Use of Advanced Analysis Tools to Support Freeway Corridor Freight Planning

Final Report

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Disclaimer

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

Metric Conversion Chart

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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Mr. Vidya Mysore of the Systems Planning Office at the Florida Department of Transportation served as the project manager for this project.

16. Abstract

Advanced corridor freight management and pricing strategies are increasingly being chosen to address freight mobility challenges. As a result, evaluation tools are needed to assess the benefits of these strategies as compared to other alternatives. The goal of this project is to investigate methods and tools that can be used to assess combinations of such improvement strategies as part of the corridor freight planning process.

The assessment environment developed in this project utilizes a dynamic traffic assignment (DTA)/mesoscopic traffic simulation tool that is integrated with the Florida statewide traffic demand forecasting model (FLSWM). The developed environment includes utilities to convert the FLSWM network and demand files to DTA tool inputs. A method is used to estimate the time-variant (short-time interval) demand matrices required as inputs to the DTA tool. Both conventional traffic detector data and data obtained from Intelligent Transportation Systems (ITS) detectors are imported to the developed environment. The imported data is used to support the calibration of the traffic flow model of the DTA tool and to estimate the time variant demand matrices. The study demonstrates the use of the developed environment in assessing two advanced corridor freight management strategies: advanced traveler information systems and truck/toll lanes.

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Executive Summary

Increasing congestion of transportation networks has significantly constrained freight mobility, leading to higher direct economic costs for producers and consumers. Furthermore, the increase in freight traffic demand has also led to significant indirect costs related to additional mobility issues, safety issues, and environmental impacts associated with the transportation systems. Advanced corridor freight management and pricing strategies are increasingly being chosen to address freight mobility challenges and freight impacts on transportation systems. To assist in the decision making process when selecting these strategies, advanced evaluation tools are needed to assess the benefits of these strategies as compared to other alternatives, and to aid in selecting the best sets of parameters associated with these strategies.

The goal of this project is to investigate methods and tools that can be used to assess the combinations of corridor freight management and pricing strategies as part of the corridor freight planning process.

The specific objectives of the project are (1) identification and development of advanced analysis tool(s) and methods, which are able to assess the effectiveness of advanced technologies and strategies in support of corridor freight management; (2) identification of the required data and the sources of the data to support the aforementioned assessment; and (3) illustration of the use of the identified tools and methods to assess selected corridor freight management strategies.

The assessment environment developed in this project utilizes a dynamic traffic assignment (DTA)/mesoscopic traffic simulation tool (Dynasmart/DynusT) that is integrated with the Florida statewide traffic demand forecasting model (FLSWM). As such, a number of tools and methods must be developed by this study to assist in this utilization.

The first task of this research is a literature review in areas relevant to the tasks herein. The review areas include corridor freight management strategies, evaluation approaches and tools that have been used to assess the impacts of management strategy alternatives, and proposed methods for dynamic (time-variant) trip matrix estimation.

Advanced modeling such as DTA requires detailed and high quality data to ensure accurate modeling of the transportation system. In this study, data from various sources were used including data obtained from both conventional traffic detectors and Intelligent Transportation Systems (ITS) detectors. Data from these sources are imported to the developed environment and used in the calibration of the utilized models to estimate the time-variant demand matrices, as described below.

One of the important sets of inputs to advanced modeling tools are the network physical attributes. Considering that many of the attributes required as inputs to the advanced tools are also required inputs to demand forecasting models, the developments of this study include a utility that converts sub-networks extracted from the Florida statewide demand model to the transportation network format, in the DTA tool (Dynasmart/DynusT) selected herein. Once the automatic conversion is performed using this tool, the analyst can refine the network and add additional details, as needed, to satisfy the requirements of the more detailed modeling of the DTA tool.

An additional utility was developed in this study to convert the trip tables of the Florida statewide demand model to the selected DTA format. In the selected DTA tool (Dynasmart/DynusT), the user can input a maximum of three matrices for each modeling interval. Cube allows the user to code a large number of trip matrices and is much more flexible in this regard. Thus, the conversion procedure has to account for this limitation of the DTA tool. In addition, DTA requires *time-variant* trip matrices specified for short time intervals (e.g., 15 minutes or 30 minutes). This study uses a multi-step procedure to estimate time-variant matrices. The first step is to convert the daily matrices or peak-period matrices to hourly matrices using hourly distribution factors that are derived to reflect the proportion of the trip tables for each hour of the day. Second, these matrices are adjusted using the Cube Analyst matrix estimation program. This matrix estimation process considers a number of input parameters based on the static assignment process of the Cube demand forecasting tool. Finally, an optimization procedure is used to derive the time-variant trip matrices based on minimizing the differences between the measured volumes and the volumes produced by the DTA (with consideration of the initial trip tables, resulting through the Cube Analyst estimation process mentioned above).

The macroscopic traffic flow model used in the selected DTA tool is the Modified Greenshields model. In this study, the parameters of the modified Greenshields model were derived for freeways using an iterative procedure combined with regression analyses. The availability of detailed ITS data on I-95 and I-295 in the Jacksonville area allows the calibration of the model parameters for freeways. However, for arterial streets, the default values of the parameters are used in this study due to the unavailability of detector data for these segments at the present time.

Another important and challenging task of applying dynamic traffic assignment is the calibration of the application to reproduce traffic parameters measured in the field such as volumes and speeds. In this study, this calibration is conducted, at least in part, in an iterative manner with the time-variant demand estimation process mentioned above.

The results from modeling tools such as dynamic traffic assignment can be further processed to supply additional performance measures not provided by the tools, or provided by the tools but with different estimation parameters from what is required by the analyst. In this study, a utility was developed to illustrate the post-processing of the outputs of the DTA tool. Three modules are introduced as examples for such post-processing. These modules allow the calculation of safety impacts, emission, and fuel consumption based on the selected DTA tool outputs.

The developed environment in this study is applied to the assessment of two advanced corridor freight management strategies: advanced traveler information systems and truck/toll lanes. This application is made to illustrate the ability of the developed environment to model such advanced strategies. The modeling of the two strategies takes advantage of the DTA tool's ability to account for different types of road users/vehicles and their different responses to pricing strategies and provided traveler information.

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1. Introduction

This section is an introduction to the final report of the Florida Department of Transportation project entitled "Use of Advanced Analysis Tools to Support Freeway Corridor Freight Planning." It includes background information, the project goal and objectives, and an overview of the project activities.

1.1. Background

Increasing congestion of transportation networks has significantly constrained freight mobility. This congestion has led to higher direct economic costs for producers and consumers. In addition, the increase in freight traffic demand has led to significant indirect costs associated with additional mobility issues, safety issues, and environmental impacts.[1] The Federal Highway Administration estimated that delays caused by highway bottlenecks cost the trucking industry alone more than $8 billion a year in the United States.[2]

According to United States Department of Transportation (USDOT) estimates, the volume of goods moved by truck and rail is projected to increase 98% and 88%, respectively, by 2035 from the 2002 levels[3]. This will increase the adverse effects mentioned above, particularly considering the limitations on the capacity of the transportation infrastructure. Thus, advanced management and pricing strategies will increasingly be chosen to address freight mobility challenges.

Planners face challenges when attempting to propose freight improvements. These challenges include competition for public funds from non-freight projects, gaining community support, the lack of coordination among various government entities, and private sector stakeholders, and limited or restricted availability of public funds for freight transportation[1]. Thus, advanced evaluation tools will be needed to assess the benefits and costs of freight improvement alternatives as compared to other alternatives. Such tools will be essential in corridor freight planning. Corridor freight planning will increasingly include the assessment of combinations of advanced infrastructure and operational strategies such as capacity additions, truck lanes, express toll lanes, congestion pricing, intelligent transportation systems, optimized commercial vehicle routing, and optimized business hours. This project aims to investigate the development of methods and tools that can be used to adequately assess various combinations of these improvements.

1.2. Project Goal and Objectives

The goal of this project is the investigation of those methods and tools used to assess combinations of improvement strategies as part of the corridor freight planning process. The specific objectives of the study are as follows:

1. Identification and development of advanced analysis tool(s) and methods, which are able to assess the effectiveness of advanced technologies and strategies in support of corridor freight management.
2. Identification of the required data and the sources of the data to support the above mentioned assessment.
3. Investigation of the use of the tools and methods identified to assess the selected corridor freight management strategies.

