		
9045	-78649173	35759415	--	--	--	WAKE	13	2		
7879	-78639952	35759086	--	--	--	WAKE	15	1		
7865	-78631252	35756027	--	--	--	WAKE	16	2		
7884	-78628047	35755008	--	--	--	WAKE	16	2		
7971	-78631224	35750437	--	--	--	WAKE	15	1		
7972	-78631744	35748675	--	--	--	WAKE	15	1		
7744	-78622238	35751104	--	--	--	WAKE	16	2		

Figure A.27 Data View for Node Table with SignalDensity and FClass

Table A.4 Properties of SignDNS and FClass

SIGNLDNS	Per mile signal density	1 = Less than 2 signals per mile 2 = 2 – 3 signals per mile 3 = 4 – 6 signals per mile 4 = 5 – 7 signals per mile 5 = Greater than 7 signals per mile **99 = Signals irrelevant**
FCLASS	Functional Classification	**11 = Urban Interstate** **12 = Urban Freeway/Expressway** 13 = Urban Principal Arterial 14 = Urban Minor Arterial 15 = Urban Collector 16 = Urban Local/Unclassified/Centroid Connectors **21 = Rural Interstate** 22 = Rural Principal Arterial 23 = Rural Minor Arterial 24 = Rural Major Collector 25 = Rural Minor Collector 26 = Rural Local/Unclassified/Centroid Connectors 99 = Apply to Mode = 1, 4, 5, and external connectors

To export the dataview, we click “File’ menu, choose “Save as” option, define the file name, and then save the file as a *.csv file as shown in Figure A.28.

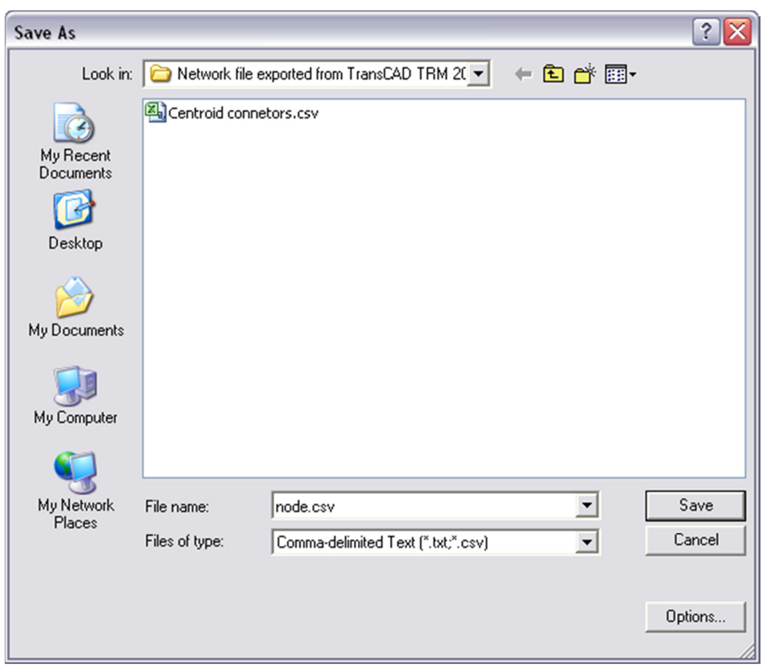


Figure A.28 Export Dataview for Nodes

A.1.4. Link data view and export

The dataview does not contain "From node" and "To node" information for link. To bring this information into the dataview as shown in Figure A.30, click the "Dataview" menu, then click "Formula Fields, then click "Node Fields", and finally select ID and mark the "both" option. These steps are shown in Figure A.29.

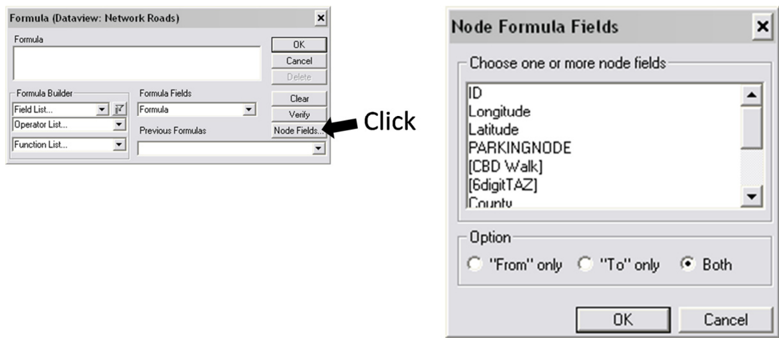
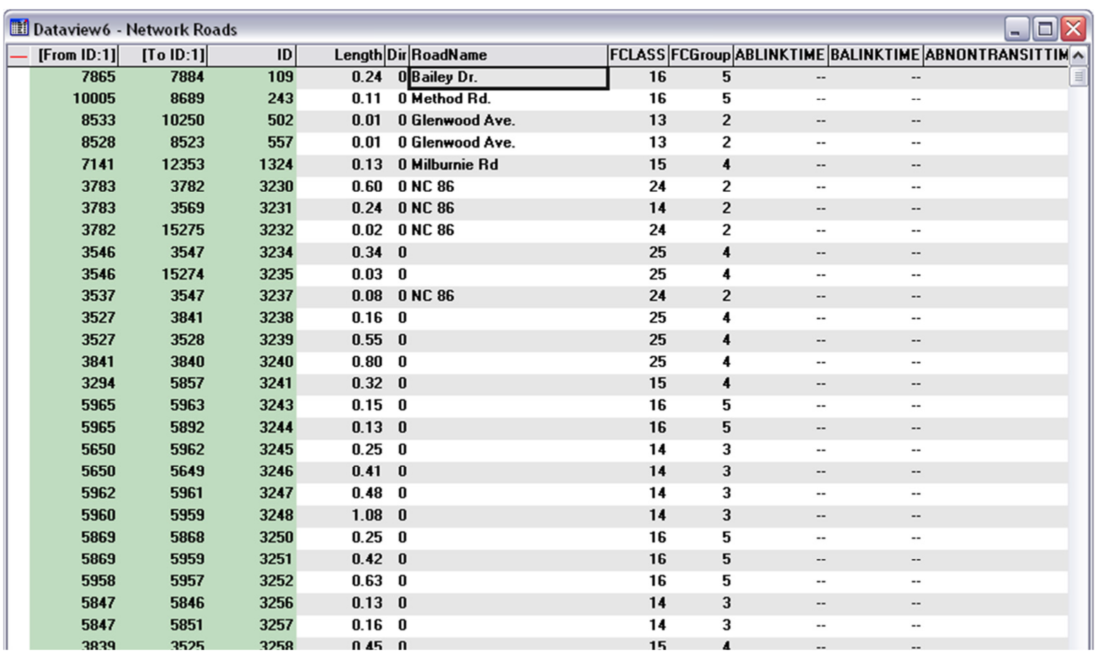


Figure A.29 Procedure to Get Node Information in Link Dataview



[From ID:1]	[To ID:1]	ID	Length	Dir	RoadName	FCLASS	FCGroup	ABLINKTIME	BALINKTIME	ABNONTRANSITTIM
7865	7884	109	0.24	0	Bailey Dr.	16	5	--	--	
10005	8689	243	0.11	0	Method Rd.	16	5	--	--	
8533	10250	502	0.01	0	Glenwood Ave.	13	2	--	--	
8528	8523	557	0.01	0	Glenwood Ave.	13	2	--	--	
7141	12353	1324	0.13	0	Milburnie Rd	15	4	--	--	
3783	3782	3230	0.60	0	NC 86	24	2	--	--	
3783	3569	3231	0.24	0	NC 86	14	2	--	--	
3782	15275	3232	0.02	0	NC 86	24	2	--	--	
3546	3547	3234	0.34	0		25	4	--	--	
3546	15274	3235	0.03	0		25	4	--	--	
3537	3547	3237	0.08	0	NC 86	24	2	--	--	
3527	3841	3238	0.16	0		25	4	--	--	
3527	3528	3239	0.55	0		25	4	--	--	
3841	3840	3240	0.80	0		25	4	--	--	
3294	5857	3241	0.32	0		15	4	--	--	
5965	5963	3243	0.15	0		16	5	--	--	
5965	5892	3244	0.13	0		16	5	--	--	
5650	5962	3245	0.25	0		14	3	--	--	
5650	5649	3246	0.41	0		14	3	--	--	
5962	5961	3247	0.48	0		14	3	--	--	
5960	5959	3248	1.08	0		14	3	--	--	
5869	5868	3250	0.25	0		16	5	--	--	
5869	5959	3251	0.42	0		16	5	--	--	
5958	5957	3252	0.63	0		16	5	--	--	
5847	5846	3256	0.13	0		14	3	--	--	
5847	5851	3257	0.16	0		14	3	--	--	
3839	3525	3258	0.45	0		15	4	--	--	

Figure A.30 Link Dataview

To export the dataview, click the "File' menu, then choose the "Save as" option, define the file name, and then save the file as a *.csv file as shown in Figure A.31.

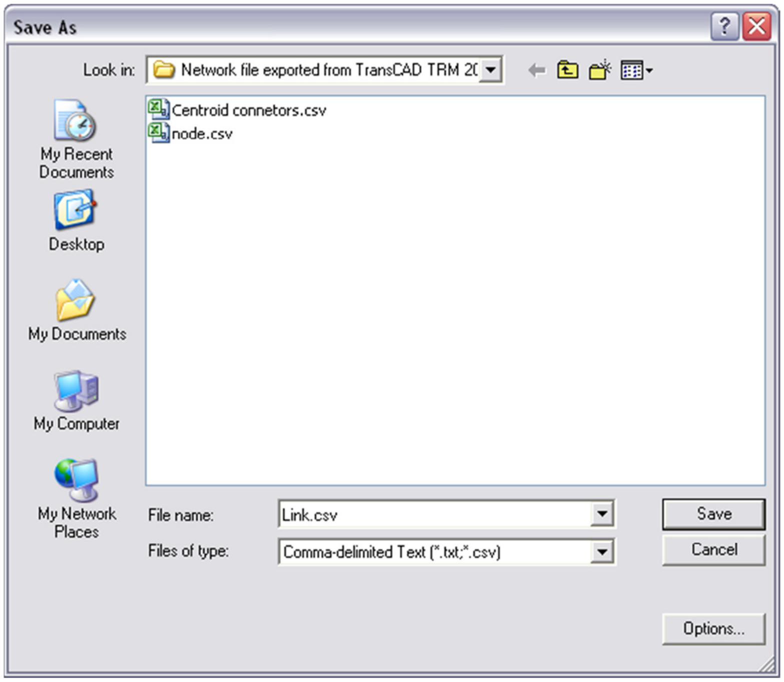


Figure A.31 Export Dataview for Link

A.1.5. Export OD matrix

The raw demand files available from the 2015 TRM TransCAD model have 9 separate OD tables: three time periods (AM Peak 4 hours, PM Peak 4 hours and Off Peak 16 hours) and each period of time has three vehicle types: SOV, Trucks and CVs. These original demand tables from TransCAD network must be edited for import formatting in a text editor. NEXTA is then used to develop the time dependent OD demand tables for DynusT. The multiplication factors for the time dependent OD demand within the AM and PM analysis periods are explained in Chapter 8.

As explanation of how to export a TransCAD demand matrix follows. First, open a matrix as shown Figure A.32. Figure A.33 shows a portion of the OD matrix for the TRM 2015 PM SOV trips.

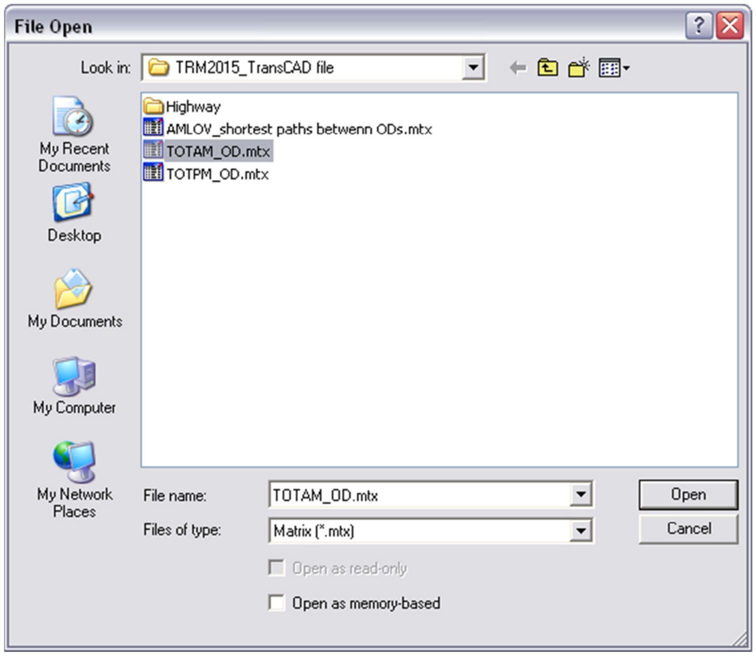


Figure A.32 Open Demand Matrix

Matrix1 - PMTrip (SOV)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.19	0.81	1.19	0.96	0.54	0.14	0.49	0.24	0.02	0.63	0.13	0.05	0.07
2	0.14	0.99	1.44	0.68	0.64	0.11	0.93	0.23	0.16	0.47	0.57	0.17	0.14
3	0.18	1.21	3.36	1.16	1.05	0.20	1.50	0.38	0.24	0.80	0.88	0.28	0.22
4	0.14	0.73	1.43	1.28	0.63	0.12	1.03	0.28	0.14	0.49	0.52	0.17	0.15
5	0.10	0.55	1.07	0.52	0.83	0.10	0.67	0.19	0.12	0.40	0.44	0.14	0.12
6	0.05	0.11	0.23	0.11	0.12	0.04	0.16	0.04	0.03	0.08	0.11	0.03	0.03
7	0.09	0.64	1.22	0.77	0.53	0.11	2.33	0.27	0.10	0.44	0.38	0.11	0.11
8	0.06	0.21	0.42	0.27	0.19	0.04	0.35	0.16	0.04	0.16	0.16	0.05	0.05
9	0.03	0.06	0.11	0.06	0.05	0.01	0.06	0.02	0.05	0.04	0.06	0.03	0.02
10	0.11	0.44	0.90	0.54	0.42	0.08	0.65	0.19	0.11	0.60	0.38	0.13	0.11
11	0.05	0.27	0.48	0.26	0.23	0.05	0.27	0.10	0.07	0.18	0.50	0.09	0.07
12	0.04	0.08	0.15	0.09	0.07	0.02	0.07	0.03	0.03	0.06	0.08	0.08	0.02
13	0.04	0.11	0.19	0.12	0.10	0.02	0.11	0.04	0.02	0.09	0.07	0.02	0.04
14	0.03	0.02	0.04	0.02	0.02	0.00	0.02	0.01	0.01	0.02	0.02	0.01	0.01
15	0.05	0.08	0.15	0.09	0.08	0.02	0.10	0.03	0.02	0.06	0.09	0.03	0.02
16	0.13	0.69	1.40	0.82	0.62	0.12	1.41	0.27	0.14	0.48	0.51	0.16	0.14
17	0.11	0.76	1.43	0.90	0.64	0.13	1.60	0.30	0.11	0.52	0.42	0.13	0.16
18	0.04	0.26	0.45	0.32	0.23	0.05	0.27	0.11	0.04	0.22	0.17	0.05	0.05
19	0.04	0.30	0.51	0.38	0.26	0.06	0.29	0.13	0.04	0.25	0.16	0.05	0.05
20	0.06	0.41	0.71	0.51	0.30	0.07	0.49	0.20	0.08	0.28	0.25	0.12	0.12
21	0.04	0.18	0.31	0.22	0.13	0.03	0.20	0.08	0.02	0.13	0.08	0.03	0.03
22	0.04	0.11	0.19	0.14	0.08	0.02	0.12	0.05	0.01	0.08	0.05	0.02	0.02
23	0.04	0.22	0.38	0.28	0.16	0.03	0.26	0.10	0.03	0.15	0.11	0.04	0.04
24	0.06	0.53	0.93	0.66	0.40	0.09	0.80	0.24	0.07	0.38	0.28	0.09	0.09
25	0.05	0.16	0.31	0.19	0.13	0.03	0.33	0.07	0.03	0.10	0.11	0.03	0.03
26	0.06	0.96	1.70	1.16	0.73	0.16	1.78	0.36	0.11	0.63	0.40	0.13	0.14
27	0.04	0.23	0.39	0.29	0.16	0.04	0.30	0.11	0.03	0.16	0.11	0.04	0.04
28	0.28	1.99	3.75	2.41	1.67	0.35	3.96	0.74	0.32	1.39	1.21	0.33	0.28
29	0.06	0.53	0.93	0.63	0.40	0.09	0.96	0.20	0.06	0.35	0.23	0.07	0.08
30	0.06	0.46	0.84	0.55	0.36	0.08	0.88	0.17	0.06	0.30	0.25	0.08	0.07
31	0.04	0.26	0.45	0.31	0.19	0.04	0.46	0.10	0.03	0.17	0.10	0.04	0.04
32	0.04	0.20	0.36	0.24	0.15	0.03	0.32	0.08	0.02	0.13	0.09	0.03	0.03
33	0.04	0.37	0.64	0.44	0.28	0.06	0.53	0.15	0.03	0.25	0.14	0.04	0.05
34	0.04	0.27	0.47	0.32	0.20	0.05	0.47	0.10	0.03	0.18	0.10	0.04	0.03
35	0.04	0.22	0.39	0.28	0.16	0.04	0.32	0.10	0.03	0.16	0.10	0.04	0.04
36	0.04	0.07	0.13	0.09	0.06	0.01	0.09	0.03	0.01	0.05	0.04	0.01	0.01
37	0.04	0.29	0.50	0.36	0.21	0.05	0.39	0.13	0.04	0.20	0.13	0.05	0.05

Figure A.33 Demand Matrix Example

To export the demand matrix, click “Matrix,” then “export.” Then select “Cell, with a field for each matrix”, select the relevant matrix, and click “OK” as shown in Figure A.34. Next, set up a file name and the *.csv file type as presented in Figure A.35. TransCAD exports the OD matrix as shown in Figure A.36.

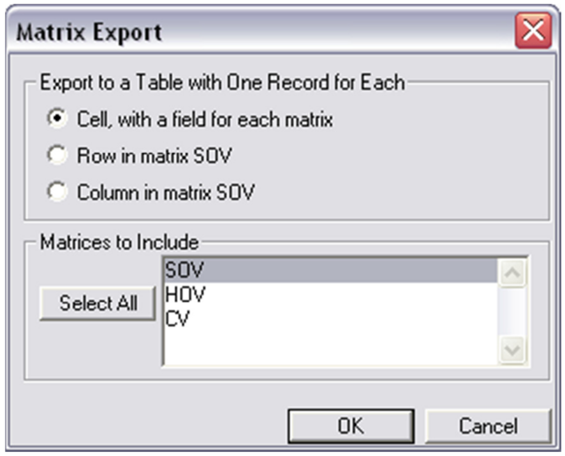


Figure A.34 Demand Matrix Export Procedure

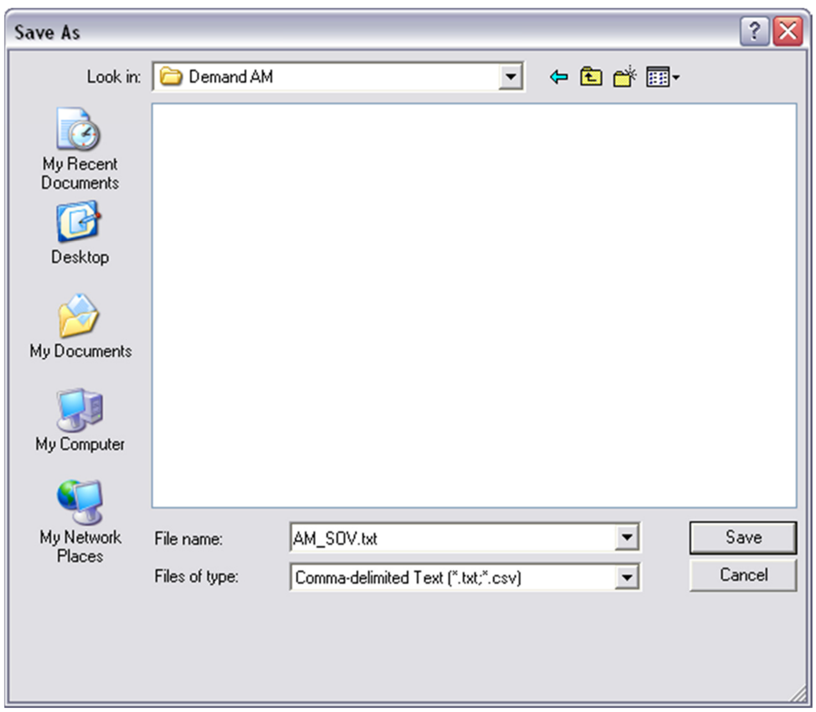
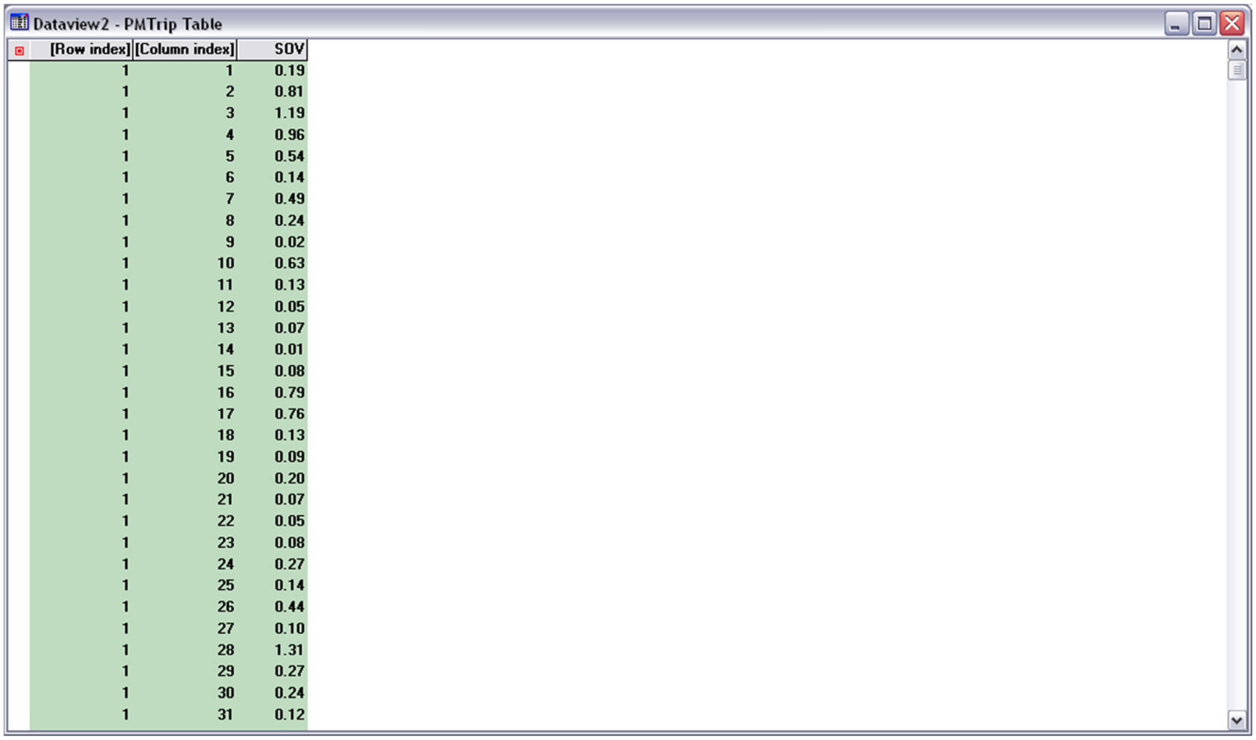


Figure A.35 Export Demand Matrix


Dataview2 - PMTrip Table

[Row index]	[Column index]	SOV
1	1	0.19
1	2	0.81
1	3	1.19
1	4	0.96
1	5	0.54
1	6	0.14
1	7	0.49
1	8	0.24
1	9	0.02
1	10	0.63
1	11	0.13
1	12	0.05
1	13	0.07
1	14	0.01
1	15	0.08
1	16	0.79
1	17	0.76
1	18	0.13
1	19	0.09
1	20	0.20
1	21	0.07
1	22	0.05
1	23	0.08
1	24	0.27
1	25	0.14
1	26	0.44
1	27	0.10
1	28	1.31
1	29	0.27
1	30	0.24
1	31	0.12

Figure A.36 Exported Demand Matrix

A.3 Editing the exported data to prepare an import file for DynusT network

The data files that were exported from TransCAD must be edited before importing into DynusT. Using the Excel template (GIS_network.xls) included in the DynusT installation directory and referring to the descriptions which were explained in section A.1, files can be developed for the DynusT importing process. Short descriptions for preparing some fields of the NODE and LINK worksheets follow.

A.1.6. Node

- CTRL_TYPE

1(no control): if signal density is 99, then no control.
5(Actuated signal control): Others (if signal density is not 99)

- TAZ

Step1. Open centroid connector.csv file
Step2. Leave “from node” and “to node” fields
Step3. Sort the table by ascending order (first: to node, second: from node)

Because “To node” values 1~2389 are Centroid nodes and represent zone numbers, the “From node(s)” of centroids indicate destination node(s) for the zone. For example, in Table A.5, Nodes 4739, 4819, and 4821 are Destination nodes for TAZ 1. Node 4743 is Destination node for TAZ 2. Therefore, the TAZ in node sheet can be filled based on this information. “VLOOKUP” function is useful for automatic fill in Excel.

Table A.5 Centroid Connectors-Destination Nodes

From node	To node
4739	1
4819	1
4821	1
4743	2
4742	3
4743	3
4786	3
4699	4
4821	4
…	…

A.1.7. Link

- Dir

We had to pay special attention to the "Dir" column which is the indicator for link direction, because in DynusT the code "1" designates the link as a one-directional link from the From_ID to the To_ID, while the code "0" will designate this segment as a bi-directional link. Lastly, a -1 will create a link in the opposite direction, from the To_ID to the From_ID. TransCAD also has similar coding mechanism to represent directional and bi-directional links, so users must be aware of the difference between them. It is also recommended that users avoid using bi-directional links, because correctly setting up the number of lanes is problematic with bi-directional links. Using directional links throughout the network development requires users to manually modify the bi-directional links in TransCAD into one-directional links. However, this step reduces the overall amount of effort and provides a network model that is easier to maintain. Specifically, coding one-direction links allows each link to have a unique of lanes.

- TAZ

Step1. Open centroid connector.csv file
Step2. Leave "from node" and "to node" fields
Step3. Sort the table by ascending order (first: to node, second: from node)
Step4. Switch "from node" and "to node" fields (because all connectors are two-way links)

Because "From node", 1~2389 are Centroid nodes and provide the zone number, the "To node(s)" of centroids indicate the "From node(s)" of origin link(s) for the zone. For example, in Table A.6, Nodes 4739, 4819, and 4821 are "From node(s)" of origin link(s) for TAZ 1. Node 4743 is "From node(s)" of origin link(s) for TAZ. Therefore, the TAZ in link sheet can be filled based on this information. The "VLOOKUP" function is useful for automatic fill in Excel.

Table A.6 Centroid Connectors-Origin Links

From node	To node
1	4739
1	4819
1	4821
2	4743
3	4742
3	4743
3	4786
4	4699
4	4821
…	…

- Length

The length that is exported from TransCAD is in miles so this must be converted to feet.

- Type

The classification coding for DynusT links is also different from that of TransCAD (See the Table A.7). Therefore, the user has to be careful to match the index accordingly when doing the conversion. If the link has a functional class of “interstate” or “freeway” then there should be a “1(Freeway)" placed in the “TYPE” column. If the functional class is “principal arterial” then a “7 (Highway)", should be placed in the “TYPE” column. For all other functional classes place a value of “5 (Arterial)".

Table A.7 Link Types in TRM and DynusT

TRM2015	DynusT
11 = Urban Interstate	1
12 = Urban Freeway/Expressway	1
13 = Urban Principal Arterial	7
14 = Urban Minor Arterial	5
15 = Urban Collector	5
16 = Urban Local/Unclassified/Centroid Connectors	5
21 = Rural Interstate	1
22 = Rural Principal Arterial	7
23 = Rural Minor Arterial	5
24 = Rural Major Collector	5
25 = Rural Minor Collector	5
26 = Rural Local/Unclassified/Centroid Connectors	5

A.4 Importing the network and modifying the DynusT network for fine tuning

A.1.8. Import

- Import the network table.

Step1. Click File-Import Files → Import GIS Data Set → Import Network Table.
Step2. Select the spreadsheet that contains the data for nodes, links, zones, and signals.

- Import the demand table.

Step1.Click File-Import Files → Import GIS Data Set → Import Demand Table
Step2. Select the demand files (SOV→demand, HOV→demand_HOV, CV→demand_truck)

A.1.9. Initial run

After finishing importing steps, it is necessary to run a simulation. System parameter settings for the initial run were:

- One-shot Simulation-Assignment
- Planning horizon: 400 Minute
- Other parameters: default values

A.1.10. Destination node error

The destination node error occurred in the initial run as shown in Figure A.37. The error message is like the follow:

```
Error in reading destination.dat
Each zone needs to have at least one dest
Please check zone          1
Error in reading destination.dat
Each zone needs to have at least one dest
Please check zone          8
```

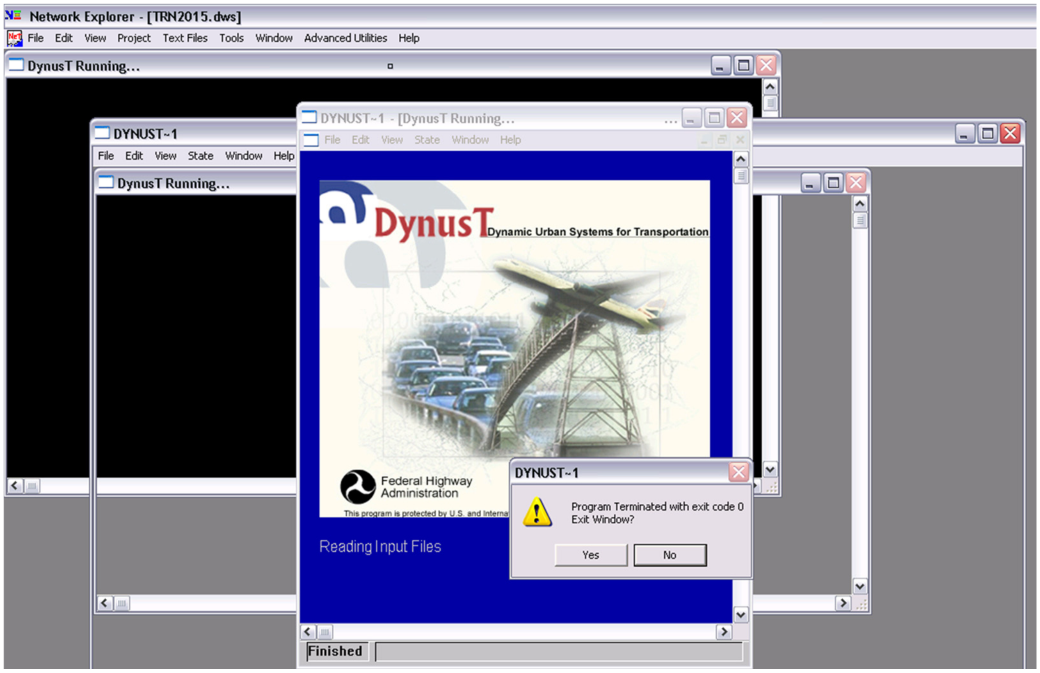


Figure A.37 DynusT Ends-Input Data Error

Setting up the network zone structure is relatively straightforward by following template and keeping in mind that if there are ODs from external stations, users have to manually create the external TAZs to accommodate the external ODs (otherwise DynusT would report the "destination node" error when executing the simulation.) Although DynusT does a decent job of automatically assigning generation links and destination nodes, inconsistencies do arise. In the project network creation, destination nodes were missing in some of the TAZs in DynusT network. To correct this issue, the team had to record the index of the TAZs with no destination nodes. The correction involved manually assigning destination nodes to make sure each TAZ has at least one destination node. This process can be extremely time consuming, requiring days of effort if there are many TAZs that need to be corrected. TAZs can be edited one by one in NEXTA by right clicking the zone and choose "Properties" (See Figure A.38).

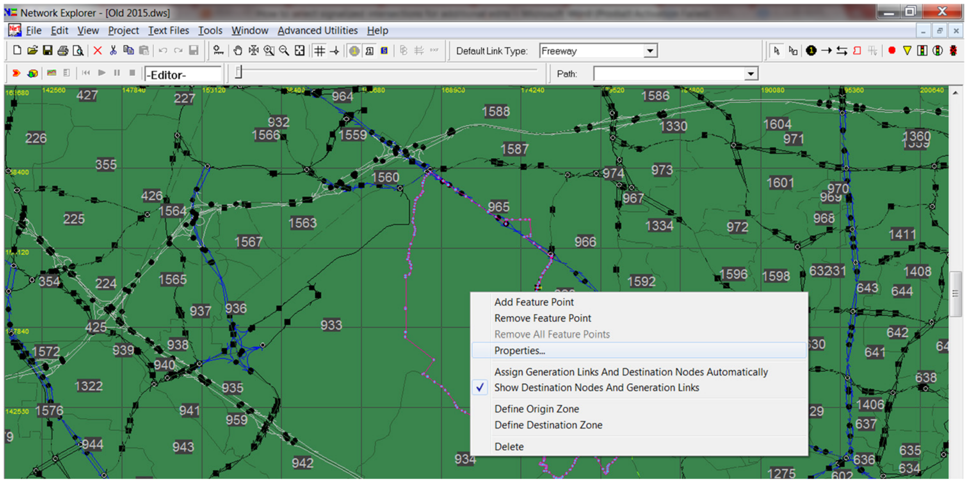


Figure A.38 Define Destination Nodes

A.1.11. origin link (generation link) error

Another common error after fixing the destination node error is Generation link error. The Error log is presented in Figure A.39. These erros can be fixed using same technique as fixing destination node errors. If the user is familiar with the DynusT input data file format and comfortable editing input files off line, the destination node errors and generation link errors can be fixed by editing “destination.dat” and “origin.dat file” directly rather than using the NEXTA interface.

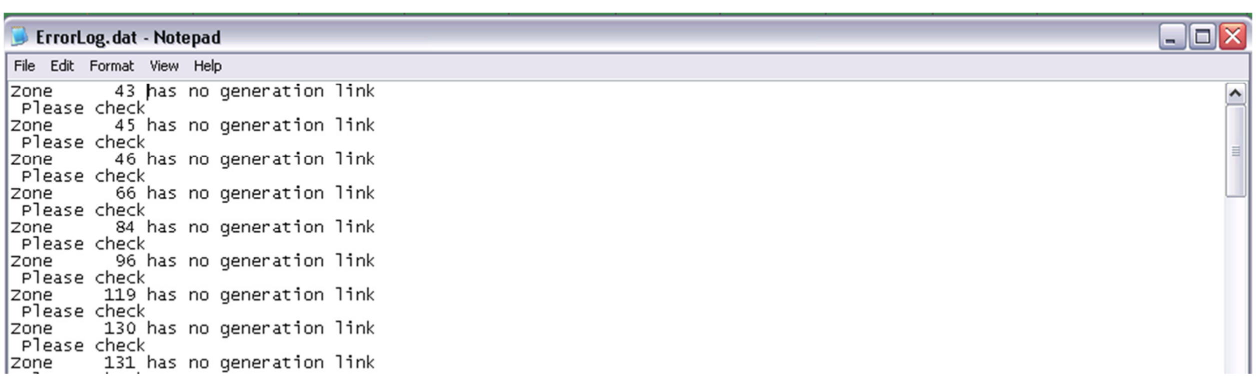


Figure A.39 Generation Link Error

A.1.12. Signal

Because regional networks like TRM2015 include hundreds of traffic signals, it is not practical to manually enter and set precise timings for every signalized intersection. A reasonable and realistic approach is to apply a "default" signal timing scheme to all the network signals and then modify the signal timing of critical intersections as necessary. The default phasing plan for signalized intersections created in the DynusT import process is depicted in Figure A.40.

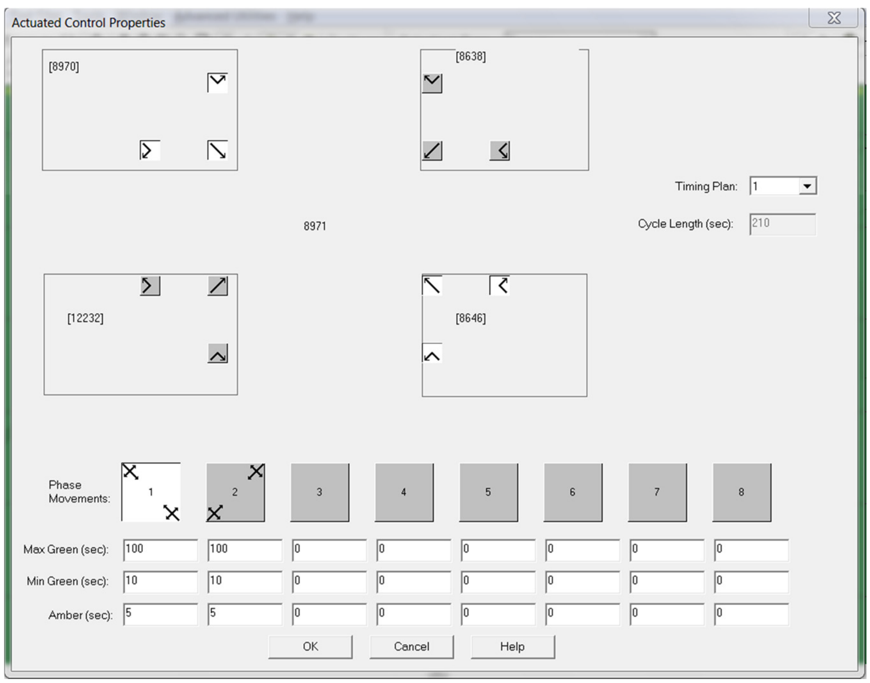


Figure A.40 Default Two-Phase Plan

While such two-phasing plans operate well in locations with light traffic, the permissive left turn movements in these simple plans cannot accommodate the interaction between significant left turn and through movements. Therefore, initial runs with these default signal control plans will result in signal failure at critical intersections in the DynusT simulation network. In order to deal with this issue, the critical signalized intersections must be identified and their phasing had to be manually improved as shown in Figure A.41 (the phases are led by protected left-turn movement)

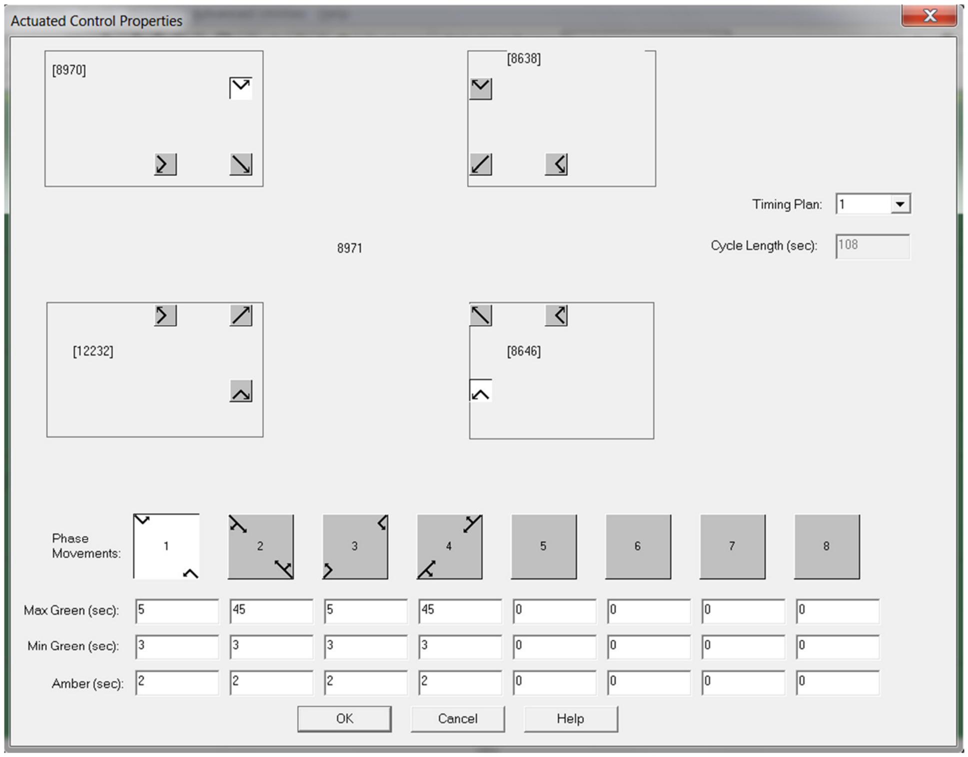


Figure A.41 Improved Four-phase Plan

For the project, critical intersections were identified based on link movement delay. After completing an initial DynusT simulation, the simulation results can be loaded into NEXTA, and turning movement performance can be viewed and sorted using the "Sort Movement Performance Data" feature from "Advanced Utilities" (See Figure A.42).