1.3. Overview of the Project Activities

This section presents an overview of the project processes that will be detailed in the remaining chapters of this document. To meet the project objectives listed in the previous section, the project tasks include the development of methods for the use of dynamic traffic assignment (DTA)/mesoscopic traffic simulation tool(s) to assess corridor freight management strategies and the development of tools to support this use. The project tasks include the following:

- A literature review with emphasis on corridor freight management strategies, advanced strategy evaluation approaches, and dynamic trip matrix estimation. The estimation of dynamic (time-variant) trip matrix is critical to a successful implementation of DTA. The literature review is presented in Chapter 2 of this document.
- Detailed traffic data are required for the use of the advanced tools investigated in this study. Both conventional traffic detector data and data obtained from Intelligent Transportation Systems (ITS) detectors were used in this study. Chapter 3 describes the data and the tools used to process it.
- As with other modeling tools, DTA/mesoscopic simulation models require the specification of the configuration and geometry of the modeled transportation network. A tool was developed in this study to convert extracted subarea transportation networks from the Florida FSUTMS statewide model to the input format of the DTA tool utilized herein. The user can edit the converted network to add details or correct problems with the network. Chapter 4 of this document describes the network conversion process and the tool developed to support this process.
- All DTA models require the use of trip demand matrices, also referred to as origin-destination (O-D) matrices. A tool was developed in this study to conduct the required transformations of the daily trip matrices of the FSUTMS statewide model to allow their use as initial seed matrices in the dynamic trip matrix estimation process, outlined later in this list. Chapter 5 presents a discussion of this transformation.
- The mesoscopic simulation models that are used in conjunction with the DTA tools include traffic flow model parameters that can be calibrated by the user. Chapter 6 discusses the derivation of these model parameters in this study.
- The calculation of dynamic (short-interval time-variant) trip matrices of a robust quality is essential to the successful implementation of DTA. Chapter 7 details the method used for this purpose.
- To illustrate the use of the tools identified and developed to assess advanced corridor freight management strategies, this study investigates the assessment of

two strategies: advanced traveler information systems and truck/toll lanes. Chapters 8 and 9 include a discussion of this investigation.

- The developed tools in this project include a user interface that was developed using Visual Studio and the Cube tool script language. Chapter 10 includes a review of this user interface.
- Modules were used in this study to post-process the data produced by the DTA tool to obtain additional performance measures including emission, fuel consumption, and safety impacts. Chapter 11 includes a discussion of this processing of the outputs.

The selected DTA/mesoscopic model tool in this study is the Dynasmart-P tool, developed for the Federal Highway Administration (FHWA). This tool has many of the functionalities required for the assessment of advanced corridor freight management strategies. In addition, the tool is supported by the FHWA DTA program and it was felt that it is a logical choice for this study. More detailed evaluation and selection among existing DTA tools will be conducted as part of a FDOT DTA research project that is starting soon. However, based on conversations with a team that supports the FHWA in DTA development and maintenance, DynusT, a DTA tool that is a modification of Dynasmart, was used in many of the tasks of this study. The official version of Dynsmart does not allow the specification of different tolls for different vehicle types. Thus, different toll fees could not be assigned for freight vehicles with this tool. DynsuT allows such assignment and can be used to assess truck toll lane strategies. However, as discussed later in this document, software bugs were found with DynsuT when using the tool to simulate advanced traveler information systems. Thus, the official version of Dynasmart was used for this evaluation.

The tools and methods of this study were tested using a network located in the Jacksonville area that is extracted from the Florida Statewide FSUTMS model. This model is referred to as the Integrated Florida Statewide Model (FLSWM). This network is described in Chapter 4 of this document. In some cases, however, a simple hypothetical network is also used in the testing. The use of this hypothetical network simplifies the testing by allowing easier isolation of different effects.

It should be noted that although the tools of this study were used to assess Advanced Traveler Information Systems (ATIS) and truck/toll lanes for the Jacksonville network, the results of this investigation (presented in Chapters 8 and 9 of this document) should not be used to make decisions regarding the implementation of these strategies in the Jacksonville area. This is because the purpose of the investigation was simply to illustrate the use of the tools and methods of this study in assessing advanced strategies and not to support making decisions regarding specific strategies. To support these decisions, a more detailed examination of the results, and possibly additional fine-tuning of the model parameters, will be needed.

2. Literature Review

This section presents a review of the literature on topics that are relevant to the tasks of this study. The following subjects are reviewed herein:

Freight Corridor Management Strategies: The developed tool will be used to assess a number of strategies that support freight mobility on highway corridors. This section presents a review of such strategies.

Review of Existing Evaluation Tools: This section presents a review of existing tools used to assess advanced transportation strategies.

Trip Matrix Estimation: One of the most critical inputs to dynamic traffic assignment models is a set of time-variant trip (O-D) matrices that capture, as close as possible, the dynamic nature of transportation system demands. This section includes a review of previous studies that address time-variant O-D matrix estimation with consideration to freight demand matrix estimation.

2.1. Freight Corridor Management Strategies

As stated in the Introduction section of this document, innovative and advanced strategies will increasingly be required to address corridor freight mobility problems. The Government Accountability Office of the United States Congress (GAO) reviewed various strategies to address freight transportation problems[1,3]. Among these strategies were a number of strategies that are applicable to corridor freight management problems, as listed below:

- ***Capacity addition:*** This approach is to add new capacity to the transportation network by adding lanes, widening roads and bridges, and building new roads and bridges. Improving or replacing bridges at certain locations can improve freight transportation and the impact on the transportation network. The highway project and bridge replacement can allow trucks to transport their loads more quickly from/to the ports.

- ***Truck lanes:*** A special case of the capacity addition strategy is the addition of truck-only lanes, which are lanes designated for trucks that are physically separated from passenger vehicles. A detailed discussion of truck lane analyses and previous studies on the subject is presented in Chapter 9 of this document.
- ***Virtual container yard:*** A virtual container yard is a web-based information exchange platform that allows users to match empty equipment needs so they can interchange, or *street turn*, empty containers without first returning them to a terminal, rail ramp, or container yard.
- ***Hours of operation/Extending business hours:*** Modifying operation hours and extending business hours can improve the freight corridor operations and reduce peak hour congestion. For example, some businesses in New York City have extended the hours of operation for receiving shipments to reduce peak daytime traffic congestion. As a result, these businesses receive special incentives from the city to receive deliveries late in the day.
- ***Congestion Pricing/Toll Lanes:*** Congestion pricing involves charging users a toll, fee, or surcharge for using transportation infrastructure during certain peak periods of travel, while toll lanes involve charging all the users or subsets of users for using the toll lanes. An example of a congestion pricing approach related to freight traffic is that developed by PierPASS, a not-for-profit company created by marine terminal operators at the Los Angeles and Long Beach ports. This program imposes a $50 per 20-foot equivalent unit “Traffic Mitigation Fee” on loaded containers that are moved during the peak hours. The program has resulted in approximately 36% of traffic moving at night. A detailed discussion of toll lane analyses and previous studies on the subject are presented in Chapter 9 of this document.
- ***Establishing inland ports:*** An inland port is a site located away from traditional ports to reduce some of the processes required at the conventional ports. For

example, the Virginia Inland Port provides a link between truck and rail for the transport of ocean-bound containers. Containers are transported by truck from seaports located in Virginia to the Inland Port for immediate loading upon a rail car or for short-term storage prior to loading.

- ***Freight rail improvements:*** Railroad improvements include building new intermodal facilities and adding tracks to the rail network to relieve capacity constraints and enhance freight mobility.
- **On-dock rail access***:* On-dock rail places rail facilities at the port terminal, eliminating the need for transport by truck to the rail facilities.

The National I-10 Freight Corridor Study[4] was a joint effort by eight State departments of transportation, including Florida. The purpose of this study was to investigate freight specific strategies that can improve congestion along a given corridor. Seven different approaches were investigated, as follows:

- ***Widen I-10 as much as needed:*** This resulted in the average number of lanes needed by the year 2025 to increase from 6 to 10.1 lanes along urban sections and from 4.1 lanes to 5.2 lanes along rural sections. The value of the overall benefits was estimated to be $6.74 million annually per mile.
- ***Deploy Intelligent Transportation Systems (ITS) along the corridor:*** ITS deployments were evaluated using the SCRITS sketch planning spreadsheet. The ITS technologies evaluated were advanced traffic management, traveler information systems, tracking/dispatching, commercial vehicle operations, IntelliDrive-type technologies, and emergency management**.** The overall ITS deployment benefit/cost ratio was estimated to be 3.0.
- ***Separate truck traffic from automotive traffic:*** Four possible configurations were evaluated for this separation. The best configuration resulted in a level of service improvement of the congested section by 67% in the year 2000 and by 41% in the year 2025. The value of the annual per mile savings for the truck/general traffic separation was found to be $6.25 million.