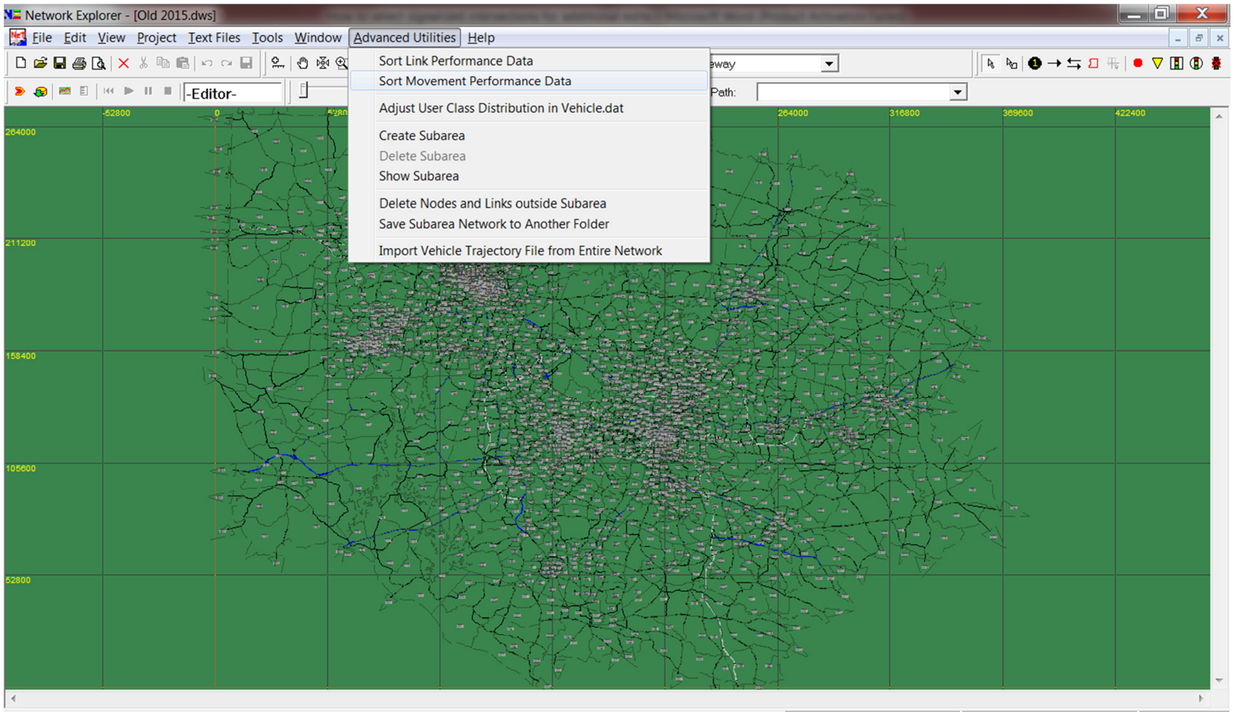


Figure A.42 Sort Movement Performance Data Feature

The “Delay” listed in Figure A.43 refers to the total delay experienced by all the vehicles. Therefore, in order to get the average delay per vehicle, the data must be exported as .*.csv files. The resulting files can then be opened in Excel and the total delay divided by the number of vehicles to produce average vehicle delay. Finally, the turning movements can then be sorted by average vehicle delay to identify the intersections with the worst performance. For the project, we set a delay threshold to define intersections that were critical in terms of requiring manual timing to accommodate heavy movement demand. This was for the project and will likely in general be an iterative process because of the redistribution of traffic as problematic intersections are recoded.

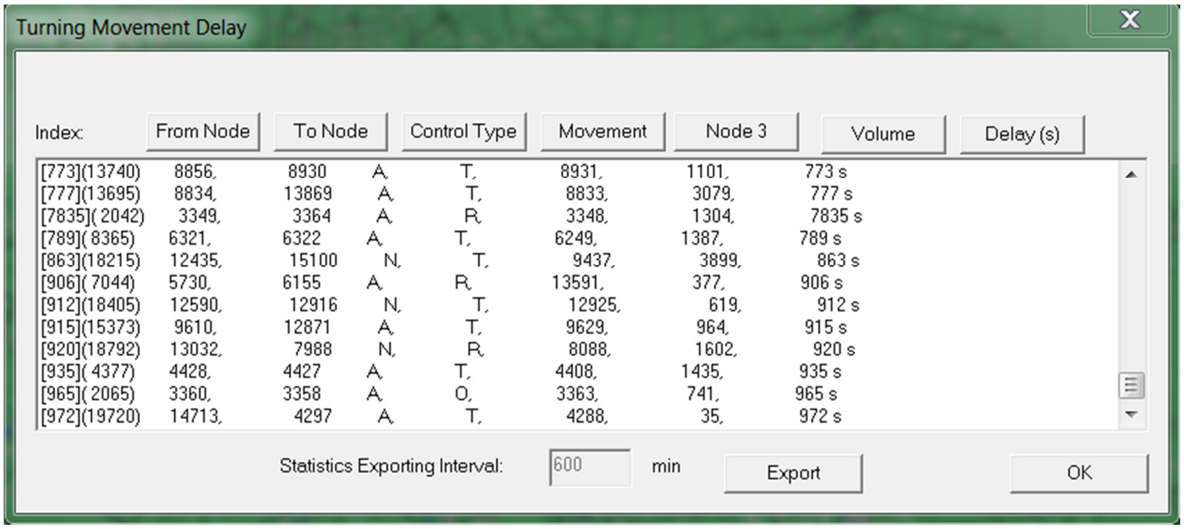


Figure A.43 Movement Performance Results

A.1.13. On/Off ramps

Ramp metering is one of the key operational strategies investigated under this project. In the current version of NEXTA/DynusT ramps to which ramp metering will be applied must be identified and specified individually and manually. This was one of more time consuming manual tasks that will hopefully be improved in future editions of the software.

APPENDIX B. SURVEY QUESTIONNAIRES

A.5 Short Call-Back Survey

Survey to be implemented by NCDOT Statewide Operations Center staff
At the end of their 511 call, ask potential respondents.

To help us improve the 511 service, are you willing to participate in a brief telephone survey, by answering 5 questions?

____ Yes….1 →Thank you for agreeing to participate in this brief survey. Please give us your name and telephone number, where we can contact you.

____No……2 →End

Hello, This is ___ (name) from the North Carolina Department of Transportation 511 service. You had agreed to participate in a brief telephone survey to help us improve the 511 service—will you kindly answer 5 brief questions?

- o....Yes……1 →Continue
- o....No……..2 →End

Q1. How often do you call 511?

- o Less than once a month.................................... 1
- o 2-3 times a month 2
- o 4-5 times a month (about once a week) 3
- o More than once a week...................................... 4
- o NOT SURE/ REFUSED 98

Q2. What information are you typically seeking when you call 511 (check all that apply)?

- o Traffic Updates, including traffic incidents and major closures 1
- o Road Construction and Planned Road Construction 2
- o Public transportation service information including interruptions, routes, fares, and schedules.. 3
- o OTHER (SPECIFY:______________) 4
- o NOT SURE/ REFUSED 98

Q3. How useful is the 511 information?

- Very Useful 1
- Somewhat Useful 2
- Not Useful 3
- Don't Know/Refused 98

Q4. Have you ever received information from 511 that has caused you to change your travel plans, e.g., take an alternate route or change time of departure?

- YES 1
- NO... 2
- NOT SURE/ REFUSED 98

Q5 (If yes to Q4, Ask)→**Did you**

- Divert to an alternate route 1
- Delayed time of departure or left earlier than planned 2
- Changed transportation mode, e.g., took the bus instead of your car.................. 3
- Make any other changes, such as changed destination or canceled trip (specify)__________________ 4
- NOT SURE/ REFUSED 98

THANK YOU VERY MUCH!

A.6 Detailed Survey

The North Carolina Department of Transportation (NCDOT) and Institute of Transportation Research and Education at North Carolina State University are studying ways to improve travel information and traffic congestion. We seek you help with improving the quality of traffic information. We are interested in your opinions about traveler information available through 511 in North Carolina. Your responses will be kept strictly confidential. The study is for research purposes only and we will not sell any of the information you provide. In filling out the survey, you are free to stop anywhere or refuse to answer any particular question.

Thank you for your willingness to complete the 511 survey. The survey will take about fifteen minutes. We will use your responses to evaluate and improve the functionality of the 511 North Carolina services.

1.0 NORTH CAROLINA 511 PHONE SERVICE

Please tell us about your awareness, access and satisfaction with the 511 service.

1. About how often do you call 511?

- Never used it……………………………………………….. 0 **→Go to Q 1.1**
- Less than once a month…………………………….... 1
- 2-3 times a month……………………………………2
- 4-5 times a month (about once a week)3
- More than once a week……………….…………….. 4
- NOT SURE/ REFUSED…………………….…………………..98

[1.1 Why do you not call 511? (if never used 511)

Not aware of 511 service………………………………………………… .1
Do not usually use telephone or internet for travel information………....2
Traffic information from 511 rarely covers the routes I take…………..… 3
No alternate routes available to me……………………………………......4
511 information is not useful to me………………………………….. ...5
I cannot understand the traffic information available on 511……….. 6
OTHER (SPECIFY:______________) …………………….…………….…7
NOT SURE/ REFUSED .... …….………..98]

2. Which of the following types of 511 information have you used in the past (check all that apply)?

- o Traffic Updates, including traffic incidents and major closures 1
- o Road Construction and Planned Road Construction 2
- o Public transportation service information including interruptions, routes, fares, and schedules 3
- o OTHER (SPECIFY:_______________) 4
- o NOT SURE/ REFUSED 98

3. How satisfied are you with the 511 service? Please use the scale below, where 1 means you are "very dissatisfied" and 5 means you are "very satisfied."

Are you satisfied with:	**VERY** **<u>DISSATISFIED</u>**			**VERY** **<u>SATISFIED</u>**	NS/ REF
o How convenient it is to use	1	2	3	4	98
o How easy it is to use	1	2	3	4	98
o How fast you can get information	1	2	3	4	98
o How accurate the information is	1	2	3	4	98
o How specific the information is	1	2	3	4	98
o Having information available when you need it	1	2	3	4	98
o How complete the information is	1	2	3	4	98
o How up-to-the-minute the information is	1	2	3	4	98
o How understandable the information is	1	2	3	4	98
o Number of routes covered..	1	2	3	4	98
o Coverage of specific routes relevant to your trip	1	2	3	4	98
o The overall quality of 511?	1	2	4	5	98

2.0 TRAVEL CONTEXT

Please tell us about your typical travel habits.

1. In a typical week how often do you:

	0	<1	1	2	3	4	5+
(i) Drive alone to work by car	0	.5	1	2	3	4	5
(ii) Go to work in a carpool (as a passenger or driver)	0	.5	1	2	3	4	5
(iii) Go to work using public transportation (bus)	0	.5	1	2	3	4	5
(iv) Travel for work-related purposes (e.g., meetings)	0	.5	1	2	3	4	5
(v) Go grocery shopping	0	.5	1	2	3	4	5
(vi) Shop for other items	0	.5	1	2	3	4	5
(vii) Run personal errands (doctor's visit, bank)	0	.5	1	2	3	4	5
(viii) Drop-off/pick-up children	0	.5	1	2	3	4	5
(ix) Go out for pleasure (sports, movies, visit family)	0	.5	1	2	3	4	5
(x) Make other trips (Please specify)________________	0	.5	1	2	3	4	5

2. If you work, then excluding intermediate stops, how long does your usual route normally take from:

- home to work________(Minutes)
- work to home______(Minutes)

3.0 UNEXPECTED TRAFFIC DELAYS

Please tell us about your most recent unexpected delay experience.

1. Within the past month, did you ever become aware of unexpected congestion during your trip?

- Yes….1 →please tell us about your **most recent** experience by answering the following questions
- No…...2 →please skip this section

2. How did you first learn about the unexpected congestion? ***(please select one)***

- 511 Telephone…………………………………………………………………. 1
- Dynamic Message Signs……………………………………………………….. 2
- Commercial radio traffic reports……………………………………………… 3
- Direct observation of congestion……………………………………………… 4
- Internet website (specify, if NCDOT website or other source)_________............. 5
- Other means (specify)______... 6
- NOT SURE/ REFUSED………………………………………………………98

3. What was the cause of this unexpected congestion?

- o Disabled vehicle …………………………………………………………..1
- o Accident…………………………………………………………………... 2
- o Construction/road work …………………………………………………. 3
- o Bad weather……………………………………….……………………… 4
- o Other (please specify)_____________…………………………………... 5
- o NOT SURE/ REFUSED………………………………………………… 98

4. What was the main purpose of your trip?

(i) Drive alone to work by car ……………………………………………1
(ii) Go to work in a carpool (as a passenger or driver) ……………..………2
(iii) Go to work using public transportation (bus) ……………………..……3
(iv) Travel for work-related purposes (e.g., meetings) ……………………..4
(v) Go grocery shopping ……………………………………………………5
(vi) Shop for other items …………………………………………………....6
(vii) Run personal errands (doctor's visit, bank) ……………………………7
(viii) Drop-off/pick-up children ……………………..………………………8
(ix) Go out for pleasure (sports, movies, visit family) ……..……………… 9
(x) Make other trips (Please specify)_________ ………………………...10

- o NOT SURE/ REFUSED………………………………………………….. 98

5. How much time did you expect it to add to your trip?

- o Less than 5 minutes………………………………. 1
- o 5-10 minutes …………………………………….. 2
- o 11-15 minutes…………………………………….. 3
- o 16-20 minutes…………………………………… 4
- o 21-25 minutes…………………………………….. 5
- o 26-30 minutes…………………………………….. 6
- o 31-45 minutes…………………………………….. 7
- o 45-60 minutes…………………………………….. 8
- o More than 60 minutes…………………………… 9
- o NOT SURE/ REFUSED………………………… 98

6. What did you do in response to the unexpected congestion? *(check all that apply)*

- o Exited the road and got back on the same road at a different location…………… 1
- o Exited the road and continued all the way to destination on alternate route……... 2
- o Abandoned journey and returned to origin/home……………………………………………………………………..3
- o Added unintended intermediate stops, e.g., to run errands………………………………………………………………………… 4
- o Cancelled intended intermediate stop(s)……………………………………………………………………….. 5
- o Stayed on the road and waited it out……………………………………………………………………………… 6
- o NOT SURE/ REFUSED…………………………………………………………………… 98

4.0 SOCIO-DEMOGRAPHICS

For statistical purposes only, please tell us about yourself.

1. What is the zipcode of city/town (or county) of your primary residence?
______________(zipcode)

2. How long have you lived at this address? _______years.

3. How many motorized vehicles (cars, vans, trucks, two wheelers) does your household have? _______________(Number of vehicles)

4. Do you have a valid driving license?

o YES 1
o NO.. 2

5. Which of the following categories includes your age?

- o 18 to 24...............1
- o 25 to 34...............2
- o 35 to 44...............3
- o 45 to 54...............4
- o 55 to 64...............5
- o 65 or older 6

6. What ethnic or racial group are you a member of?

- O WHITE 1
- O BLACK/AFRICAN-AMERICAN ..2
- O ASIAN/ASIAN-AMERICAN.........3
- O HISPANIC/LATINO 4
- O NATIVE AMERICAN....................5
- O MIXED RACE 6
- O OTHER (SPECIFY:).......................7
- O NOT SURE/ REFUSED................98

7. Are you:
- MALE 1
- FEMALE.............2

8. What is your occupation?
- Professional, Technical…………………………………………… 1
- Executive, Administrative, or Managerial………..…................... 2
- Sales………………………………………………………………3
- Administrative Support, including Clerical……………………… 4
- Precision Production, Craft, and Repair …………………………. 5
- Machine Operators, Assemblers, and Inspectors…………………6
- Transportation and Material Moving ……………………………..7
- Handlers, Equipment Cleaners, Helpers, and Laborers………….. 8
- Service…………………………………………………………… .9
- Other (specify)_______... 97

9. Which one of the following categories includes your total personal income before taxes last year? (Include your own income and but NOT that of any member of your immediate family who is living with you.)
- Less than $20,000......01
- $20,000 to $29,999 02
- $30,000 to $39,999 03
- $40,000 to $49,999 04
- $50,000 to $59,999 05
- $60,000 to $69,999 06
- $70,000 to $79,999 07
- $80,000 to $99,999 08
- $100,000 or more 09
- NOT SURE/ REFUSED98

10. Comments (optional)______________________________

Thank you very much!

APPENDIX C. HARDWARE REQUIREMENTS/RECOMMENDATIONS AND COMPUTATION TIME ESTIMATES

The simulation time of TRM 2015 network really depends upon the particular hardware being used. Generally, a 64-bit Windows (XP or 7; Vista is not supported) computer with at least 8GB RAM is required. In order to achieve a reasonable simulation time, two to four parallel processors and 12 GB RAM are recommended. The configuration of the workstation used in this project is listed as follows:

- System: Microsoft Windows XP Professional ×64 Edition, Version 2003, Service Pack 2
- Hardware:
  - Processors: 4×Inter(R) Xeon(R) CPU E5530 @ 2.40GHz
  - RAM: 12.0 GB

Since the traffic demand levels are different for the AM and PM periods, the simulation time of TRM 2015 network on above workstation varies for the AM and PM periods. Run times experience for the project are summarized as follows:

- Simulation time for AM period:
  - One shot simulation: 10 minutes
  - User equilibrium: 1 hour per iteration
- Simulation time for PM period:
  - One shot simulation: 15 minutes
  - User equilibrium: 1.6 hours per iteration

APPENDIX D. PROJECT WORKSHOP AGENDA AND PRESENTATIONS

A.7 Day 1 Agenda

The Day 1 Session held on January 18, 2011 was a half-day session scheduled for 2:00 p.m. to 4:30 p.m. The session was designed as a management summary for the project steering and implementation committee and interested NCDOT and Triangle Region planning managers. The agenda for the half-day session included the following topics –

- Basic definitions of models and modeling approaches
- Overview of network baseline generation and calibration
- Framework for analysis and scenario description
- Results: Benefits of implementing improvements using scenario analysis on I-40
- System requirements for running the TRM network in the mesoscopic modeling environment
- Model future outlook and overview of relevant needed research

A.8 Day 1 Presentation

The Day 1 PowerPoint presentation is provided on the following pages in two-slide per page handout format.