- ***Rail intermodal solution:*** This alternative yielded only 1 to 2% improvement in performance.
- ***Waterway intermodal solution:*** This alternative also gave minimal improvement.
- ***Urban truck bypass:*** This alternative was estimated to provide a truck bypass and level of service improvements that are 36%, 38%, and 35% for the years 2008, 2013, and 2025, respectively. The value of the annual savings from truck bypasses was estimated to be $4.98 million.
- ***Truck productivity:*** This alternative was found to provide minimal savings, but can be used as a complimentary solution with truck bypass and truck/auto separation.

Based on the above findings, the I-10 study recommended the implementation of the traditional approaches of capacity expansion with ITS deployment.

Andrew and Lester[5] presented an analysis of State DOT options for improving freight flows on the U.S. Interstate Highway System. The study discussed capacity enhancement options for increased mobility, including separate truck lanes, tolling, utilizing rail, and increasing capacity through infrastructure improvements. The conclusion based on a survey of state transportation agencies was that truck-only lanes will be an important strategy for future freight transportation. Managing lanes by applying tools such as pricing, eligibility, and/or limiting system access will also be an important future strategy. Finally, the study predicted that rail will play a larger role in the movement of freight in the future. The study also noted the important role that ITS strategies will play.

IntelliDrive technologies have increasingly been a focus of the USDOT Research and Development effort. IntelliDrive is a multimodal initiative that aims to enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and passengers' personal communications devices. IntelliDrive applications provide connectivity among vehicles to enable crash prevention. The applications also provide connectivity between vehicles and the infrastructure to enable safety, mobility, and environmental benefits[6].

Yin et al. (2004) assessed the feasibility of applying advanced automobile technologies referred to as cooperative vehicle-highway automation systems (CVHAS) to freight movements in the metropolitan Chicago area. The study found that truck lanes with and without CVHAS are economically feasible and that these technologies are able to help improve the performance of the intermodal freight system. The study estimated the B/C ratio for different combinations of CVHAS and truck lanes to range from 3.3 to 5.3 for different deployment alternatives. The study concluded that providing a truck-only lane at the beginning of the project, then upgrading to full automation of the truck lane in the future, results in the greatest benefit to the Chicago area freight system.

A study by Lee et al.[7] investigated the congestion and environmental impacts associated with port traffic in Los Angeles. The study's approach for assessing environmental impacts involved combining a microscopic traffic simulation model to capture detailed vehicle trajectories (speeds and accelerations) and congestion effects, with an emissions model and a spatial dispersion model to facilitate the estimation of the health and environmental justice impacts of freight corridor operations. The study investigated replacement of the current fleet of port heavy-duty diesel trucks with zero emission vehicles, elimination of port heavy-duty diesel truck trips that would correspond to shifting more containers to other modes such as rail, and implementation of a truck-restricted lane preventing trucks from using the left-most lanes. The results show that fleet replacement with cleaner trucks yields the most emission reductions.

2.2. Analysis Approaches

Different types of modeling approaches can be proposed to evaluate corridor freight operations. Thus, it is useful to include a brief review of such modeling approaches. An FHWA document[8] presented a reviewed of the types of existing tools, as listed below:

- ***Sketch-planning tools:*** For travel demand and traffic operations, sketch-planning tools estimate change by producing general order of magnitude estimates in response to transportation improvements. They allow for the evaluation of alternatives without the need of an in-depth engineering analysis, and are used primarily to prepare preliminary estimates of potential benefits. STEAM, SCRITS, IDAS, and FITSEVAL are examples of such tools.

- ***Travel demand models:*** While travel demand models allow for the prediction of travel demand, they were not designed to evaluate travel management strategies, such as ITS and operational strategies. Travel demand models have only a limited capability to accurately estimate changes in operational characteristics (such as speed, delay, and queuing) that result from the implementation of ITS/operational strategies. These inadequacies generally occur due to the poor representation of the dynamic nature of traffic in travel demand models. Examples of travel demand modeling tools are CUBE, TransCAD, and EMME/2.
- ***Analytical/deterministic tools:*** Analytical/deterministic tools implement procedures such as those of the Highway Capacity Manual (HCM) or other techniques such as queuing analysis and shockwave theory. Analytical/deterministic tools are good for analyzing the performance of isolated or small-scale transportation facilities; however, they are limited in their ability to analyze network or system effects.
- ***Macroscopic simulation models***: Macroscopic simulation models are based on the deterministic relationships of the flow, speed, and density of the traffic stream, as described above. The simulation in a macroscopic model takes place on a section-by-section basis rather than by tracking individual vehicles. Macroscopic models are less complicated and have considerably lower computer requirements than microscopic models. They do not, however, have the ability to analyze transportation improvements in as much detail as the microscopic models. The FREEVAL, the computational engine of the HCM freeway facility, is an example of this procedure.
- ***Mesoscopic simulation models:*** Mesoscopic simulation models combine the properties of both microscopic (discussed below) and macroscopic simulation models, as discussed earlier. As in microscopic models, the mesoscopic models'

unit of traffic flow is the individual vehicle. Their movement, however, follows the macroscopic approach of traffic flow. Mesoscopic models provide less fidelity than the microsimulation tools, but are superior to the typical planning analysis and macroscopic modeling techniques. Examples of mesoscopic simulation models are Dynasmart-P, Cube Avenue, Transmodeler, and Dynameq.

- ***Microscopic simulation models:*** Microscopic models simulate the movement of individual vehicles based on car-following and lane-changing theories. Vehicles are tracked through the network over small time intervals (e.g., 1 second or a fraction of a second). Modeling and computer requirements for microscopic models are large, usually limiting the network size and the number of simulation runs that can be completed. Examples of microscopic simulation models are VISSIM, Paramics, CORSIM, and AIMSUN.

From the above discussion, it can be seen that the selection of the tool-type represents a tradeoff between geographic scope and level of resolution. Depending on the scope of analysis, various tool-types can be applied to corridor freight management analysis.

2.3. Estimation of Time-Variant Trip Matrices

Dynamic (time-variant) trip (Origin-Destination or O-D) matrices are required inputs to dynamic traffic assignment (DTA) analysis. Information gathered for estimating static trip matrices for the purposes of planning demand forecasting models, however, is not detailed enough to estimate dynamic trip matrices for DTA tools. Thus, methods have been developed to estimate these dynamic matrices based on the demand forecasting model trip information, combined with other information such as link traffic counts. These methods are discussed in this section.

Currently, dynamic trip matrix estimation methods can be classified as assignment based or non-assignment based methods, according to whether or not an assignment routine is used as part of the estimation process[9]. Non-assignment based O-D estimation models are too complicated to solve for a large network. Thus, dynamic O-D estimations in most recent studies utilize assignment based estimation models. These models employ traffic assignment as part of a process to obtain the dynamic relationship between traffic demand (in terms of O-D pair demands) and traffic measurements (in terms of link traffic counts). Optimization algorithms are applied to estimate dynamic O-D matrices by minimizing the differences between observed and simulated traffic count measurements. In most cases, the optimization procedures also consider initial values for the O-D matrices and other variables, and attempt to reduce the deviation from these values, as explained later in this document.

Because of the multidimensional and nonlinear nature of dynamic O-D estimation problems, the final estimation result depends heavily on the initial O-D matrix. Thus, a good initial O-D matrix estimation method is needed. This section first presents a review of past studies that attempted to estimate more fine-grained trip matrices based on *static* traffic assignment; a review is then presented of estimation methods based on *dynamic* traffic assignment. Finally, a review is presented of the methods used to estimate truck trip matrices, which is of particular importance to this study.

2.3.1. O-D Matrix Estimation based on Static Assignment

Static O-D matrix estimation for regional demand forecasting models are usually based on data collected using home and/or road surveys. O-D matrices for static models, however, have also been estimated at least in part based on traffic counts. Static O-D matrix estimation matrices are used mainly in transportation planning demand forecasting models. However, they can also be used as a basis for estimating initial O-D matrices for dynamic O-D estimation procedures.

Chu et al.[10] adopted a trial-and-error procedure to slice O-D matrices of the peak period from a planning model into five minute time-dependent O-D matrices based on time-variant observed traffic volumes. Lin[11] proposed another initial O-D estimation method based on the traffic conservation condition. In this study, a large road network was decomposed into several simple sub-networks, and the partial O-D matrices were estimated iteratively from the first sub-network to the last sub-network.