Assessing Operational, Pricing, and Intelligent Transportation System Strategies for the I-40 Corridor Using DYNASMART-P

PROJECT NO. HWY-2009-05

Workshop Session 1 –
Management Summary

January 18, 2011

Outline of Coverage

- Basic definitions of models and modeling approaches
- Overview of network baseline generation and calibration
- Framework for analysis and scenario description
- Results: Benefits of implementing improvements using scenario analysis on I-40
- System requirements for running the TRM network in the mesoscopic modeling environment
- Model future outlook and overview of relevant needed research

DynusT and DYNASMART-P: An Overview

- <u>What do the two models have in common?</u>
  - Both rooted in the original DYNASMART meso-scopic modeling environment
  - Both contain network traffic models, dynamic traffic assignment (DTA) features and same user interface (NEXTA)
  - Both have the capability to model multiple user classes
- <u>How do the two models differ?</u>
  - DynusT has ongoing FHWA support
  - DynusT is moving to public domain status (free software)
  - The traffic flow models are different (next slide)

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Mesoscopic Modeling

- <u>Meso framework considers *individual* vehicle entities</u>
  - Route decisions are made at the vehicle level
  - MOE's collected as vehicles traverse various links
  - Enables dynamic traffic assignment and consideration of multiple user classes
- <u>Meso framework does not model vehicle interaction</u>
  - Vehicles move through network based on macroscopic flow principles on each link – that can be calibrated
  - Enables scalability to large networks
  - DynusT used modified "anisotropic" flow model that provides greater fidelity and realism of vehicle motion

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Dynamic Traffic Assignment

- A method to predict/estimate how trip-makers may shift to other routes in response to –
  - Recurring and non-recurring congestion
  - Pricing
  - Traffic Controls
  - Geometric, design and operational improvements
- Enables an understanding of how individual travel decisions impact an entire region, by
  - Time of day
  - Origin-Destination (OD) zone
  - Transportation mode

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User Classes Defined

- Rationale for having multiple user classes
- User Classes in Dynus-T
  - *User Class 1* – Habitual traveler
    - Respond only to *mandatory* detours
  - *User Class 2* – System Optimal (SO)
    - Optimize system travel time
  - *User Class 3* – User Equilibrium (UE)
    - Optimize individual travel times
  - *User Class 4* – En-route Info (Boundedly Rational Behavior)
    - Update path at each intersection based on prevailing shortest path tree
  - *User Class 5* – Pre-Trip
    - Responds to pre-trip information
- All user classes except User Class 1 respond to Variable Message Signs

MUC Distribution

		1: Habitual	2: System Optimal	3: User Equilibrium	4: En-route Info	5: Pre-trip Info	Totals
Passenger Car		10	10	60	10	10	100
Truck	☑ Same as PC	0	0	0	0	0	0
HOV	☑ Same as PC	0	0	0	0	0	0

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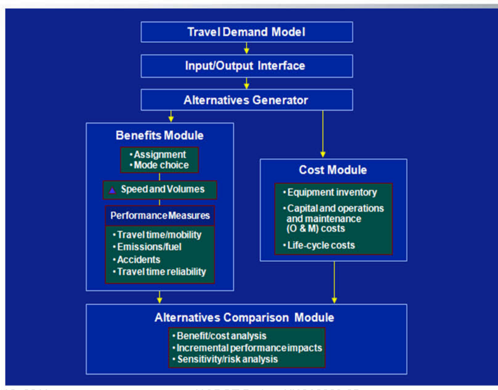
An alternative approach: IDAS



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DynusT Compared to IDAS VMS Effects

- **DynusT**
  - For User Class 5, vehicles switch to current shortest path when they pass VMS signs
  - MOEs based on actual vehicle paths considering this DTA effect
- **IDAS**
  - No reassignment done for VMS scenarios
  - Travel time savings is computed by simple expression:

    Travel time savings (person–hours)=
    [Traffic volume in DMS-equipped link] × [percent time sign is turned on] ×
    [percent vehicles passing sign that save time] ×
    [average amount of time savings in hours]
  - Savings calculated as a rough estimate based on number of vehicles passing VMS signs and pre-determined values for percent vehicles saving time and average time savings

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DynusT Compared to IDAS Ramp Metering Effects

- **DynusT**
  - Time varying metering rate in fixed or traffic responsive logic
  - Full mesoscopic, DTA, user-class modeling completed with ramp meters in place
  - MOEs based on actual paths considering this DTA effect
- **IDAS**
  - Effect captured by *increasing* freeway link capacity and lowering metered ramp capacity
  - Modified capacity modifies BPR speed function
  - Traffic assignment rerun with new BPR functions for freeway and ramp
  - Assumes static capacity effect for metering logic chosen

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Baseline Scenario Creation and Calibration (6-Step Process)

- Step 1 – Create network link and zone input structure from travel demand network model
- Step 2 – Create O/D input files from travel demand model
- Step 3 – Check for network connectivity errors
  - Problems arise from –
    - Non-standard ramp systems
    - Skewed intersections
  - Team recommends one-shot simulation with fraction of analysis OD
  - Abnormally high densities under these conditions may indicate correctible connectivity errors

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Baseline Creation and Calibration (cont.)

- Step 4 – Make necessary signal control adjustments
  - Signal control defaults to two-phased actuated control
  - Another one-shot simulation with network connectivity errors corrected and a low flow demand table will help isolate problem intersections
- Step 5 – Calibrate freeway models.
  - Where available, collect freeway data
  - Fit an appropriate model or models
- Step 6 – Validate link flows
  - This can be a “calibration” step, usually with O/D table adjustment to match link flows
  - For Triangle region, soft validation was done using links not expected to change significantly before 2015

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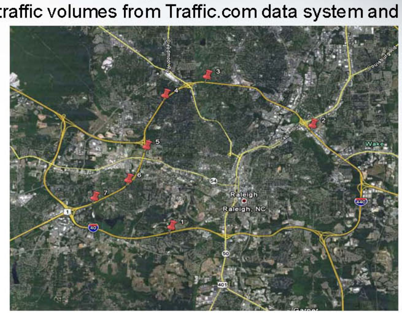
Baseline Creation and Calibration (cont.)

Soft Validation:

- Seven representative freeway links in 2005 and 2015
- Peak hour traffic volumes from Traffic.com data system and TRM estimate



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Baseline Creation and Calibration (cont.)

Peak Hour Link Volume Comparison

Location	Traffic.com Count	2015 TRM Model	2005 TRM Model	TRM Model Average	DynusT	DynusT vs. TRM Model	DynusT vs. TRAFFIC.com
1	2386	2596	2506	2551	2942	15%	23%
2	1859	1739	1698	1718	2631	53%	42%
3	3096	3046	3009	3028	3109	3%	0%
4	2576	2697	2625	2661	2683	1%	4%
5	2455	2768	2654	2711	3426	26%	40%
6	2378	2452	2283	2368	3180	34%	34%
7	1992	2355	2292	2323	2332	0%	17%

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Framework for Summarizing and Comparing Model Outputs

- Comparisons are done at various spatial and temporal levels
- Improvement effects of an alternative scenario may not be significant at all spatial levels
- Improvement effects of an alternative scenario may vary by time of day as well

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Framework for Summarizing and Comparing Model Outputs (cont.)

- Results summarized at the following spatial levels for the following MOE's
  - Entire Network (average travel time)
  - I-40 directional corridor or facility (density, speed, travel time, etc.)
  - Highest Demand O/D pair (average travel time)
  - Critical Segments (density, speed, travel time, etc.)
- AM and PM Peaks analyzed separately

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Simulation Scenarios

- Scenario #1: 2015 Baseline
- Scenario #2: Full Build Network
- Scenario #3: Low-Cost Bottleneck Improvements
- Scenario #4: HOT Lanes
- Scenario #5: Ramp Metering (Short Term)
- Scenario #6: Ramp Metering (Short & Medium Term)

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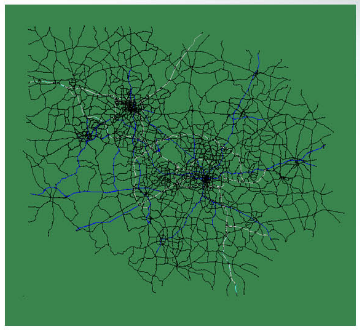
Scenario # 1: Baseline TRM 2015 Network



- *Network data*

Number of Nodes: 9,527
Number of Links: 20,250
Number of OD demand Zones: 2,389

- *Travel Demand (4-hour demand)*

AM: 1,092,648 vehicles
PM: 2,124,827 vehicles

- *Link Attributes*

Freeway: 1,165
On/Off Ramps: 649
Arterial Links: 15,792
Highway Links : 2,644

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Scenario #2: Full Build

- Five-lanes in each direction along the entire I-40 facility
- Allocated as four general purpose lanes and one HOV lane.

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Scenario #3: Low Cost Improvements

EXIT#	EXIT ROUTE NAMES	IDEAS TO CONSIDER	Comments
282	Page Rd	Dualize EB on-ramp loop	
285	Aviation Pkwy	Dual lane exit for WB I-40 to Aviation Pkwy	
285	Aviation Pkwy	Widen Aviation to 3 lanes over causeway (e.g. 2 lanes SB/WB), w/ reduced lane width	
290	NC 54 / E Cary / W Raleigh	Ramp metering	Only for PM
293	US1/US64 W/440W at Crossroads	I-40 EB - Auxiliary lane from Jones Franklin overpass to Gorman St	WB (not EB)
293	US1/US64 W/440W at Crossroads	Dual lefts from Jones Franklin offramp	
295	Gorman Street	Separate right turns allowing lefts and rights to move at same time	
297	Lake Wheeler	Dualize R-turn lane, WB offramp	
298	S Saunders	Dualize EB offramp	
303	Jones Sausage	Add Dual Left for Off ramps	Only for WB during AM
303	Jones Sausage	Ramp metering	
312	NC 42	I-40 WB loop from EB 42	

Source: Draft I-40 "Brainstorming List" provided by Meredith McDiarmid

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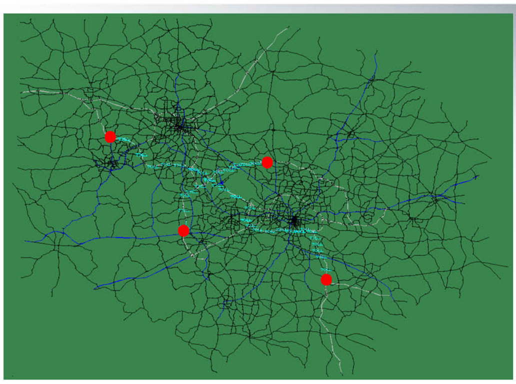
Scenario #4: HOT Lanes



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Scenario #4: HOT Lanes (cont.)

Study Corridors

- I-40 Corridor: between US 70 and NC 86
- I-540 Corridor: between US 64 and NC 50

(Source: I-40 High Occupancy Vehicle/Congestion Management Study)

- **Cross section on I-40 and I-540**
  General purpose lanes from 2015 network plus One HOT lane

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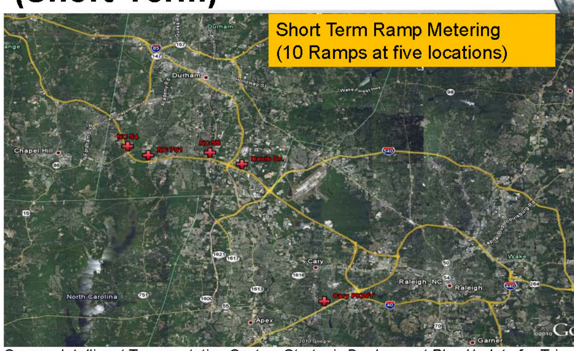
Scenario #5: Ramp Metering (Short-Term)



Source: Intelligent Transportation System Strategic Deployment Plan Update for Triangle Region

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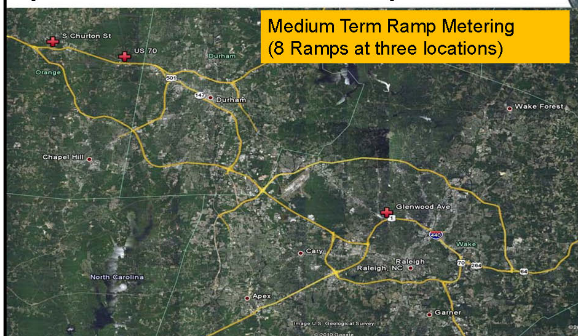
Scenario #6: Ramp Metering (Short & Medium Term)



Source: Intelligent Transportation System Strategic Deployment Plan Update for Triangle Region)

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Metering Rate Determination

- Based on downstream freeway link density
- Convert DynusT link *Density* to *Occupancy* for each 15-min interval
- Select appropriate Metering Rate

Occupancy (%)	Metering Rate (Vehicles/Minute)
≤ 10	12
11 – 16	10
17 – 22	8
23 – 28	6
29 – 34	4
> 34	3

Source: FHWA Freeway Management and Operations Handbook

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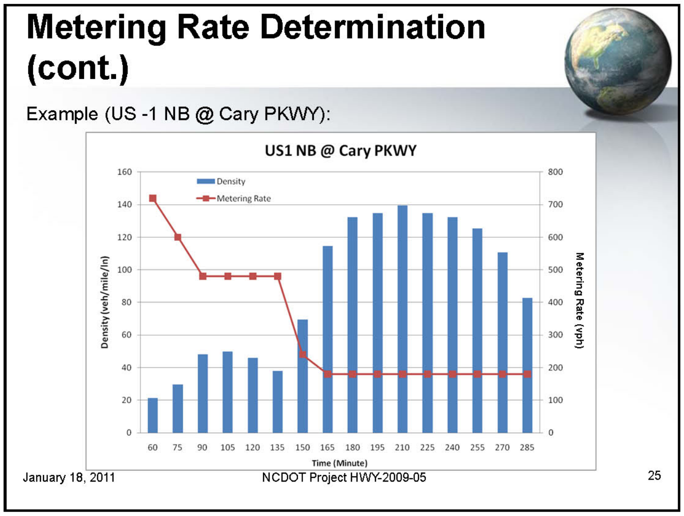
Metering Rate Determination (cont.)
Example (US -1 NB @ Cary PKWY):
US1 NB @ Cary PKWY
Density
Metering Rate
Density (veh/mile/ln)
Metering Rate (vph)
Time (Minute)
60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285
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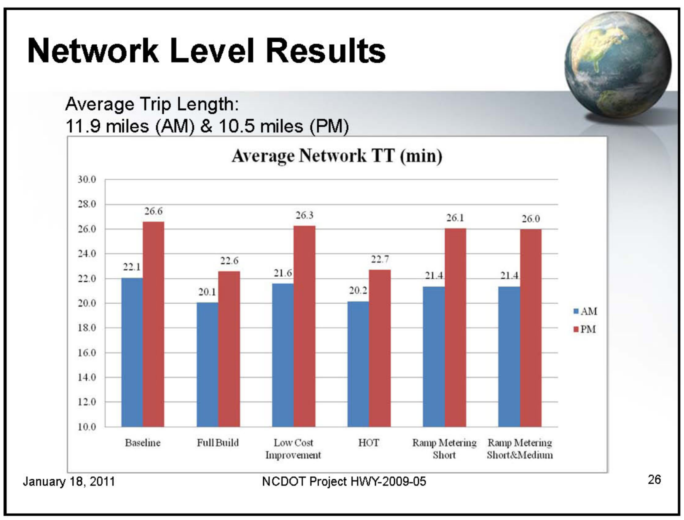
Network Level Results
Average Trip Length:
11.9 miles (AM) & 10.5 miles (PM)
Average Network TT (min)
22.1 26.6
20.1 22.6
21.6 26.3
20.2 22.7
21.4 26.1
21.4 26.0
AM
PM
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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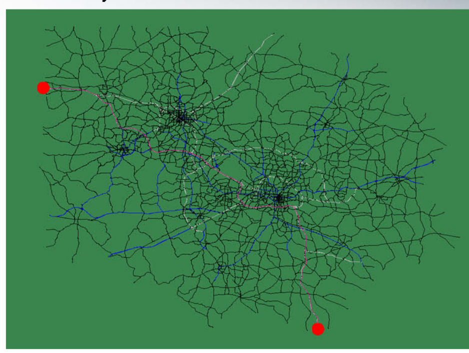
Corridor Performance (I-40 Facility)

Length of I-40 facility considered: 78.8 miles



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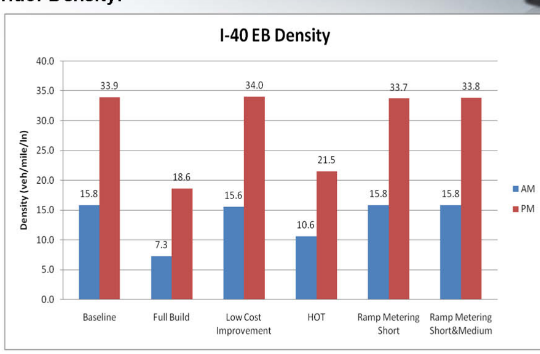
Corridor Performance (I-40 EB)

Corridor Density:



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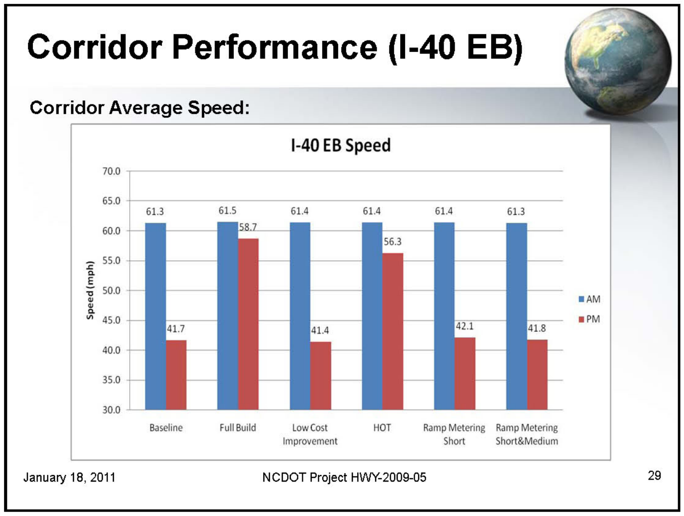
Corridor Performance (I-40 EB)
Corridor Average Speed:
I-40 EB Speed
Speed (mph)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
61.3
41.7
61.5
58.7
61.4
41.4
61.4
56.3
61.4
42.1
61.3
41.8
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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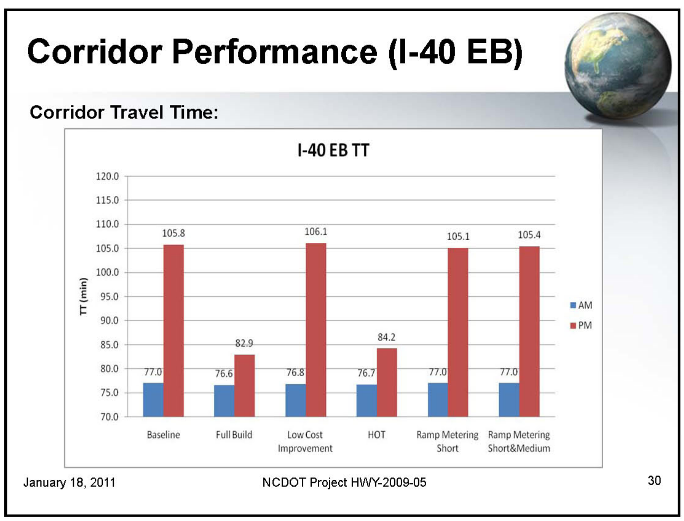
Corridor Performance (I-40 EB)
Corridor Travel Time:
I-40 EB TT
TT (min)
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
77.0
105.8
76.6
82.9
76.8
106.1
76.7
84.2
77.0
105.1
77.0
105.4
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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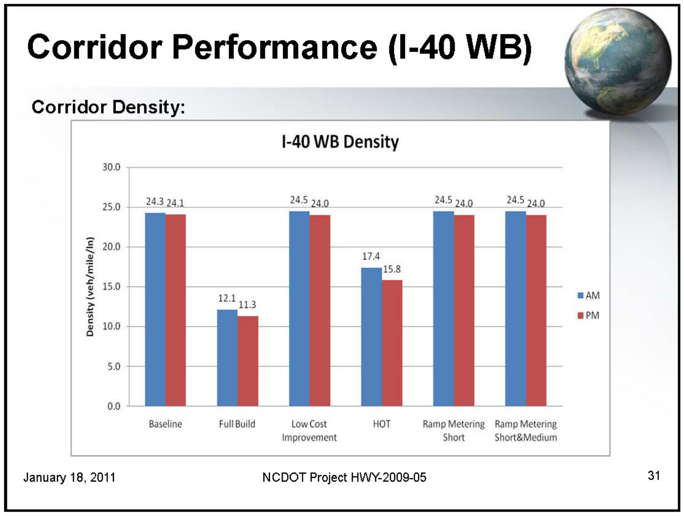
Corridor Performance (I-40 WB)
Corridor Density:
I-40 WB Density
Density (veh/mile/ln)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
24.3 24.1
12.1 11.3
24.5 24.0
17.4 15.8
24.5 24.0
24.5 24.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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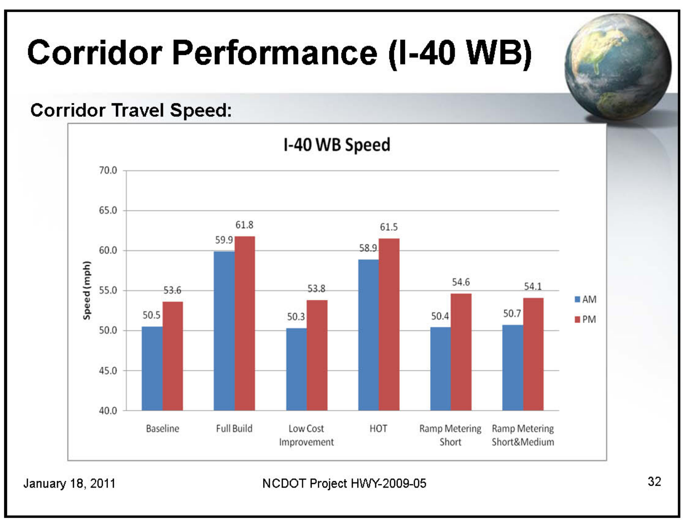
Corridor Performance (I-40 WB)
Corridor Travel Speed:
I-40 WB Speed
Speed (mph)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
50.5 53.6
59.9 61.8
50.3 53.8
58.9 61.5
50.4 54.6
50.7 54.1
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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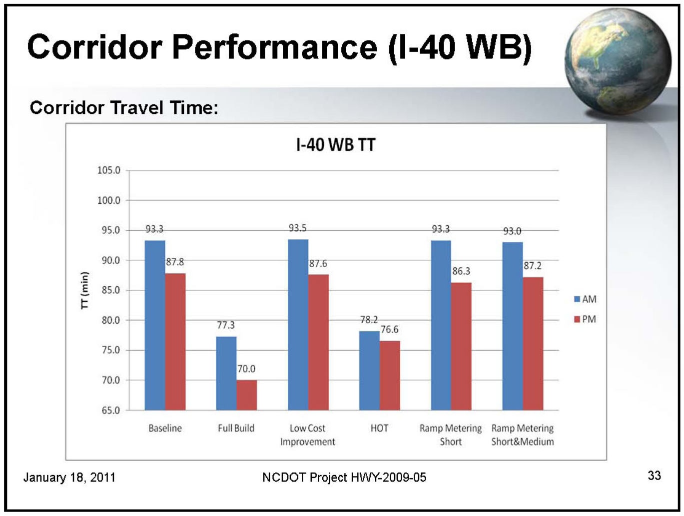
Corridor Performance (I-40 WB)
Corridor Travel Time:
I-40 WB TT
TT (min)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
93.3
87.8
77.3
70.0
93.5
87.6
78.2
76.6
93.3
86.3
93.0
87.2
AM
PM
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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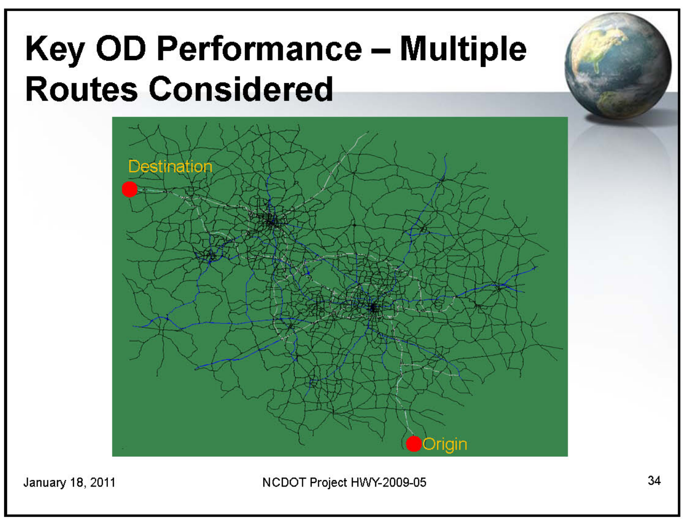
Key OD Performance – Multiple Routes Considered
Destination
Origin
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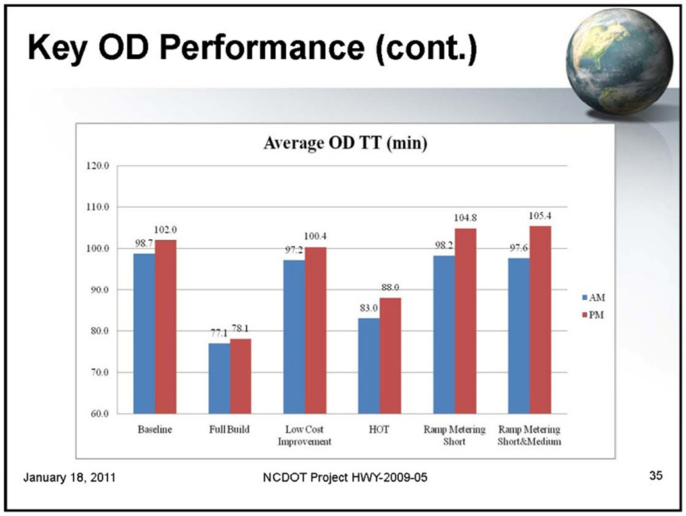
Key OD Performance (cont.)
Average OD TT (min)
120.0
110.0
100.0
90.0
80.0
70.0
60.0
98.7
102.0
77.1
78.1
97.2
100.4
83.0
88.0
98.2
104.8
97.6
105.4
AM
PM
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
January 18, 2011
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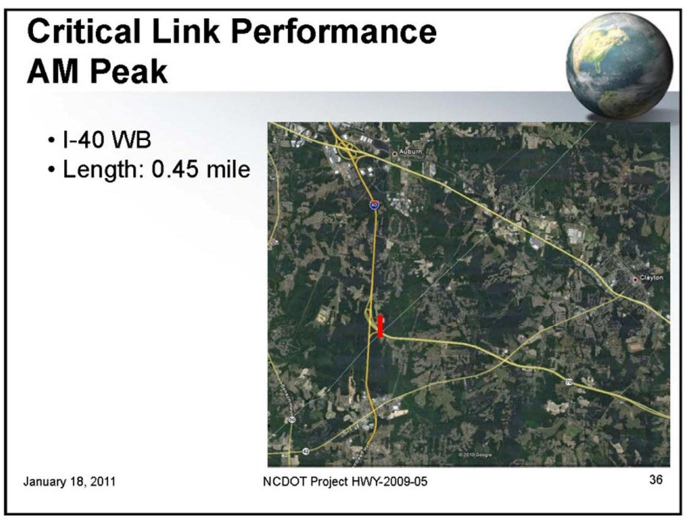
Critical Link Performance
AM Peak
• I-40 WB
• Length: 0.45 mile
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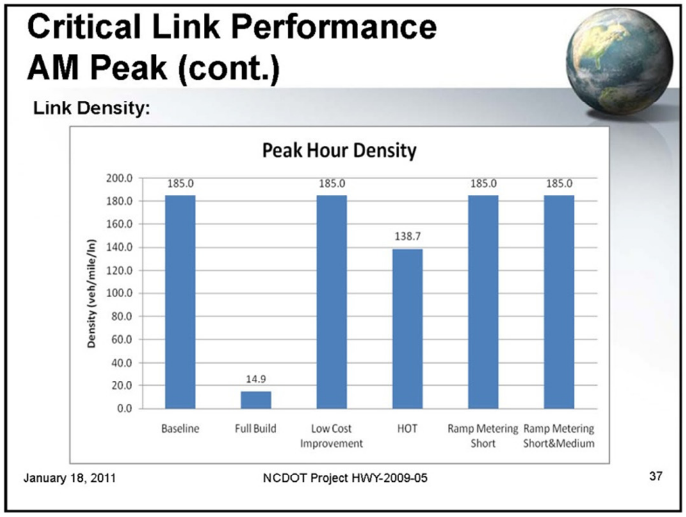
Critical Link Performance
AM Peak (cont.)
Link Density:
Peak Hour Density
Density (veh/mile/ln)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
185.0
14.9
185.0
138.7
185.0
185.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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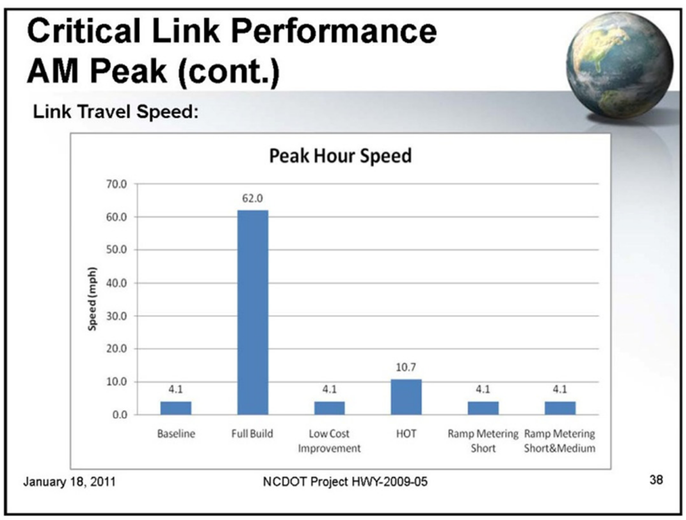
Critical Link Performance
AM Peak (cont.)
Link Travel Speed:
Peak Hour Speed
Speed (mph)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.1
62.0
4.1
10.7
4.1
4.1
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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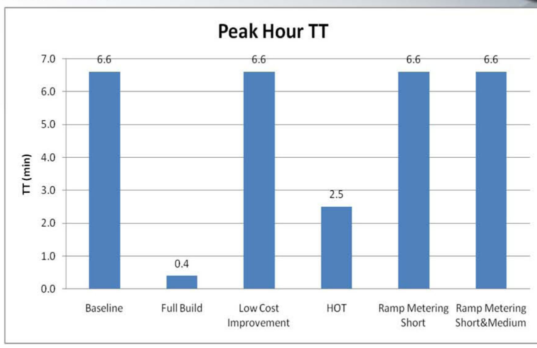
Critical Link Performance AM Peak (cont.)

Link Travel Time:



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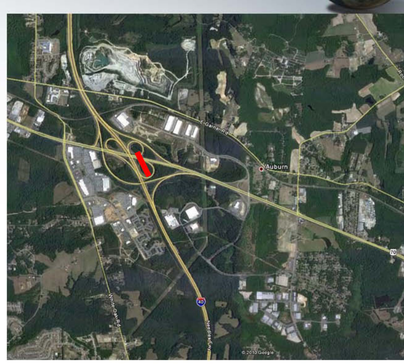
Critical Link Performance PM Peak

- I-40 EB
- Length: 0.3 mile



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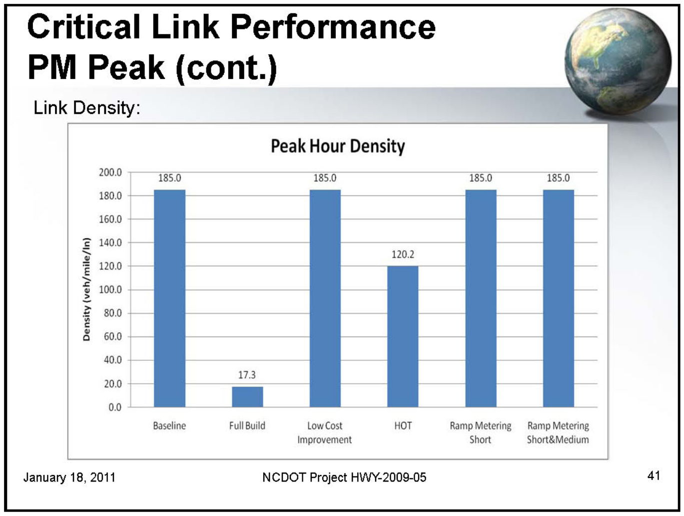
Critical Link Performance
PM Peak (cont.)
Link Density:
Peak Hour Density
Density (veh/mile/ln)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
185.0
17.3
185.0
120.2
185.0
185.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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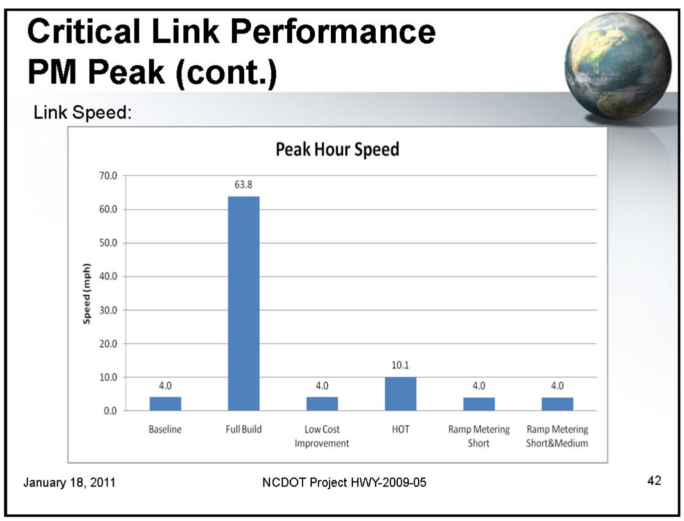
Critical Link Performance
PM Peak (cont.)
Link Speed:
Peak Hour Speed
Speed (mph)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.0
63.8
4.0
10.1
4.0
4.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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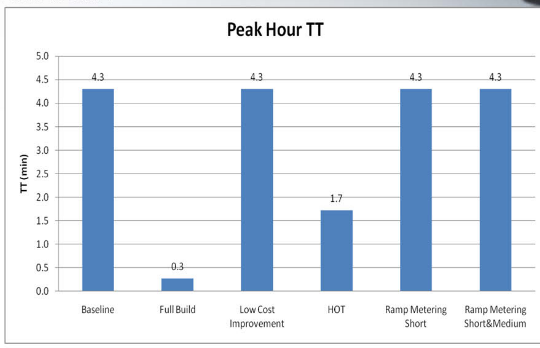
Critical Link Performance PM Peak (cont.)

Link Travel Time:



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Concluding Observations

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Result Interpretation: Ramp Metering in DynusT and IDAS

- Difficult to compare directly
- IDAS includes many items in benefits, most are estimates based on v/c
- With some effort, a near apples to apples comparison would be possible
- "Travel Time Reliability" is a major benefit for Ramp Metering in the *ITS Strategic Deployment Plan Update: Triangle Region*
- IDAS determines this solely by comparing baseline and scenario estimated incident delay
- The incident delay estimates are derived from lookup tables based on v/c, analysis period, and number of lanes

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IDAS-Ramp Metering Benefit Estimation Method (User Manual - Appendix A)

- Review and modify (if desired) ramp metering-specific default IDAS impact estimation parameters[1] for each link, including:
  - Capacity reduction at metered on-ramps of:
    - 33 percent for pre-set ramp metering.
    - 28 percent for traffic actuated ramp metering.
    - 27 percent for centrally controlled ramp metering.
  - Capacity increase at freeway links affected by the ramp metering improvement by:
    - 9.5 percent for pre-set ramp metering (observed increases range from four percent to 62 percent).
    - 13.5 percent for traffic-actuated and centrally-controlled ramp metering (observed increases range from two percent to 100 percent).
  - Accident rate reduction on the affected freeway and ramp links of 38 percent for all types of ramp metering, over all types of accidents (observed values range from four percent to 62 percent).

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Transit Modeling in DynusT
Why There Is No Scenario

- A transit scenario was originally planned
- Summer 2010 – “Bus Scenario” feature not functional in DynusT version 2
- Fall 2010 – Feature is enabled in version 3
- Insufficient time to complete planned scenario
- Raleigh-Chapel Hill express routes were coded to test the functionality

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Transit Modeling in DynusT
How It Works and Our Findings

- NEXTA user interface allows graphical creation of routes in a “*bus.dat*” file
- Routes are defined by –
  - Starting Link
  - Starting Time
  - Average Dwell Time (applied at all stops)
  - Stop Locations (click on corresponding links in NEXTA GUI)
- Team estimates 2 hours per route for coding (of course this is dependent on route length and stop density)
- Transit vehicles become additional vehicles in network with fixed routes, fixed starting times, and defined stops

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Transit Modeling in DynusT How It Could Be Used

- All scheduled service transit routes could be entered in a regional network
- The impact of the operation of these vehicles would then be included in operational metrics
- New service could be added for analysis scenarios
- Mode choice impacts and resulting effects on single occupancy vehicle demand tables would be done off line

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System Requirements

- DynusT can run on most desktops, workstations, and portable computers
- Controlling factor for specific applications is memory
- On 32-bit platforms, RAM is limited to 3 GB
- For TRM 2015 –
  - AM memory demand peaks between 5 and 6 GB
  - PM memory peaks about 1 GB higher
- Therefore, a 64-bit computer with at least 8 GB of RAM is recommended for regional scale models
- Run time for the scenarios above depends on type of simulation –
  - One shot simulation (10 min. for AM and 15 min. for PM)
  - User Equilibrium –
    - 15 iterations and 15 hrs. for AM
    - 20 iterations and 32 hrs. for PM

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Key Lessons Learned About Regional Modeling with DynusT

- Significant effort to "*clean up*" the network when converting from regional demand model format to DynusT. Manual corrections will be inevitable and may require a few weeks to complete the input.
- If possible obtain close to final OD table by vehicle class. Size of tables is very large and requires specialized software for manipulation (SAS)
- DynusT Online User Manual is still a work in progress
- Some incompatibilities still exist between DynusT and NEXTA as they evolve as related but independent software

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Key Lessons Learned About Regional Modeling with DynusT

- Various modeling platforms not easily comparable in terms of their outputs (e.g. DynusT and IDAS). However, each has its role in the ITS evaluation process.
- DynusT type models are likely to continue to progress at the national level since they:
  - Integrate planning and operational features of network operations within an acceptable computational cost
  - Enable the incorporation of pricing mechanism effects
  - Enable the accounting for information sources and quality on mobility and other impacts

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Future of Dynus-T and Relevant Ongoing Research

- DynusT is Moving to Open Source
- SHRP2 – C05 Will Bring New Features –
  - Stochastic freeway capacity and saturation flow rate at signalized intersections
  - Day to day learning algorithms with "bounded rationality"
  - Additional post-processing tools such as bottleneck analysis
- Follow on research to C05 proposed to further improve the tool to include non-recurring congestion

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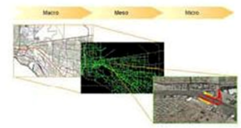
Thank you for your attention !

Questions, Comments?

A.9 Day 2 Agenda



ITRE

ITRE, NC STATE UNIVERSITY
January 19, 2011
Dynus-T workshop

Project HWY-2009-05

AGENDA

AM SESSION

9:00-9:15	Self introductions of participants and project team
9:15-9:45	Introductions to research project: objectives, scope, methods, limitations, sample high-level results
9:45-10:15	Introduction to DYNUS-T, architecture, process, capabilities, etc. (contrast with IDAS as appropriate)
10:15-10:30	**BREAK**
10:30-11:15	Creating Network files from Trans-Cad; Network Checking; Signalization
11:15-12:00	Graphical User Interface (NEXTA) basics, hands on demonstration
12:00-1:30	**LUNCH--- ON YOUR OWN**

PM SESSION

1:30-2:00	Model calibration methods
2:00-2:30	Working with a small case study network (FW)—presentation
2:30-2:45	**BREAK**
2:45-3:45	Case Study Scenarios on FW network--- building and coding --*hands-on* 1. Baseline 2. Increased Traffic Demand 3. Traditional Capacity Addition 4. Congestion Warning VMS 5. Ramp Metering
3:45-4:15	*Scaling up to Full TRM Network—Navigation of a Realistic DYNUST-Model and Sample Results*
4:15-4:30	Summary, questions and discussion

A.10 Day 2 Presentation

The Day 2 PowerPoint presentation is provided on the following pages in two-slide per page handout format.

Assessing Operational, Pricing, and Intelligent Transportation System Strategies for the I-40 Corridor Using DYNASMART-P

PROJECT NO. HWY-2009-05

Workshop Session 2 –
Hands On DynusT Introduction

January 19, 2011

Agenda

- Detailed agenda handed out
- Morning – Introductions to:
  - The project
  - Mesoscopic, DTA network modeling
  - The DynusT/Nexta software system
- Afternoon – Hands on software exercises
  - Baseline Model Calibration
  - Forth Worth Sub-network Case Study
    - Scenario definition and coding
    - Scenario measures of effectiveness
  - Scaling up to regional network – Interaction with Triangle Regional DynusT scenarios
  - Wrap up and Questions

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Project HWY-2009-05 Objectives

- A calibrated DYNASMART-P model of the Triangle region
- Model will provide performance assessment capability that can adapted for use throughout the state
- Foundational first step for a five-year program to bring DYNASMART-P capability to statewide modeling
- Support professional capacity building to enable effective use of the model by NCDOT

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DynusT and DYNASMART-P: An Overview

- What do the two models have in common?
  - Both rooted in the original DYNASMART meso-scopic modeling environment
  - Both contain network traffic models, dynamic traffic assignment (DTA) features and same user interface (NEXTA)
  - Both have the capability to model multiple user classes
- How do the two models differ?
  - DynusT has ongoing FHWA support
  - DynusT is moving to public domain status (free software)
  - The traffic flow models are different (next slide)

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Mesoscopic Modeling

- Meso framework considers *individual* vehicle entities
  - Route decisions are made at the vehicle level
  - MOE's collected as vehicles traverse various links
  - Enables dynamic traffic assignment and consideration of multiple user classes
- Meso framework does not model vehicle interaction
  - Vehicles move through network based on macroscopic flow principles on each link – that can be calibrated
  - Enables scalability to large networks
  - DynusT used modified "anisotropic" flow model that provides greater fidelity and realism of vehicle motion

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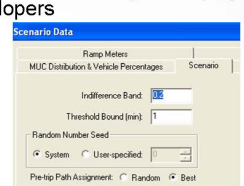
Random Number Seeds

- Most simulation models use a random number generator
- A random number seed allows users to control the series of random numbers and thus replicate an experiment
- DynusT does provide the users with the ability to specify a random seed
- However, the model is not producing the same results from run to run (if using more than 1 Thread) – The project team has informed the software developers



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Dynamic Traffic Assignment

- A method to predict/estimate how trip-makers may shift to other routes in response to –
  - Recurring and non-recurring congestion
  - Pricing
  - Traffic Controls
  - Geometric, design and operational improvements
- Enables an understanding of how individual travel decisions impact an entire region, by
  - Time of day
  - Origin-Destination (OD) zone
  - Transportation mode

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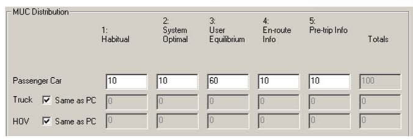
User Classes Defined

- Rationale for having multiple user classes
- User Classes in Dynus-T
  - *User Class 1* – Habitual traveler
    - Respond only to *mandatory* detours
  - *User Class 2* – System Optimal (SO)
    - Optimize system travel time
  - *User Class 3* – User Equilibrium (UE)
    - Optimize individual travel times
  - *User Class 4* – En-route Info (Boundedly Rational Behavior)
    - Update path at each intersection based on prevailing shortest path tree
  - *User Class 5* – Pre-Trip
    - Responds to pre-trip information
- All user classes except User Class 1 respond to Variable Message Signs



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Framework for Summarizing and Comparing Model Outputs

- Comparisons are done at various spatial and temporal levels
- Improvement effects of an alternative scenario may not be significant at all spatial levels
- Improvement effects of an alternative scenario may vary by time of day as well

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Framework for Summarizing and Comparing Model Outputs (cont.)