Cube includes a tool that estimates trip matrices based on traffic counts and an initial seed matrix. The tool is referred to as Cube Analyst[11]. The estimation process is based on the maximum likelihood technique, and data from different sources are used. The user can assign different levels of confidence or reliability levels. The additional data could include flow counts, prior (old) matrices, partially observed matrices, zonal trip end (generation and attraction) data, vehicle routing, travel cost matrices, and previously calibrated trip cost distribution functions. These data types are described below.

- Link counts: This information can be obtained from automatic counters, permanent count stations, or ITS data. However, in the case of oversaturated conditions, the counts may not show the current demand for travel (which the O-D matrix should represent).
- Turning counts: Turning counts can also be used. However, the same comments for link counts apply.
- Prior trip matrix: This matrix might be an out-of-date matrix for the study area, derived from the planning model forecasts or possibly a previous study forecast.
- Trip cost matrix: This matrix summarizes the cost of travel between zones, where cost is normally defined as a user-specified combination of time and distance, and any tolls or fares. The costs may be based on either modeled or surveyed speed data.
- Partial O-D matrix: With Cube Analyst, it is possible to use partial information that specifies the demands for some O-D cells.
- Trip ends: The total number of trips generated from and/or attracted to zones can also be used.
- Routing information: It is possible to survey routing data, though this is rarely done. Cube Analyst can use routing information, if available.
- Cost distribution function

- Partail-trip data: These are O-D matrices in which the origin and destination is not necessarily the ultimate origin and destination of the trips.

Safety Analyst can use any of the above information, when provided, as inputs by the user to the matrix estimation model.

2.3.2. O-D Estimation Based on Dynamic Assignment

A number of studies have proposed trip (O-D) matrix estimation based on dynamic traffic assignment. These studies have used least-square based methods, maximum likelihood methods, and Kalman filter methods.

Tavana and Mahmassani [12] (2001) proposed a bi-level optimization structure for estimating the dynamic O-D matrix from observed traffic volume data. At the upper level, the generalized least square method is used to minimize the difference between the observed and simulated traffic counts. At the lower level, a DTA simulator is employed to perform user equilibrium (UE) assignment to then generate dynamic link proportion matrices (the proportions of each O-D pair demands on each link), which are required inputs to the optimization process. Zhou et al. [13] improved the dynamic O-D estimation method of Tavana and Mahmassani by incorporating a historic estimated O-D matrix into the upper level function, which allowed for the full utilization of a priori-known O-D demand information, and improved the stability of the solutions.

Gajewski et al.[14] proposed an integrated square error (L2E) dynamic O-D estimation model instead of the traditional least square (LS) model. The L2E model was claimed to be more theoretically robust for the measurement of traffic error.

Van Aerde et al.[15] introduced the QUEENSOD model for generating dynamic synthetic O-D matrices and applied the QUEENSOD model to a 35 km section of a highway. Based on an iterative approach, the QUEENSOD model starts the first iteration from a seed O-D matrix, which can be a uniform or historic O-D matrix. The adjustment of the seed O-D matrix is conducted based on the quantitative comparisons between observed and estimated link flows. In this manner, the seed O-D matrix is systematically modified to produce a new O-D matrix. Hellianga and Van Aerde compared a least square error (LSE) model and least relative error (LRE) model. The first minimizes the sum of the squared absolute deviations between the estimated and observed flows. The later minimizes the relative link error. The two models were applied to the 35 km section of the highway mentioned above. The study results showed that the LRE model provides better estimates than the LSE model. The study concluded that the LSE model tends to overestimate the link flows.

Ashok[16] developed a method to address the off-line and real-time O-D estimation and prediction problems. Generalized least square models (linear or non-linear) were used to estimate the unknown parameters. A Kalman filter algorithm was used to solve the least square method problems in an incremental fashion for real-time applications, and to allow an update to the solution when additional data is available.

Hu[17] used a Kalman filter algorithm in dynamic O-D estimation for the predication problem. The approach was evaluated at the hypothetical freeway network. The advantage of a Kalman filter algorithm is its ability to accommodate estimation and on-line prediction of the dynamic O-D matrix. The main drawback of the Kalman filter algorithm appears to be its inability to handle large scale O-D estimation problems.

He et al. [18] proposed a maximum likelihood estimation approach to estimate parameters of dynamic O-D demand and route choice, simultaneously. The paper presented approximates the joint probability distribution function of the temporal link flows on a network. The proposed model can incorporate prior information and estimate the parameters with measurement errors and incomplete data.

Based on the above review, it appears that the relative square error is generally the recommended method for use in the estimation of O-D matrices for off-line applications. Other models, such as the Kalman filter algorithm, have been proposed, but the solutions of these algorithms are hard to compute because they require the inverse of large scale matrices and cannot exploit the sparsity of a given matrix[19]. As such, Kalman filter algorithms have mainly been proposed for on-line (real-time) applications.

2.3.3. Estimation of Truck Trip Matrices

Since a major focus of this study is freight traffic, this section presents a review of the methods used for estimating freight and truck trip matrices. Pendyala[20] reviewed the approaches used for freight transportation demand estimation. In the trip generation step, two approaches were identified, as follows:

- The commodity based approach: With this approach, the focus is on the producers and consumers of goods. Economic data and input-output information are used to estimate the production and attraction for each commodity in each zone. One problem with this approach is that it is ill-equipped to deal with secondary movements (multi-channel distribution and trans-shipments between modes). In addition, this approach requires more detailed socioeconomic data. Another issue is that a method needs to be derived to convert the commodity tonnage flow to truck flows. On the other hand, this approach has the potential to better estimate the production and attraction in each zone, and the implications of changing policies on these productions and attractions.
- The vehicle-based approach: In the vehicle-based approach, the truck trips are generated directly, usually based on land use. The developed models are similar to those used for passenger car trip generation. This approach assumes that the truck trip can be estimated based on socioeconomic factors, such as employments without consideration to the estimates of the production and consumption of different commodities in the zone. A vehicle-based approach is usually used for estimating trip matrices for non-good movement trucks. The two primary subcategories of these trucks are construction and service/repair.

As stated earlier, this study uses the Integrated Florida Statewide Model (FLSWM) as the basis for its modeling activities. The truck trip generation estimation is based on freight tonnage estimation by commodity group, and non-freight truck trip estimation by vehicle class, using trip rates from the Quick Response Freight Manual (QRFM). The resulting freight tons and non-freight truck trips are inputs, along with the distance and time skims from the highway network, to the trip distribution module, which uses a gravity model.

A number of studies have investigated the estimation or modifying truck trip matrices based on traffic counts. List and Turnquist[21] developed a formula for estimating multi-class truck trip matrices for truck flows in urban areas with the capability of using various input data, including (1) link volumes or classification counts, (2) partial O-D estimates for various zones, including time periods and truck classification, and (3) origin/destination trip information. List et al.[22] improved the aforementioned work of List and Turnquist by adding new types of information to the original input set, introducing a new solution engine to address large-scale problems, and identifying a seed-trip table for use as an initial matrix for the search process.

Crainic et al.[23] introduced a model for adjusting freight demand matrices to observed flows for the multimodal, multicommodity transportation planning process, and described an algorithm to solve the corresponding bi-level optimization problem. They implemented the proposed algorithm using STAN, an interactive-graphic transportation planning package designed for the national or regional strategic analysis and planning of multimode, multiproduct freight transportation. Data from an actual application was then used to characterize the performance of the proposed methodology.

Al-Battaineh and Kaysi[24] developed a model that combines truck trip generation using the commodity based approach, with O-D estimation based on traffic counts. The method estimates the O-D matrix for each commodity that is transported by trucks. The method first estimates the total number of commodity generating and terminating at each zone. Truck link flows that were collected based on counts are then converted to the value of truck commodity, which are based on a commercial vehicles survey (CVS).

CVS has specific information about each surveyed truck commodity type and its value. The value of commodity shipped in each truck, when summed together for each survey station, provides the link flow in the appropriate format that is required for the optimization. After obtaining the zonal attraction and production values, the Genetic Algorithm (GA)-based O-D estimation approach is used to search for the global minimum. The input values to the GA model are the total originating vector O, terminating vector T, and the link counts from the CVS.

2.4. Assessment

Based on the literature review presented above, it can be concluded that there are a number of advanced strategies that can be proposed to address corridor freight mobility and safety issues. The tools developed in this study will be used to assess ATIS and truck/toll lanes, for illustration purposes. These two strategies were selected for the illustration because their evaluation is challenging using the conventional modeling processes.