- Results summarized at the following spatial levels for the following MOE's
  - Entire Network (average travel time)
  - I-40 directional corridor or facility (density, speed, travel time, etc.)
  - Highest Demand O/D pair (average travel time)
  - Critical Segments (density, speed, travel time, etc.)
- AM and PM Peaks analyzed separately

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Simulation Scenarios:

- Scenario #1: 2015 Baseline
- Scenario #2: Full Build Network
- Scenario #3: Low-Cost Bottleneck Improvements
- Scenario #4: HOT Lanes
- Scenario #5: Ramp Metering (Short Term)
- Scenario #6: Ramp Metering (Short & Medium Term)

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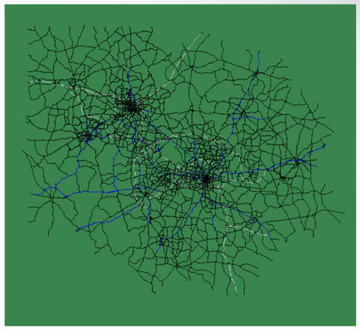
Scenario # 1: Baseline TRM 2015 Network



- *Network data*

Number of Nodes: 9,527
Number of Links: 20,250
Number of OD demand Zones: 2,389

- *Travel Demand (4-hour demand)*

AM: 1,092,648 vehicles
PM: 2,124,827 vehicles

- *Link Attributes*

Freeway: 1,165
On/Off Ramps: 649
Arterial Links: 15,792
Highway Links : 2,644

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Scenario #2: Full Build

- Five-lanes in each direction along the entire I-40 facility
- Allocated as four general purpose lanes and one HOV lane.

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Scenario #3: Low Cost Improvements

EXIT#	EXIT ROUTE NAMES	IDEAS TO CONSIDER	Comments
282	Page Rd	Dualize EB on-ramp loop	
285	Aviation Pkwy	Dual lane exit for WB I-40 to Aviation Pkwy	
285	Aviation Pkwy	Widen Aviation to 3 lanes over causeway (e.g. 2 lanes SB/WB), w/ reduced lane width	
290	NC 54 / E Cary / W Raleigh	Ramp metering	Only for PM
293	US1/US64 W/440W at Crossroads	I-40 EB - Auxiliary lane from Jones Franklin overpass to Gorman St	WB (not EB)
293	US1/US64 W/440W at Crossroads	Dual lefts from Jones Franklin offramp	
295	Gorman Street	Separate right turns allowing lefts and rights to move at same time	
297	Lake Wheeler	Dualize R-turn lane, WB offramp	
298	S Saunders	Dualize EB offramp	
303	Jones Sausage	Add Dual Left for Off ramps	Only for WB during AM
303	Jones Sausage	Ramp metering	
312	NC 42	I-40 WB loop from EB 42	

Source: Draft I-40 "Brainstorming List" provided by Meredith McDiarmid

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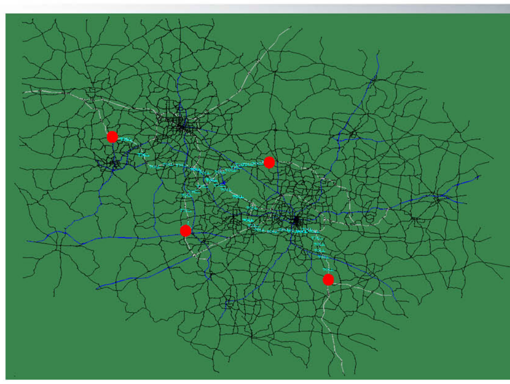
Scenario #4: HOT Lanes



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Scenario #4: HOT Lanes (cont.)

Study Corridors

- I-40 Corridor: between US 70 and NC 86
- I-540 Corridor: between US 64 and NC 50

(Source: I-40 High Occupancy Vehicle/Congestion Management Study)

- **Cross section on I-40 and I-540**
  General purpose lanes from 2015 network plus One HOT lane

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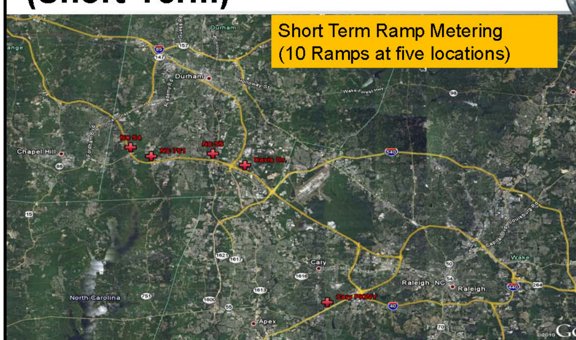
Scenario #5: Ramp Metering (Short-Term)



Source: Intelligent Transportation System Strategic Deployment Plan Update for Triangle Region

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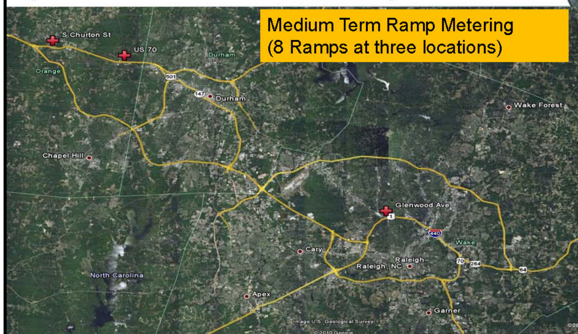
Scenario #6: Ramp Metering (Short & Medium Term)



Source: Intelligent Transportation System Strategic Deployment Plan Update for Triangle Region)

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Metering Rate Determination

- Based on downstream freeway link density
- Convert DynusT link *Density* to *Occupancy* for each 15-min interval
- Select appropriate Metering Rate

Occupancy (%)	Metering Rate (Vehicles/Minute)
≤ 10	12
11 – 16	10
17 – 22	8
23 – 28	6
29 – 34	4
> 34	3

Source: FHWA Freeway Management and Operations Handbook

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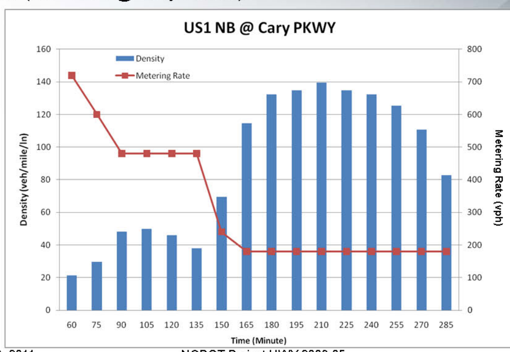
Metering Rate Determination (cont.)

Example (US -1 NB @ Cary PKWY):



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Project Scenario Results

- Summarized at the levels described above –
  - Network
  - Corridor
  - Key Origin-Destination
  - Critical Link
- Network level results on following slide
- Remaining results will be presented this afternoon following the hands-on case study

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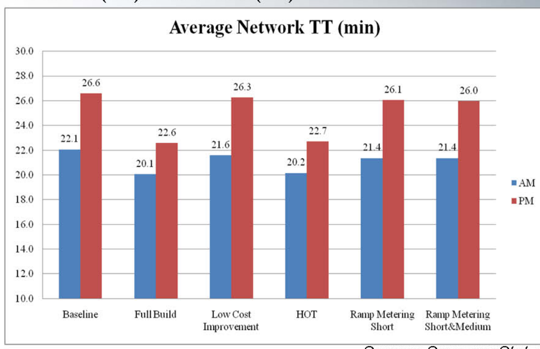
Sample: TRM Network Results

Average Trip Length:
11.9 miles (AM) & 10.5 miles (PM)



Source: SummaryStat.dat

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Baseline Scenario Creation and Calibration (6-Step Process)

- Step 1 – Create network link and zone input structure from travel demand network model
- Step 2 – Create O/D input files from travel demand model
- Step 3 – Check for network connectivity errors
  - Problems arise from –
    - Non-standard ramp systems
    - Skewed intersections
  - Team recommends one-shot simulation with fraction of analysis OD
  - Abnormally high densities under these conditions may indicate correctible connectivity errors

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Baseline Creation and Calibration (cont.)

- Step 4 – Make necessary signal control adjustments
  - Signal control defaults to two-phased actuated control
  - Another one-shot simulation with network connectivity errors corrected and a low flow demand table will help isolate problem intersections
- Step 5 – Calibrate freeway models (more in the afternoon)
  - Where available, collect freeway data
  - Fit an appropriate model or models
- Step 6 – Validate link flows
  - This can be a "calibration" step, usually with O/D table adjustment to match link flows
  - For Triangle region, soft validation was done using links not expected to change significantly before 2015

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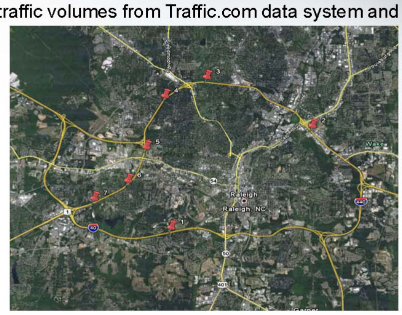
Baseline Creation and Calibration (cont.)

Soft Validation:

- Seven representative freeway links in 2005 and 2015
- Peak hour traffic volumes from Traffic.com data system and TRM estimate



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Baseline Creation and Calibration (cont.)

Peak Hour Link Volume Comparison

Location	Traffic.com Count	2015 TRM Model	2005 TRM Model	TRM Model Average	DynusT	DynusT vs. TRM Model	DynusT vs. TRAFFIC.com
1	2386	2596	2506	2551	2942	15%	23%
2	1859	1739	1698	1718	2631	53%	42%
3	3096	3046	3009	3028	3109	3%	0%
4	2576	2697	2625	2661	2683	1%	4%
5	2455	2768	2654	2711	3426	26%	40%
6	2378	2452	2283	2368	3180	34%	34%
7	1992	2355	2292	2323	2332	0%	17%

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Signalization

- As noted above, the travel demand model translation process creates two-phased actuated control for all nodes identified as signalized
- Heavy left turns cannot be handled by this control
- Critical nodes can be identified by local knowledge and one-shot simulation runs (viewing density in GUI and/or link delay output)
- Left turn pockets must be added for protected left turn phases
- Control can be changed to four-phased actuated or actual control

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HANDS ON TUTORIAL

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Overview of NEXTA tutorial

- Explore basic functionalities
  - Features available on pull-down menu and toolbar
- Run simulation
  - One-shot simulation (planning period = 60 minutes)
- View simulation results
  - Network statistics, link statistics
  - Shortest paths
- Scenario analysis
  - ITS, ATIS, demand management, operational improvement, etc.

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Basic Functionalities

- Pull-down Menu

- Toolbar Menu

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Basic Functionalities: Your turn to try

- Open network files
  - look for baseline.dws in your local directory
- Things to try:
  - Display node and zone numbers
  - Zoom and pan
  - View node, link, and zone properties
- Exercise:
  - What are the upstream and downstream nodes of link 395?

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Run simulation

- To run the simulation model, click:
- You will then see:

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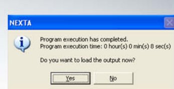
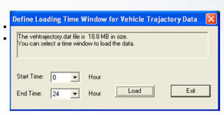
Run Simulation

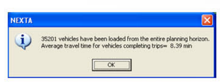
- Click *Yes* when you see:



- Click *Load* when you see:



- Click *OK* when you see:



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Run Simulation: Your turn to try

- Run the simulation and see if you get the following:
  - 35,203 vehicles loaded onto network.
  - Average network travel time = 8.1 minutes.

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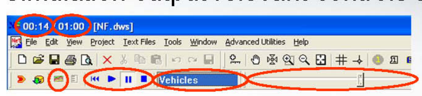
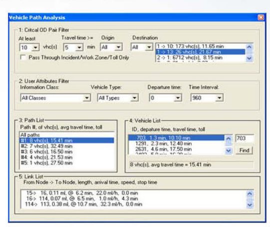
View Simulation Results

- Simulation output relevant controls and parameters



- Vehicle paths analysis



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View Simulation Results: Your turn to try

- Things to try:
  - Display vehicle trajectories
  - View link statistics
  - Examine shortest paths between ODs
- Exercise:
  - What is the speed of link 99 at minute 30?
  - Which link has the highest density during the planning horizon?

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Scenario analysis

- Scenario analysis to investigate effects of ITS, ATIS, demand management, or operational improvements can be done using:
  - Project > Assignment Simulating Settings
  - Project > Scenario Data
  - Project > Demand Data
  - Project > Capacity Data
  - Project > Traffic Flow Model Data
- Hands-on analysis to be done in the afternoon.

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LUNCH BREAK

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Model Calibration

- Travel demand models traditionally calibrated by adjusted OD tables until there is an adequate match with observed link flow
- A utility is available to implement this procedure for DynusT
- For the project, the 2015 TRM was taken as the best estimate of future demand
- Therefore, calibration was limited to calibrating the two-regime freeway traffic model to observed Traffic.com data

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Freeway Models in DynusT

- Freeway links in DynusT are modeled with a two-regime modified Greenshield's model
- Below the specified density break point (K_b) the vehicle speed is the specified speed limit plus an optional speed adjustment
- At densities above K_b the speed is calculated by –

$$V = V_{min} + (V_{int} - V_{min}) \times \left(1 - {K}/{K_j}\right)^{\alpha}$$

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Freeway Model Calibration for the Project

- Traffic.com data was assembled for 46 locations for the months of May and October, 2009
- The distribution of sites by number of lanes was –
  - Two lanes: 3
  - Three lanes: 19
  - Four lanes: 18
  - Five lanes: 6
- After individual site model fitting and analysis of similarities by lane configuration, a single general freeway model was selected at shown on the following slide

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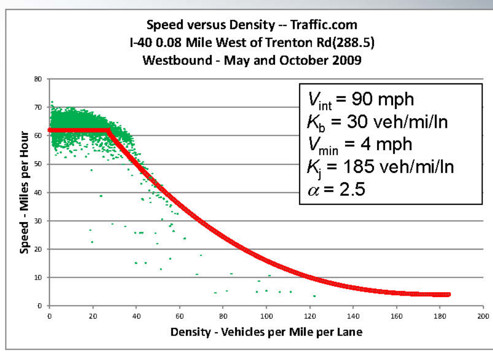
General Freeway Flow Model



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HANDS ON CASE STUDY

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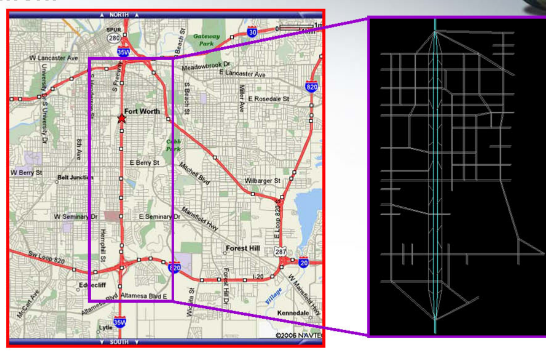
Fort Worth Case Study

Network



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Simulation Scenarios

- Scenario #1: Baseline
- Scenario #2: Increased Traffic Demand
  - This becomes the new Baseline for comparison
- Scenario #3: Traditional Capacity Addition
- Scenario #4: Congestion Warning VMS
- Scenario #5: Ramp Metering

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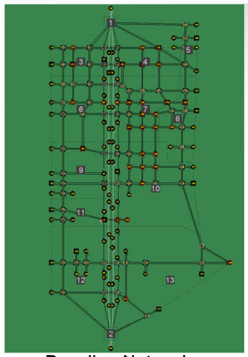
Scenario #1: Baseline



Baseline Network

- *Network data*
  - Number of Nodes: 180
  - Number of Links: 445
  - Number of OD demand Zones: 13
- *Link Attributes*
  - Freeway: 29
  - Arterial: 393
  - On/Off Ramp: 23
- *Node control type*
  - No Control (on and off ramps): 87
  - 4-Way Stop: 24
  - 2-Way Stop: 6
  - Signalized (actuated control): 59

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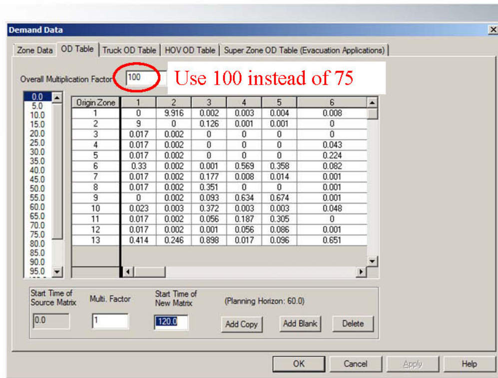
Scenario #2: Increased Traffic Demand: New Baseline for Comparison



Origin Zone	1	2	3	4	5	6
1	0	9.916	0.002	0.003	0.004	0.008
2	9	0	0.126	0.001	0.001	0
3	0.017	0.002	0	0	0	0
4	0.017	0.002	0	0	0	0.043
5	0.017	0.002	0	0	0	0.224
6	0.33	0.002	0.001	0.569	0.358	0.082
7	0.017	0.002	0.177	0.008	0.014	0.001
8	0.017	0.002	0.351	0	0	0.001
9	0	0.002	0.093	0.634	0.674	0.001
10	0.023	0.003	0.372	0.003	0.003	0.048
11	0.017	0.002	0.056	0.187	0.305	0
12	0.017	0.002	0.001	0.056	0.086	0.001
13	0.414	0.246	0.898	0.017	0.096	0.651