Various tool types can be used to support freight corridor management. Dynamic traffic assignment combined with mesoscopic simulation models seems to be the most attractive for assessing strategies on a subarea or corridor wide basis. However, microscopic simulation models may still be applicable for small networks when a more detailed assessment than can be accomplished with mesoscopic models is needed. As stated earlier, this study investigates the use of DTA/mesoscopic simulation tools as part of a modeling environment for corridor freight management.

There are a number of tools that can be used to estimate time-variant (dynamic) trip matrices. Among these, the least-square relative error approach appears to be the most attractive for off-line DTA applications. Such an approach is used in this study, as detailed in Chapter 7 of this document.

3. Data Collection and Manipulation

As mentioned in Chapter 1, the objective of this research is to investigate the use of advanced dynamic traffic assignment/mesocopic modeling tools to assess freight corridor management. Advanced modeling tools such as dynamic traffic assignment models require detailed and high-quality data to ensure that the developed model applications accurately simulate existing or future real-world conditions.

This chapter describes the collection of traffic detector data that provides estimates of measures which are essential to the development and calibration of DTA/mesoscopic simulation tool applications. These measures include counts that can be used in the derivation of time-variant trip tables, as described in Chapter 7 of this document. In addition to these data, count, speed, and occupancy measurements are useful for the calibration of the applications. The following sections describe the data collected from various sources for this study.

3.1. ITS Data

ITS deployments have the potential of providing data for transportation modeling and traffic operations that are much more detailed than what is possible from existing sources. This section presents a description of the ITS data that are useful for the objectives of the tools employed in this study.

The Florida Department of Transportation (FDOT) Districts and toll authorities around Florida have used devices such as traffic detectors to collect traffic parameters for operational purposes. These agencies utilize the SunGuide system as the central software in their traffic management centers. As such, the SunGuide system maintains operational databases for the purposes of report generation. Three of the SunGuide archive files useful for modeling are described below.

- **Incident Archives:** For each SunGuide incident record, the stored data includes timestamp, incident ID, operator, event details, and history of the event. Incident information is effective for modeling strategies such as incident management and traveler information systems.
- **Detector Data Archives:** Point traffic detector data are stored in Traffic Sensor System (TSS) text flat files, with each file including data for a 24-hour day. The TSS file contains one record for each lane of the detection stations for each 20-second polling interval. Each TSS detector record includes the following data: timestamp (HH:MM:SS 24-hour format), detector identifier, speed, occupancy, and raw counts.
- **Travel Time Archives:** These archives include travel time estimates based on point detection data. In the current version of the SunGuide, the estimates are made using a travel time estimation method referred to as the mid-point method. Each record includes the timestamp, travel time link identifier, travel time (in minutes), and link status ("in service" or "failed").

In addition to the above, the Statewide Transportation Engineering Warehouse for Archived Regional Data (STEWARD) has been developed as a proof of concept prototype for the collection and use of ITS data[25]. STEWARD archives data in a database that supports the generation of reports and queries. The development of this prototype has demonstrated that data from traffic management centers around Florida can be centrally archived in a practical manner, and that a variety of useful reports and other products can be produced. The effort concentrated on archiving information from the SunGuide traffic sensor subsystem (TSS) and the travel time subsystem (TVT). The STEWARD database contains summaries of traffic volumes, speeds, occupancies, and travel times aggregated by 5, 15, and 60-minute periods, as requested by the user. Using a web-based interface, the user can specify date and time ranges, and the detector locations, for which the data is needed. The user can also download all generated reports in comma-delimited formats, which can be easily imported into database management tools.

The STEWARD project has ended. However, a recent discussion with the FDOT has indicated that a new effort to produce an operational version of STEWARD for various agencies around Florida is being planned. Fortunately, the STEWARD data warehouse included all ITS data available from FDOT District 2, which was needed to model the Jacksonville network used as a case study in this project. STEWARD also included limited data from other districts. Since the modeling effort of this study focuses on the Jacksonville area, it was possible to use data directly from STEWARD and there was no need to utilize the TSS data files from SunGuide. Compared to raw data from the SunGuide operational databases, data from STEWARD has the advantage of being aggregated, filtered, and imputed. If STEWARD data are not available for locations, the SunGuide raw TSS files can be used. However, this data has to be filtered, cleaned, imputed, and aggregated before use.

In the Jacksonville area, the ITS data are collected from true-presence microwave traffic detectors installed for traffic management purposes. The spacing between these detectors is 0.3 to 0.5 miles. The current ITS deployment includes the I-95 corridor. It also includes the I-295 corridor between I-10 and I-95 (see Figure 3-1). There are a total of 190 detection stations, 126 on I-95, and 64 on I-295. Similar data will soon be available for I-10 in the near-future, but was not available during the period of this research. In addition, data from the I-295 section north of I-10 will be available starting in the fall of 2011. The detection measurements from I-95 and I-295 in the Jacksonville area were downloaded for the purpose of this study at the 15-minute aggregation level. A snapshot of STEWARD data are shown in Figure 3-2Figure 3-1.

Figure 3-1. Detector Locations along I-95 and I-295 in District 2

<StewardReport>
<Title>Station-level all data field data</Title>
<StartDate>10/1/2008</StartDate>
<EndDate>10/31/2008</EndDate>
<StartTime>0:00</StartTime>
<EndTime>23:59</EndTime>
<DayOfWeek>all_days</DayOfWeek>
<AggregationLevel>15Min</AggregationLevel>
</StewardReport>

DAY	TIME	STATION_	FWY_SPD	FWY_VOL	FWY_OCC	SPD_CV	VOL_RATI	ENTRY_V	EXIT_VOL	FWY_QA	ENTRY_Q	EXIT_QA	HOV_VOL	HOV_SPD	HOV_OCC	HOV_QA
10/1/2008	0:00:00	220071	65.83	112	1	2.84	7	0	0	98	0	0	0	0	0	0
10/1/2008	0:15:00	220071	66.66	106	0.9	2.52	5.44	0	0	96	0	0	0	0	0	0
10/1/2008	0:30:00	220071	62.16	99	0.9	3.27	20	0	0	98	0	0	0	0	0	0
10/1/2008	0:45:00	220071	69.82	92	0.9	2.34	20	0	0	91	0	0	0	0	0	0
10/1/2008	1:00:00	220071	67.06	78	0.8	3.02	10.5	0	0	96	0	0	0	0	0	0
10/1/2008	1:15:00	220071	64.92	71	0.8	1.43	46	0	0	93	0	0	0	0	0	0
10/1/2008	1:30:00	220071	64.94	54	0.5	1.89	33	0	0	84	0	0	0	0	0	0
10/1/2008	1:45:00	220071	68.27	60	0.7	2.27	16.5	0	0	87	0	0	0	0	0	0
10/1/2008	2:00:00	220071	66.92	74	0.8	2.11	13.67	0	0	87	0	0	0	0	0	0
10/1/2008	2:15:00	220071	69.02	66	0.7	1.65	17	0	0	80	0	0	0	0	0	0
10/1/2008	2:30:00	220071	67.24	66	0.8	2.25	9	0	0	91	0	0	0	0	0	0
10/1/2008	2:45:00	220071	70.84	67	0.9	4.52	8.75	0	0	80	0	0	0	0	0	0
10/1/2008	3:00:00	220071	70.6	80	0.8	2.52	13	0	0	87	0	0	0	0	0	0
10/1/2008	3:15:00	220071	67.27	101	0.9	4.05	7	0	0	93	0	0	0	0	0	0

Figure 3-2. Snapshot of Downloaded Data from STEWARD

3.2. Data from FDOT Statistics Office Telemetered Sites

The FDOT Statistics Office (TranStat) Traffic Monitoring Sites (TMS) are classified into permanent (telemetered) and portable (temporary) categories. This section describes the data obtained from the telemetered sites, while the next section describes the data obtained from the portable sites.

Telemetered Traffic Monitoring Sites (TTMS) refer to traffic counters that are permanently placed at specific locations throughout Florida to record the distribution and variation of traffic flow by hour of the day, day of the week, and month of the year, from year-to-year, and transmit the data to the TranStat Office in Tallahassee at the end of each day via telephone lines. These sites record traffic volumes 24 hours a day and seven days a week. They provide counts classified by vehicle type (13 FHWA classification category scheme) per lane and per direction of travel. They also provide the average speed per lane. The data is usually collected at one-hour intervals. In Jacksonville, most of the stations provide only hourly volumes.

The most common type of sensor used to collect volume data at a continuous traffic monitoring site is the single inductive loop detector. Most of the continuous traffic monitoring sites are also capable of collecting vehicle speed data. Since 1995 all Telemetred sites have been programmed to collect this data in binned files. Florida currently bins the speed data into 15 categories: <=20mph, 21-25mph, 26-30mph, 31-35mph, 36-40mph, 41-45mph, 46-50mph, 51-55mph, 56-60mph, 61-65mph, 66-70mph, 71-75mph, 76-80mph, 81- 85mph, and >=86mph. The speed data is collected by lane for each recording interval, and is generally not collected by class of vehicles.

Overall, there are about 320 statewide TTMS count locations in Florida, as presented in Figure 3-3. Each count station covers both directions of travel. As shown in Figure 3-4, there are seven operational TTMS stations in the Jacksonville region that can be used for the case study in this project.

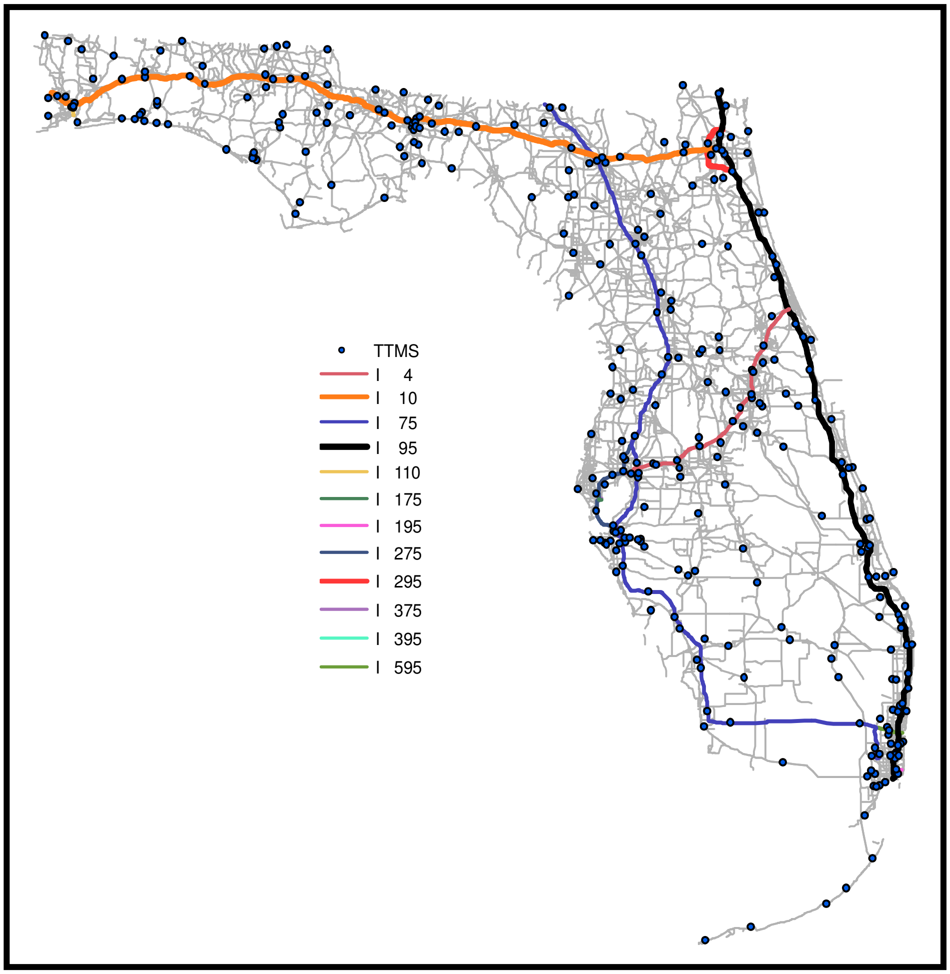


Figure 3-3. Statewide TTMS Count Stations

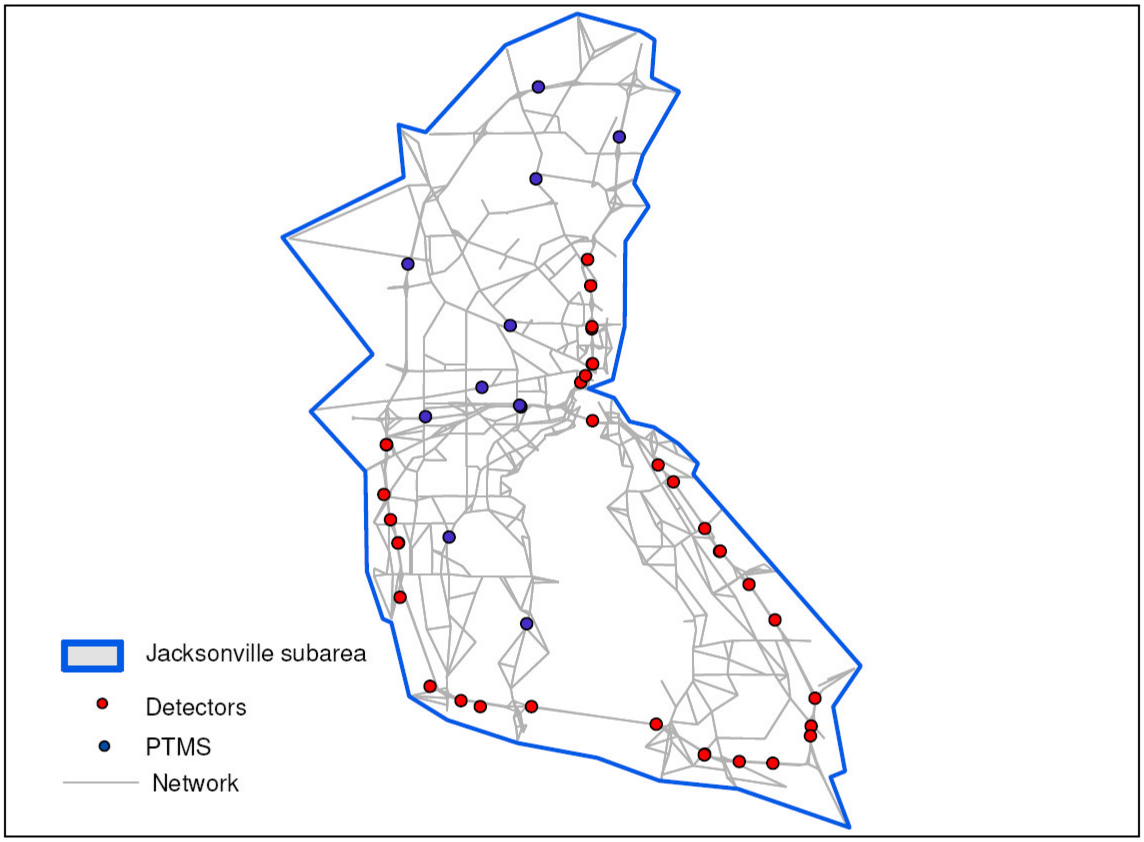
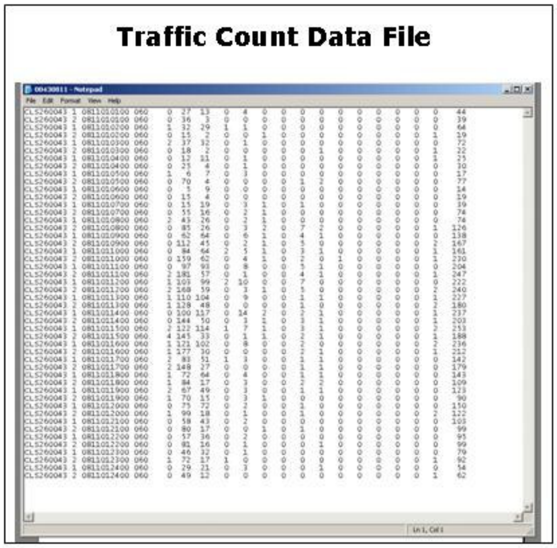


Figure 3-4. Telemetered Station Location in the Jacksonville Region

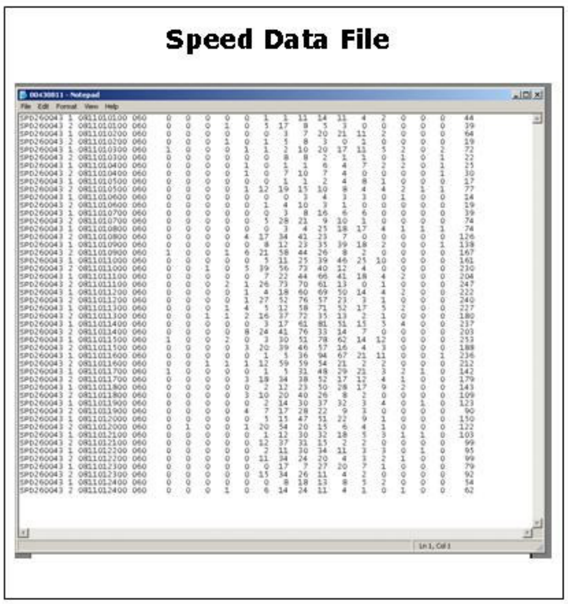
The research team obtained five-year TTMS data from FDOT (from 2003 to 2008) for the purpose of this study. The original FDOT data are in a plain text file format, with each file representing one day's traffic count or speed data for one measured data station. The format of these files is shown in Figure 3-5 and Figure 3-6. Overall, the FDOT provided a total of more than 390,000 text files for the five years. Utilizing these files directly to automatically obtain traffic information would have resulted in a tedious process, as text files are known to be slow for processing and searching, especially when the number of files is large. Thus, it was necessary to replicate the data in a relational database system and create indexes for these data to facilitate research.