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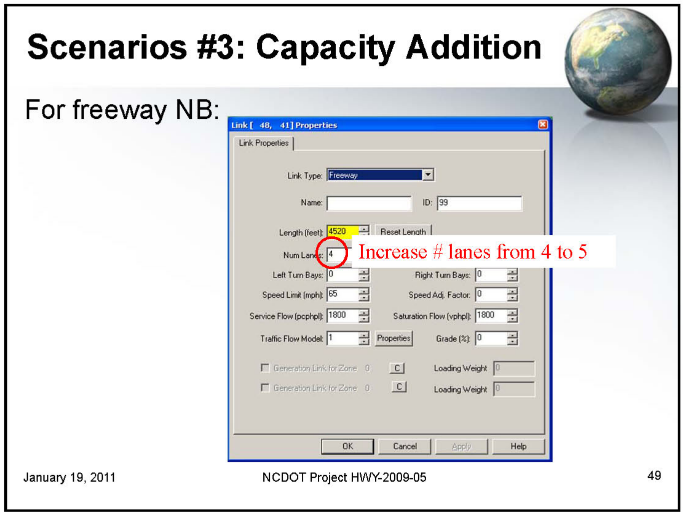
Scenarios #3: Capacity Addition
For freeway NB:
Link [48, 41] Properties
Link Properties
Link Type: Freeway
Name:
ID: 99
Length (feet): 4520
Reset Length
Num Lanes: 4
Increase # lanes from 4 to 5
Left Turn Bays: 0
Right Turn Bays: 0
Speed Limit (mph): 65
Speed Adj. Factor: 0
Service Flow (pcphpl): 1800
Saturation Flow (vphpl): 1800
Traffic Flow Model: 1
Properties
Grade (%): 0
Loading Weight
OK
Cancel
Apply
Help
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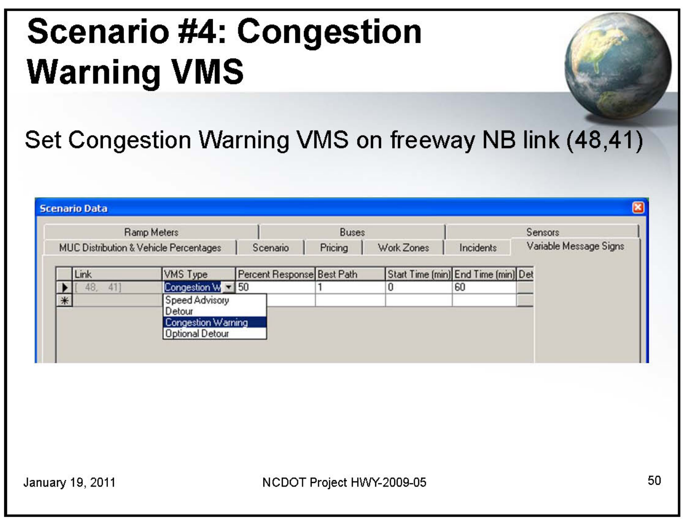
Scenario #4: Congestion Warning VMS
Set Congestion Warning VMS on freeway NB link (48,41)
Scenario Data
Ramp Meters
Buses
Sensors
MUC Distribution & Vehicle Percentages
Scenario
Pricing
Work Zones
Incidents
Variable Message Signs
Link
VMS Type
Percent Response
Best Path
Start Time (min)
End Time (min)
Speed Advisory
Detour
Congestion Warning
Optional Detour
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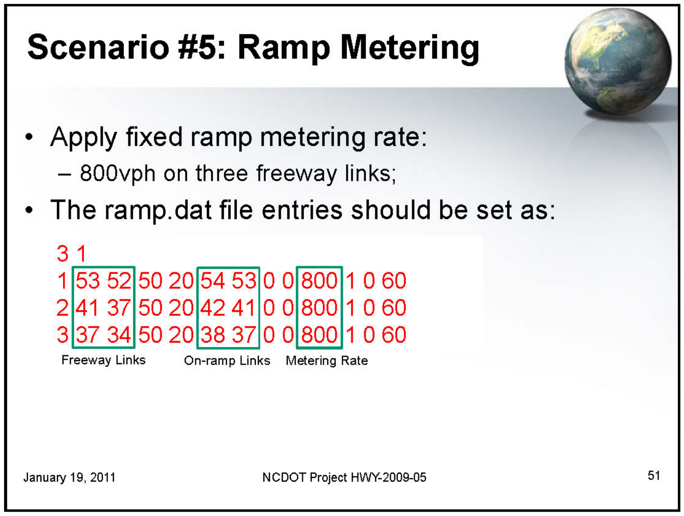
Scenario #5: Ramp Metering
• Apply fixed ramp metering rate:
– 800vph on three freeway links;
• The ramp.dat file entries should be set as:
3 1
1 53 52 50 20 54 53 0 0 800 1 0 60
2 41 37 50 20 42 41 0 0 800 1 0 60
3 37 34 50 20 38 37 0 0 800 1 0 60
Freeway Links
On-ramp Links
Metering Rate
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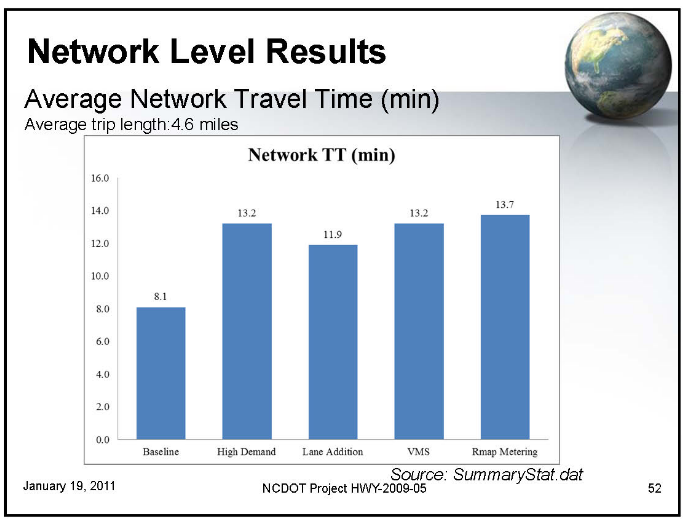
Network Level Results
Average Network Travel Time (min)
Average trip length:4.6 miles
Network TT (min)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
8.1
13.2
11.9
13.2
13.7
Baseline
High Demand
Lane Addition
VMS
Rmap Metering
Source: SummaryStat.dat
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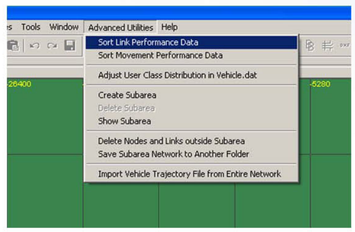
Corridor Performance- NB Freeway

- Corridor length: 7 miles
- Need post-processing of the raw model outputs

Collect all individual link performance data:



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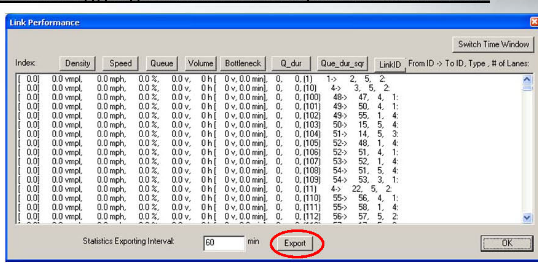
Corridor Performance- NB Freeway

Export then aggregate relevant link performance data:



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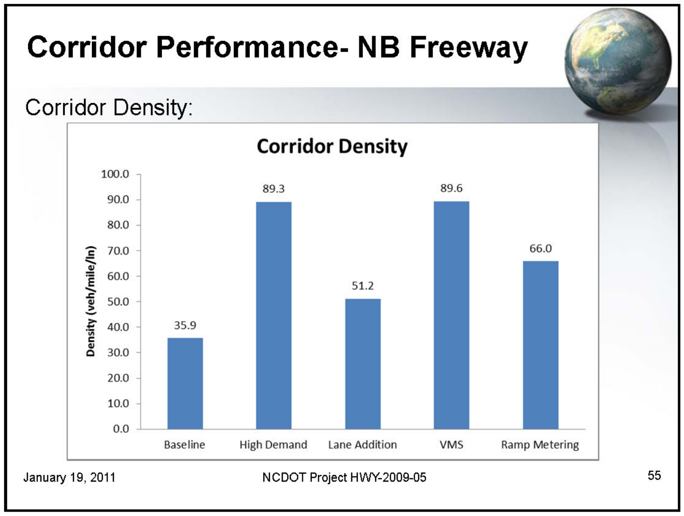
Corridor Performance- NB Freeway
Corridor Density:
Corridor Density
Density (veh/mile/ln)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
35.9
89.3
51.2
89.6
66.0
Baseline
High Demand
Lane Addition
VMS
Ramp Metering
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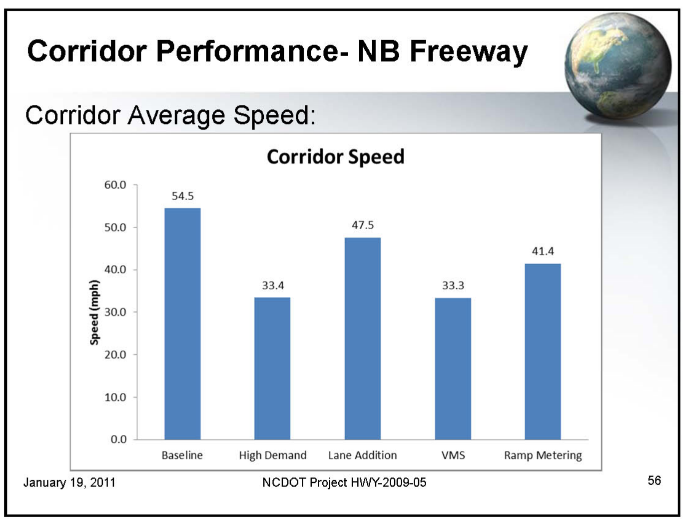
Corridor Performance- NB Freeway
Corridor Average Speed:
Corridor Speed
Speed (mph)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
54.5
33.4
47.5
33.3
41.4
Baseline
High Demand
Lane Addition
VMS
Ramp Metering
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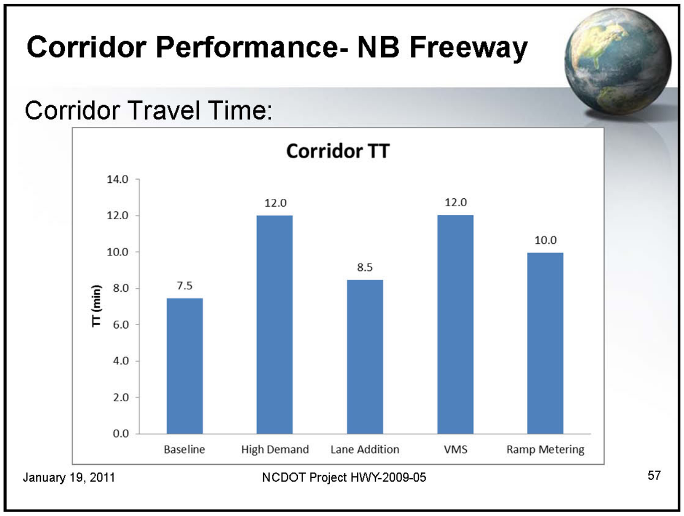
Corridor Performance- NB Freeway
Corridor Travel Time:
Corridor TT
TT (min)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
7.5
12.0
8.5
12.0
10.0
Baseline
High Demand
Lane Addition
VMS
Ramp Metering
January 19, 2011
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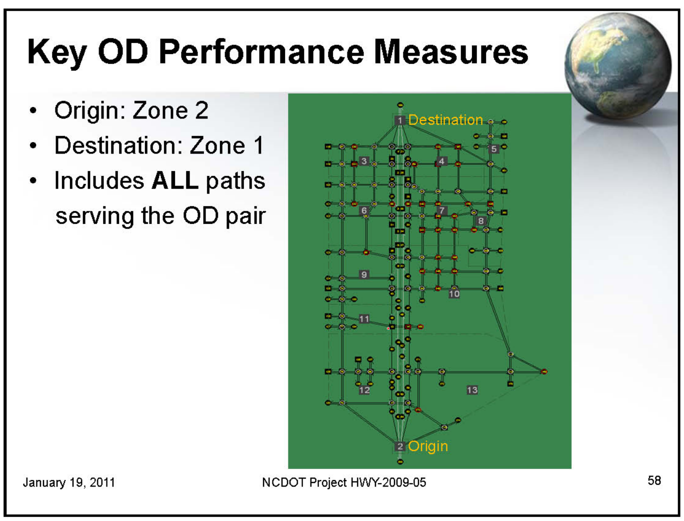
Key OD Performance Measures
• Origin: Zone 2
• Destination: Zone 1
• Includes ALL paths serving the OD pair
Destination
Origin
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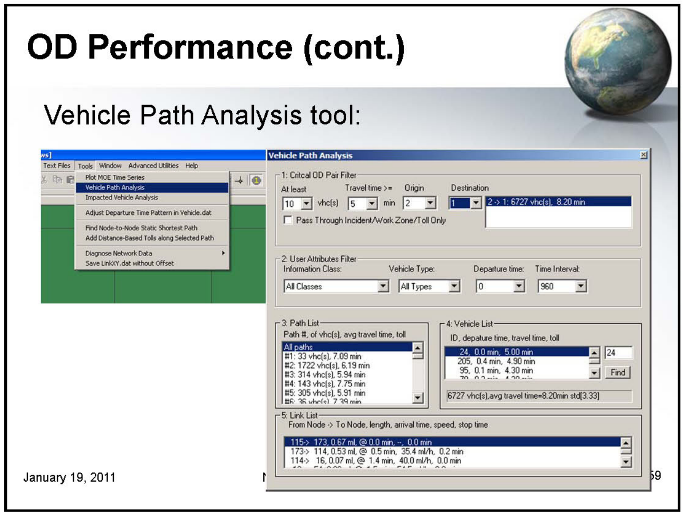
OD Performance (cont.)
Vehicle Path Analysis tool:
Vehicle Path Analysis
1: Critical OD Pair Filter
2: User Attributes Filter
3: Path List
4: Vehicle List
5: Link List
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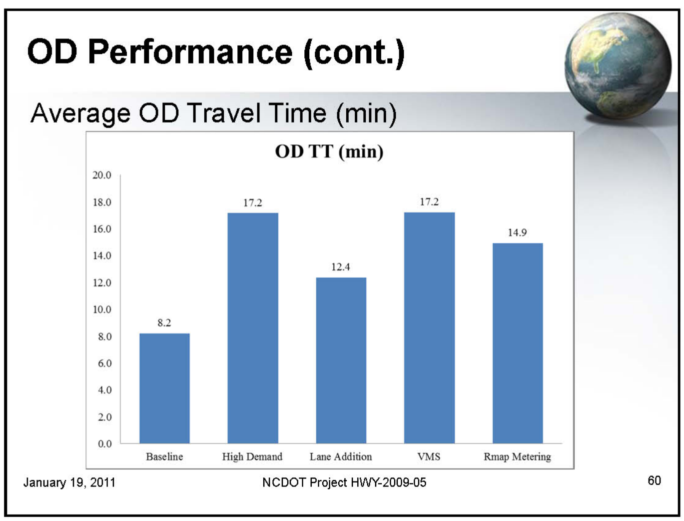
OD Performance (cont.)
Average OD Travel Time (min)
OD TT (min)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
8.2
17.2
12.4
17.2
14.9
Baseline
High Demand
Lane Addition
VMS
Rmap Metering
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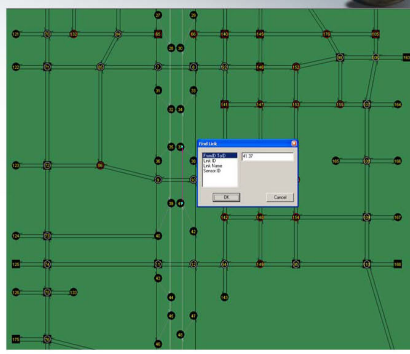
Single Link Performance – (41~37)

- Freeway NB
- Link Length: 0.46 mile



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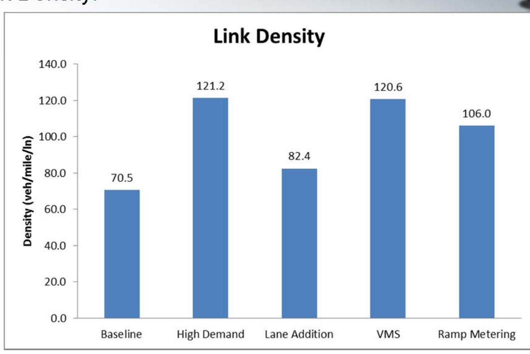
Single Link Performance – (41~37)

Link Density:



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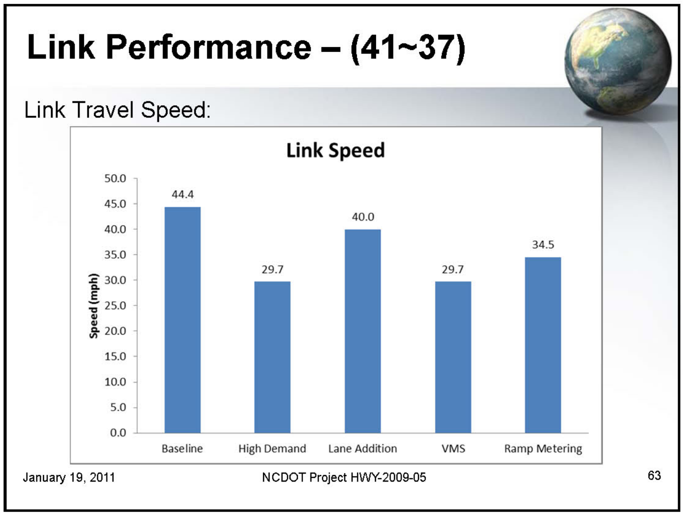

Link Performance – (41~37)
Link Travel Speed:
Link Speed
Speed (mph)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
44.4
29.7
40.0
29.7
34.5
Baseline
High Demand
Lane Addition
VMS
Ramp Metering
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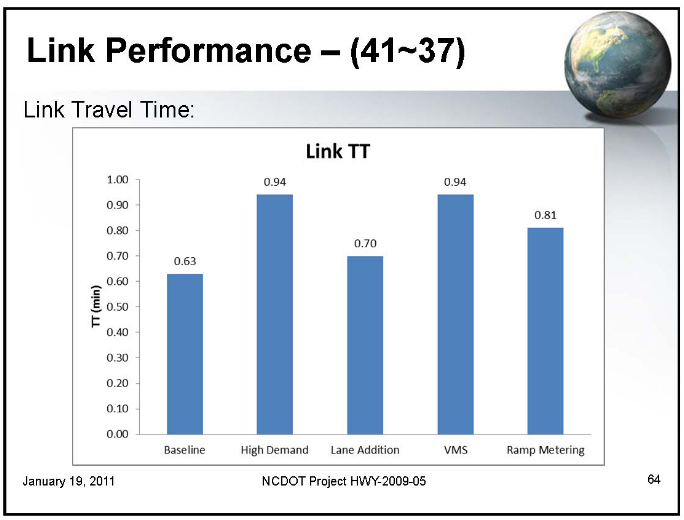

Link Performance – (41~37)
Link Travel Time:
Link TT
TT (min)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.63
0.94
0.70
0.94
0.81
Baseline
High Demand
Lane Addition
VMS
Ramp Metering
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SCALING UP TO THE TRM

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Scaling Up to Regional Modeling System Requirements

- DynusT can run on most desktops, workstations, and portable computers
- Controlling factor for specific applications is memory
- On 32-bit platforms, RAM is limited to 3 GB
- For TRM 2015 –
  - AM memory demand peaks between 5 and 6 GB
  - PM memory peaks about 1 GB higher
- Therefore, a 64-bit computer with at least 8 GB of RAM is recommended for regional scale models
- Run time for the scenarios above depends on type of simulation –
  - One shot simulation (10 min. for AM and 15 min. for PM)
  - User Equilibrium –
    - 15 iterations and 15 hrs. for AM
    - 20 iterations and 32 hrs. for PM

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Scaling Up to Regional Modeling TRM 2015 Results

- The following series of slides provide the summarized results for the TRM 2015 scenarios described earlier

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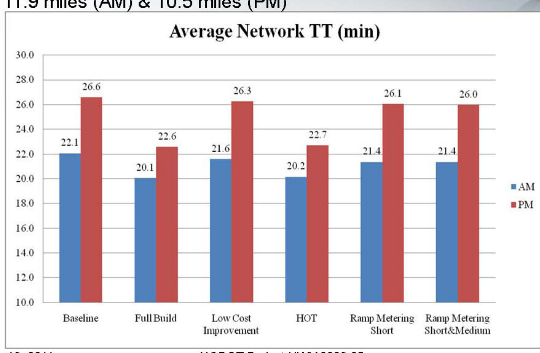
Network Level Results

Average Trip Length:
11.9 miles (AM) & 10.5 miles (PM)



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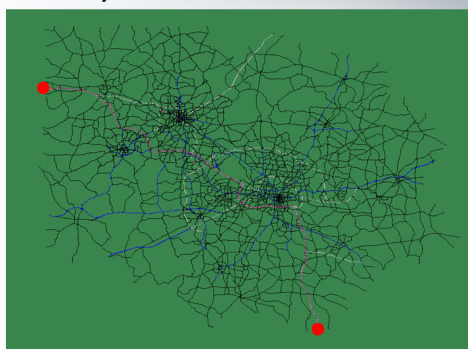
Corridor Performance (I-40 Facility)