Traffic Count Data Vehicle Classification Scheme

County - County identifier
Site - Site identifier
Begdate - Date for which speed count was taken
Lane - Number of lanes
Date - Edited speed data - B for Bad, N or Blank for Normal
Time - Minimum speed at the site
Bin1 - Class Group 1
Bin2 - Class Group 2
Bin3 - Class Group 3
Bin4 - Class Group 4
Bin5 - Class Group 5
Bin6 - Class Group 6
Bin7 - Class Group 7
Bin8 - Class Group 8
Bin9 - Class Group 9
Bin10 - Class Group 10
Bin11 - Class Group 11
Bin12 - Class Group 12
Bin13 - Class Group 13
Bin14 - Class Group 14
Bin15 - Class Group 15
TotVol - Total volume per direction/Day

Figure 3-5. TTMS Count Data File Structure



Speed Data Scheme

County - County identifier
Site - Site identifier
Begdate - Date for which speed count was taken
Dir - Direction of the road - North, South, East, West
Type - Edited speed data - B for Bad, N or Blank for Normal
MinSpd - Minimum speed at the site
MaxSpd - Maximum speed at the site
Int - Time interval speed collected
Bin1 - Speed between 0-20 MPH
Bin2 - Speed between 21-25 MPH
Bin3 - Speed between 26-30 MPH
Bin4 - Speed between 31-35 MPH
Bin5 - Speed between 36-40 MPH
Bin6 - Speed between 41-45 MPH
Bin7 - Speed between 46-50 MPH
Bin8 - Speed between 51-55 MPH
Bin9 - Speed between 56-60 MPH
Bin10 - Speed between 61-65 MPH
Bin11 - Speed between 66-70 MPH
Bin12 - Speed between 71-75 MPH
Bin13 - Speed between 76-80 MPH
Bin14 - Speed between 81-85 MPH
Bin15 - Speed between > 85 MPH
TotVol - Total volume per direction/Day
AvgSpd - Average speed per direction/Day
Spd85ThP - 85th speed percentile

Figure 3-6. TTMS Speed Data File Structure

A program was developed in Microsoft C# to read the text files and store them in an Oracle database table. Two database tables (named “VolumeData” and “SpeedData,” respectively) were created in the Oracle database to store the traffic count (volume) and speed information. Both tables have the same database structure, which is shown in Table 3-1. Overall, the created database includes 13,481,929 records of traffic volume data and 16,251,329 records of speed data for the five-year period. Indexes are created on the “Siteno,” “Yearinfo,” “Monthinfo,” “Dayinfo,” and “Hourinfo” fields to facilitate faster indexing and searching.

Table 3-1. Data Fields for Traffic Data Tables

Field Name	Date Type	Size	Explanation
DirectoryInfo	varchar2	50	Original text file directory name
FileName	varchar2	20	Original text file name
LaneNum	nchar	2	Lane number ID
Timeinfo	varchar2	12	Original text file time information
StartTime	varchar2	3	Start time of current data record
Num1 to Num15	varchar2	8	Detailed volume/speed information
Overall	varchar2	10	Total traffic counts for the time period
Siteno	varchar2	6	Data station number
Yearinfo	varchar2	2	Year information (“03”-“08”)
Monthinfo	varchar2	2	Month information
Dayinfo	varchar2	2	Day of month information
Hourinfo	varchar2	4	Hour and minute information

For complete and accurate archiving of the data, additional information related to the direction of travel and the lane for the measurements was acquired from FDOT, and an additional database table, referred to as “TTMS Direction,” was created in the database for this purpose.

3.3. Data from FDOT Statistics Office Portable Sites

The second types of monitoring sites maintained by the FDOT central office are Portable Traffic Monitoring Sites (PTMS). A PTMS site is a traffic monitoring site that has loops and/or axle sensors in the roadway, with leads running back into a cabinet located on the shoulder. When a traffic count is desired, a portable counter is connected to the sensor leads and placed in the cabinet. After the count has been collected, the counter is removed and placed at another count site (only the counter is portable, not the site). Counts are normally taken for a minimum of 48 hours per year between Monday 6:00 a.m. and Friday 2:00 p.m. There are a total of 453 PTMS stations in the region (see Figure 3-7). PTMS provide only 15-minute volume data. No speed or classification data are provided. In this study, data from only a limited number of PTMS stations in the Jacksonville area were used.

Figure 3-7. PTMS Station Location in the Jacksonville Region

3.4. Importing Detector Data to the Modeling Environment

To facilitate the use of TTMS data in model applications, the TTMS count locations were associated with the Florida statewide demand model network. This association was made manually using ArcGIS software. Overall, it was possible to associate TTMS stations with 598 links in the statewide model. These associated links are shown in Figure 3-8.