Length of I-40 facility considered: 78.8 miles



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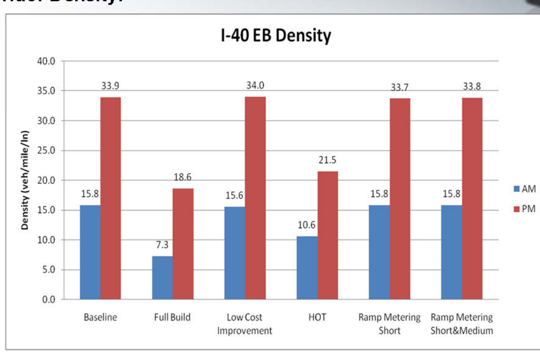
Corridor Performance (I-40 EB)

Corridor Density:



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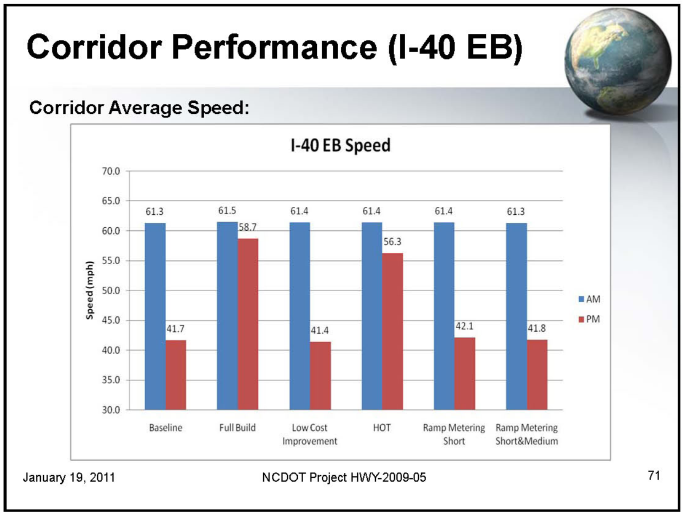
Corridor Performance (I-40 EB)
Corridor Average Speed:
I-40 EB Speed
Speed (mph)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
61.3
41.7
61.5
58.7
61.4
41.4
61.4
56.3
61.4
42.1
61.3
41.8
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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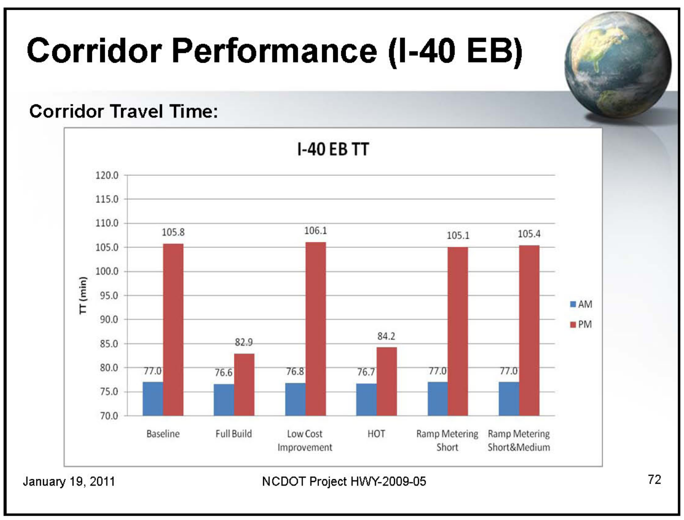
Corridor Performance (I-40 EB)
Corridor Travel Time:
I-40 EB TT
TT (min)
120.0
115.0
110.0
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
77.0
105.8
76.6
82.9
76.8
106.1
76.7
84.2
77.0
105.1
77.0
105.4
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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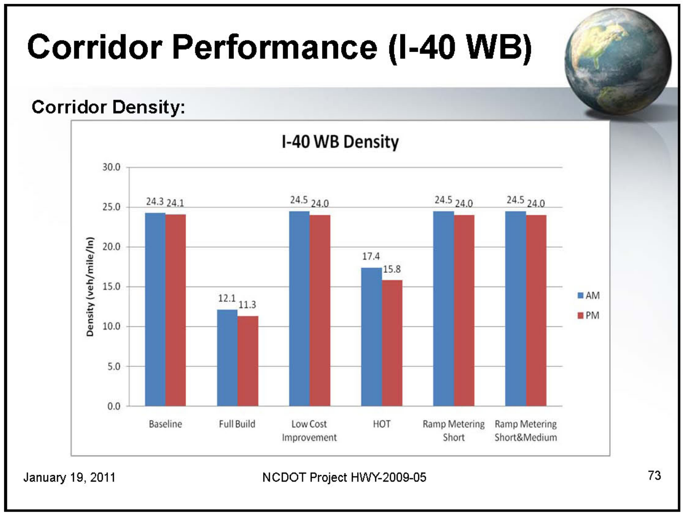
Corridor Performance (I-40 WB)
Corridor Density:
I-40 WB Density
Density (veh/mile/ln)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
24.3 24.1
12.1 11.3
24.5 24.0
17.4 15.8
24.5 24.0
24.5 24.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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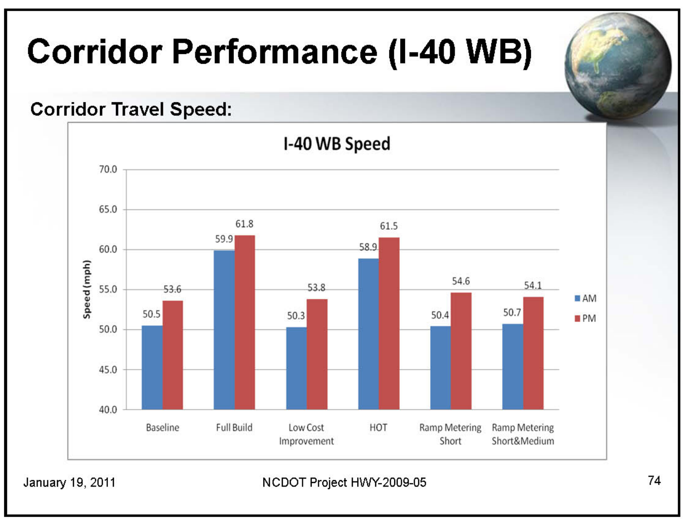
Corridor Performance (I-40 WB)
Corridor Travel Speed:
I-40 WB Speed
Speed (mph)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
50.5 53.6
59.9 61.8
50.3 53.8
58.9 61.5
50.4 54.6
50.7 54.1
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
AM
PM
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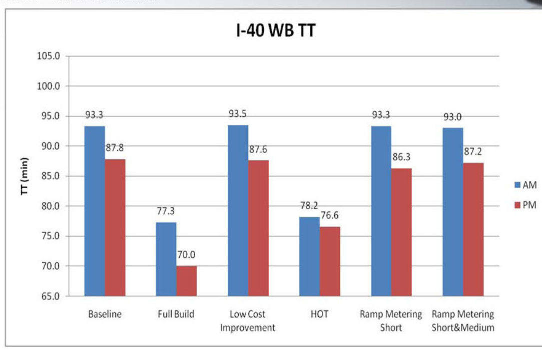
Corridor Performance (I-40 WB)

Corridor Travel Time:



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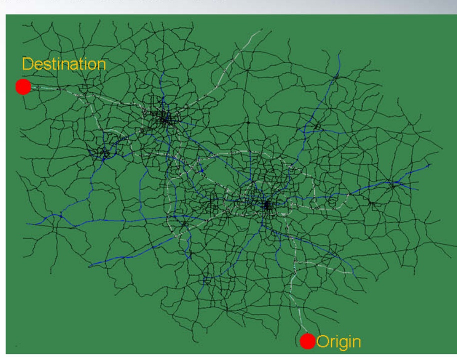
Key OD Performance – Multiple Routes Considered



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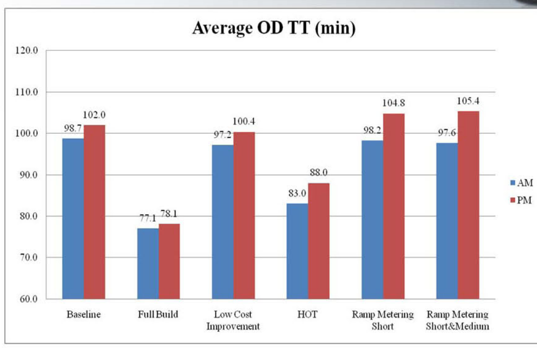
Key OD Performance (cont.)



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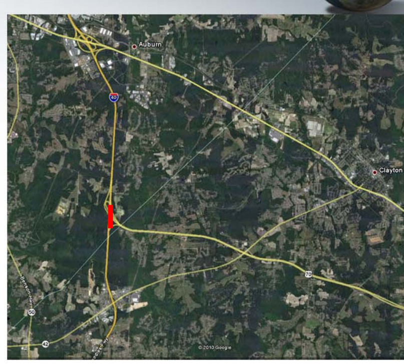
Critical Link Performance AM Peak

- I-40 WB
- Length: 0.45 mile



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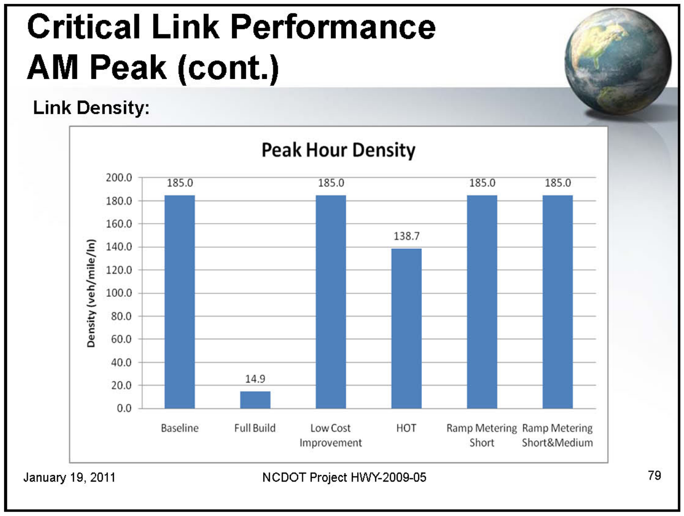
Critical Link Performance
AM Peak (cont.)
Link Density:
Peak Hour Density
Density (veh/mile/ln)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
185.0
14.9
185.0
138.7
185.0
185.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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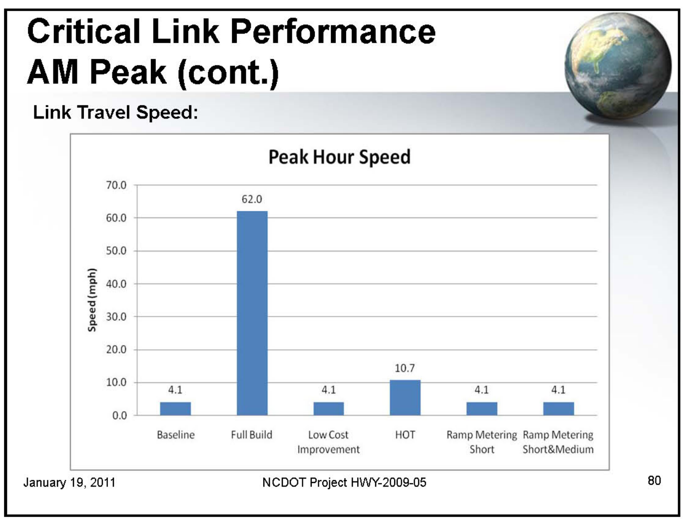
Critical Link Performance
AM Peak (cont.)
Link Travel Speed:
Peak Hour Speed
Speed (mph)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.1
62.0
4.1
10.7
4.1
4.1
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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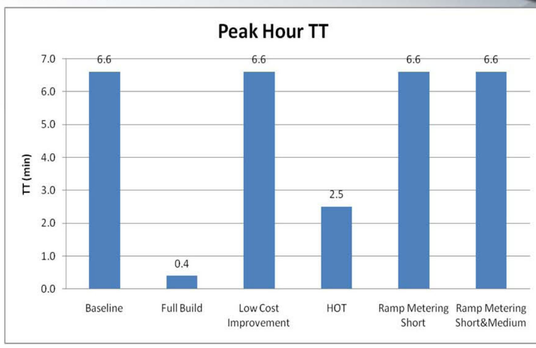
Critical Link Performance AM Peak (cont.)

Link Travel Time:



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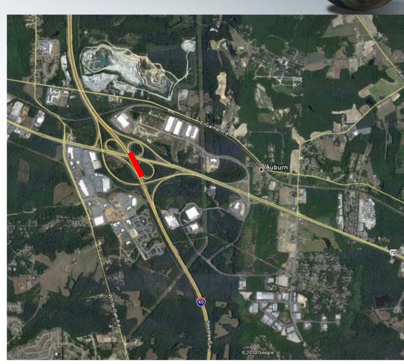
Critical Link Performance PM Peak

- I-40 EB
- Length: 0.3 mile



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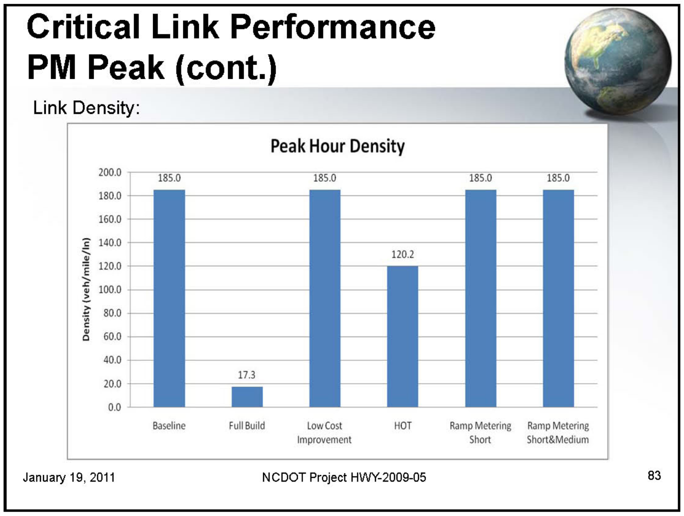
Critical Link Performance
PM Peak (cont.)
Link Density:
Peak Hour Density
Density (veh/mile/ln)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
185.0
17.3
185.0
120.2
185.0
185.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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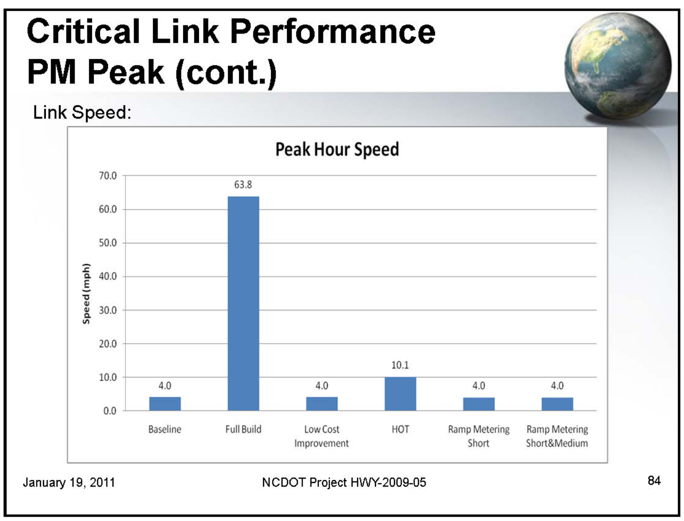
Critical Link Performance
PM Peak (cont.)
Link Speed:
Peak Hour Speed
Speed (mph)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.0
63.8
4.0
10.1
4.0
4.0
Baseline
Full Build
Low Cost Improvement
HOT
Ramp Metering Short
Ramp Metering Short&Medium
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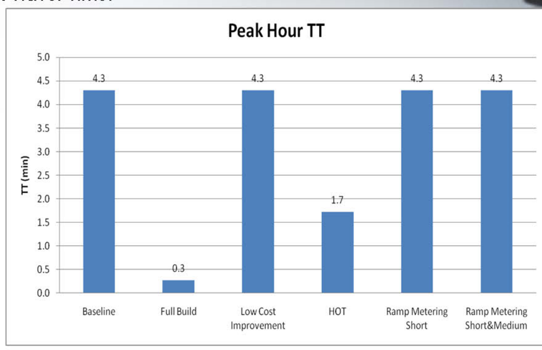
Critical Link Performance PM Peak (cont.)

Link Travel Time:



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Hands On Interaction with the TRM 2015 Model

AM Baseline

- Load network (look for TRM Baseline AM.dws on local hard drive)
- Load simulation results
- Load vehicle trajectories
- View MOEs

AM HOT

- Load AM HOT scenario (look for HOT AM.dws and follow same steps as done previously)
- View specified toll rates (Project > Scenario Data : Pricing)
- Compare link MOEs of AM HOT scenario against baseline

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Key Lessons Learned About Regional Modeling with DynusT

- Significant effort to "*clean up*" the network when converting from regional demand model format to DynusT. Manual corrections will be inevitable and may require a few weeks to complete the input.
- If possible obtain close to final OD table by vehicle class. Size of tables is very large and requires specialized software for manipulation (SAS)
- DynusT Online User Manual is still a work in progress
- Some incompatibilities still exist between DynusT and NEXTA as they evolve as related but independent software

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Key Lessons Learned About Regional Modeling with DynusT

- Various modeling platforms not easily comparable in terms of their outputs (e.g. DynusT and IDAS). However, each has its role in the ITS evaluation process.
- DynusT type models are likely to continue to progress at the national level since they:
  - Integrate planning and operational features of network operations within an acceptable computational cost
  - Enable the incorporation of pricing mechanism effects
  - Enable the accounting for information sources and quality on mobility and other impacts

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Future of DynusT and Relevant Ongoing Research

- DynusT is Moving to Open Source
- SHRP2 – C05 Will Bring New Features –
  - Stochastic freeway capacity and saturation flow rate at signalized intersections
  - Day to day learning algorithms with "bounded rationality"
  - Additional post-processing tools such as bottleneck analysis
- Follow on research to C-05 proposed to further improve the tool to include non-recurring congestion

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Summary and Wrap Up

- Brief Recap
- Reactions, Comments, and Questions
- Open Discussion

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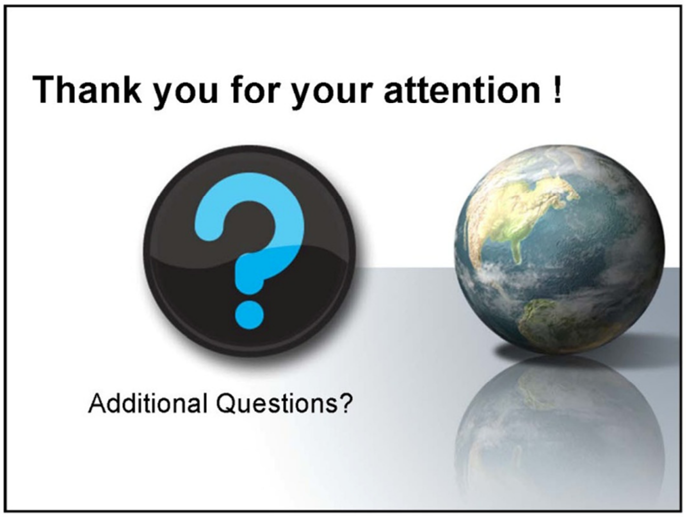
Thank you for your attention !
Additional Questions?

APPENDIX E. DIGITAL FILES DELIVERED

Files used for TRM 2015 network (project-scenario analysis):

- **Scenario #1: 2015 Baseline**
  DYNUST project name: *TRM 2015 Baseline AM.dws* and *TRM 2015 Baseline PM.dws*
- **Scenario #2: Full build network**
  DYNUST project name: *Full Build AM.dws* and *Full Build PM.dws*
- **Scenario #3: Low-cost bottleneck improvements**
  DYNUST project name: *Low Cost AM.dws* and *Low Cost PM.dws*
- **Scenario #4: HOT Lanes**
  DYNUST project name: *HOT AM.dws* and *HOT PM.dws*
- **Scenario #5: Ramp metering (short term)**
  DYNUST project name: *Ramp Metering Short AM.dws* and *Ramp Metering Short PM.dws*
- **Scenario #6: Ramp metering (short & Medium term)**
  DYNUST project name: *Ramp Metering Short&Median AM.dws* and *Ramp Metering Short&Median PM.dws*

It should be noted that above six scenarios were analyzed for both AM and PM periods.

Files used for Fort Worth Network (workshop demonstration):

- **Scenario #1: Baseline**
  DYNUST project name: *Baseline.dws*
- **Scenario #2: Increased traffic demand**
  DYNUST project name: *Increased Demand.dws*
- **Scenario #3: Traditional capacity addition**
  DYNUST project name: *Lane Addition.dws*
- **Scenario #4: Congestion warning VMS**
  DYNUST project name: *VMS.dws*
- **Scenario #5: Ramp metering**
  DYNUST project name: *Ramp Metering.dws*