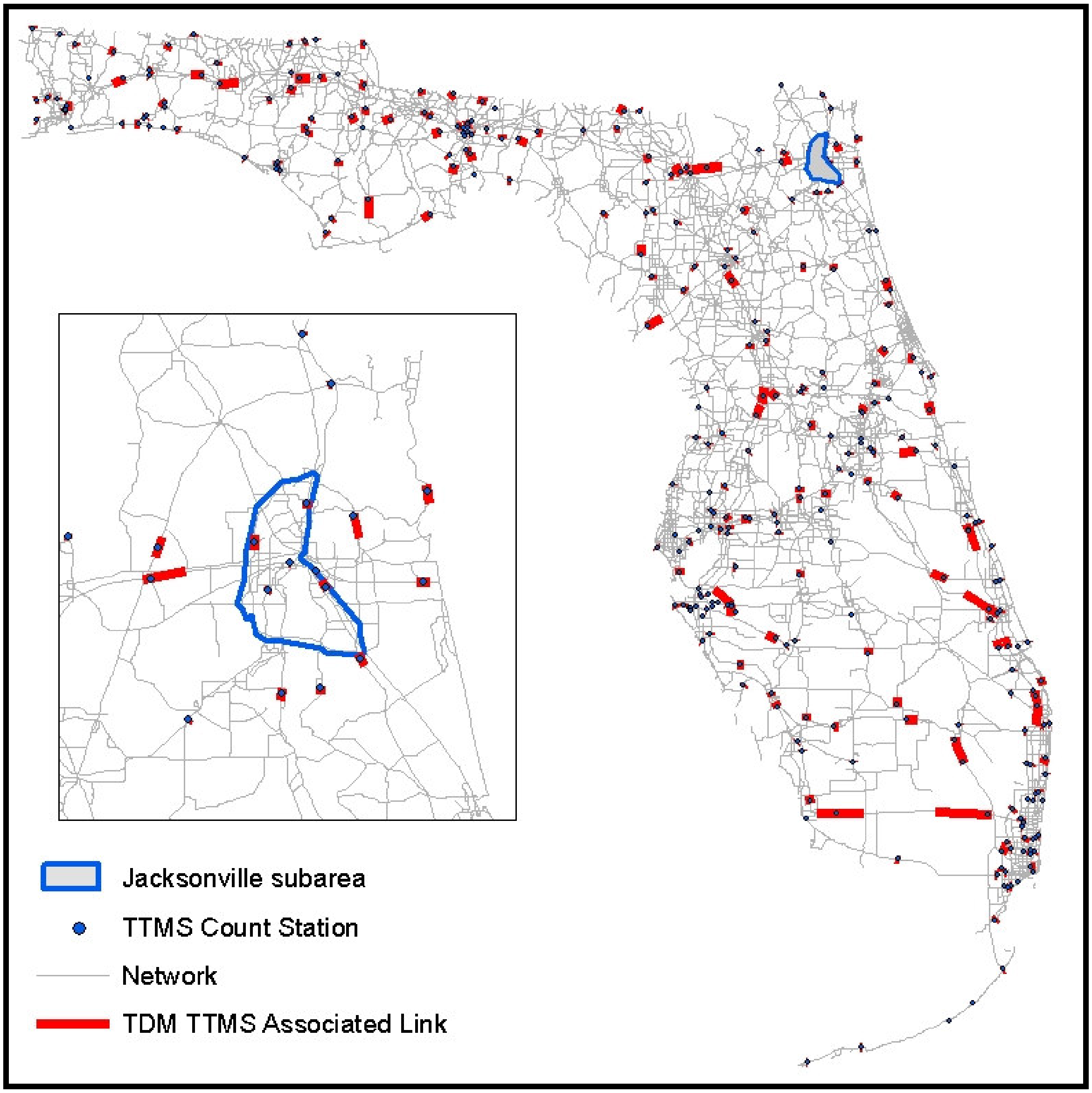


Figure 3-8. Associated Links with TTMS Count Stations

In addition, 190 ITS detectors in the study area were associated with the Jacksonville subarea network links. A select number of PTMS locations were also associated with these links to provide additional data coverage where such data was not available from other sources. The ITS detector, PTMS data locations, and the model network link files were opened in the GIS tool, allowing the matching of locations with the respective links (see Figure 3-9).

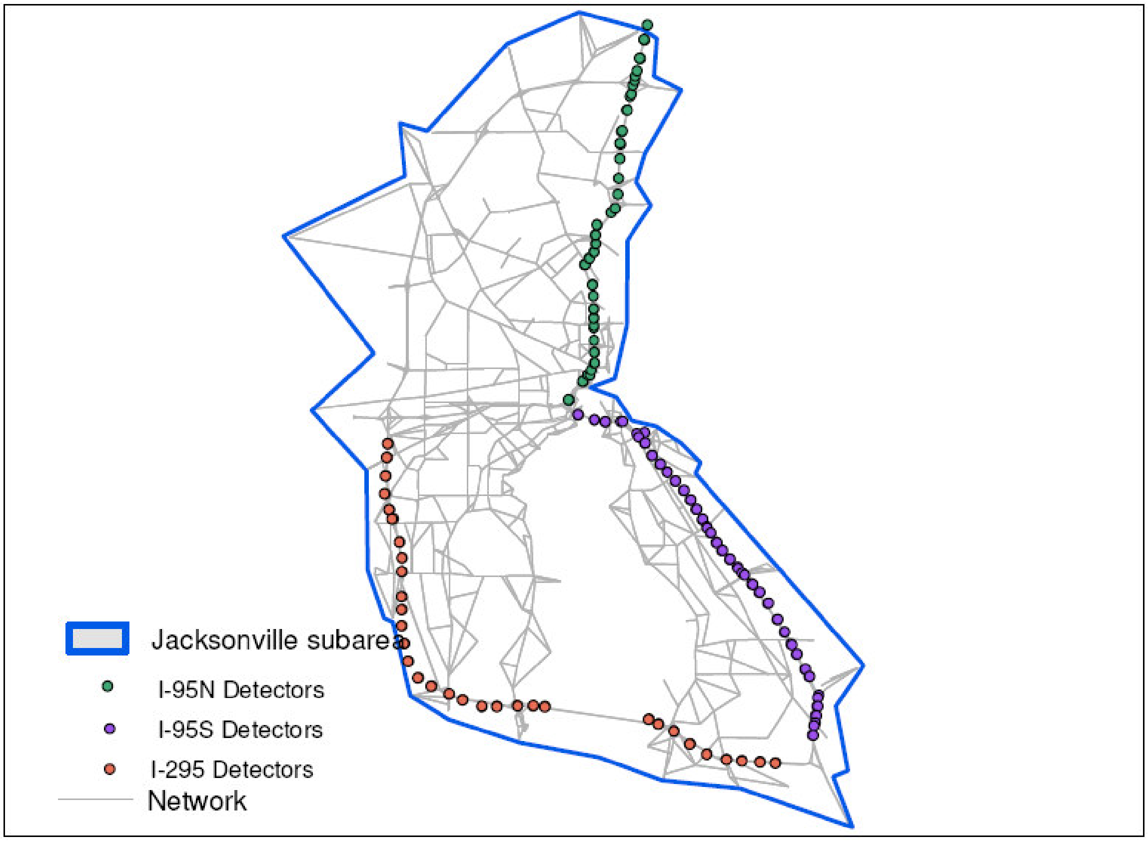


Figure 3-9. Traffic Detector Locations in Jacksonville Study Area

As part of this matching process, a number of issues need be addressed, as explained below:

- As seen in Figure 3-10, due to the high density of ITS detector deployment, each individual link can be matched with more than one detector because more than one detector is located on the link identified in the demand model. Each link must be represented by one detector's measurements because the demand and performance along the link is assumed to be non-variant. In this situation, to represent the measurements on the link, the analyst will have two options: to select either one of the detection stations or the average of all detection stations on the link. In this study, the middle detector is initially selected for use. The measurements from the selected detectors were then checked for data availability and data quality. If a problem was found with the detection station data, then another station associated with the same link was used instead.

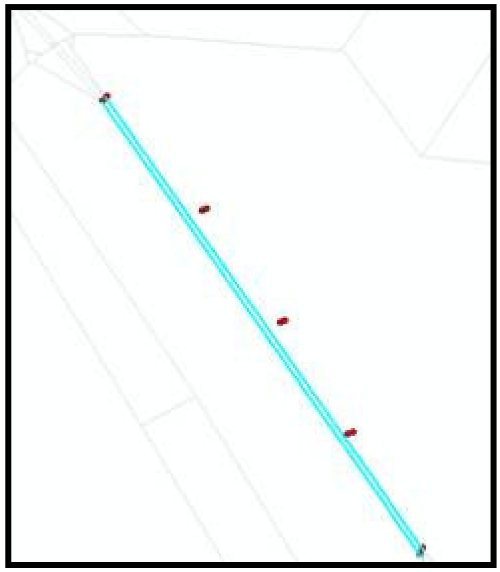


Figure 3-10. A Link with More than One Detector

- In a few cases, the location of the detectors was not easy to match with a specific model link. However, due to the high density of ITS detection stations in the network, there was no need to consider the locations of these stations further, and the data from these detection stations was excluded.
- In other instances, because of the proximity of the detection station to a merging or diverging point, it was not possible to identify if the station is on the link before or after the merge point. Thus, the data from these stations was also excluded.
- Other conditions for which detection station measurements were not used included detection stations with missing data, erroneous data, or data measurements that are inconsistent with upstream and/or downstream detectors.

After the association with the model links and the aforementioned elimination process, measurements from only 35 ITS detection stations were selected for use in this study.

As described above, once the detection stations and the associated links are identified, the user must associate each link in the demand model network with a detection station number by adding this number manually as an attribute of the link in the Cube/FSUTMS environment. A specific format was used in this study to specify the detection station number. The left most digit in the detection station number is reserved for the direction of travel. For example, the actual detection station number of the first station in Table 3-2 is “220022.” However, a “1” was added to the left of the number to indicate that the link is northbound in direction, which is important to interpreting the data from the file with the tool developed in this study. “1,” “2,” “3,” and “4” are used for northbound, southbound, eastbound, and westbound, respectively. Based on this association between links and detection stations (Figure 3-11), the developed tool extracts the volume and speed measurements of the link from an input file provided. The format of these input files is presented in Table 3-3.

Table 3-2. Detector and Model Link Lookup Table

Detector	Direction	Detector ID	Link Node	
			A	B
220022	SB	1220022	118541	118542
220122	SB	1220122	118488	119962
220142	SB	1220142	120536	118544
220202	SB	1220202	118483	118478
220362	SB	1220362	118547	118475
220432	SB	1220432	118549	118550
220562	SB	1220562	118465	119950
220602	SB	1220602	118551	118552
220631	NB	2220631	122230	120971
220551	NB	2220551	121413	120520
220491	NB	2220491	118435	118436
220382	SB	1220382	120512	120513
220311	NB	2220311	118440	120514
220131	NB	2220131	118442	118443
220071	NB	2220071	118491	118494
220011	NB	2220011	120970	118445
200132	SB	1200132	118750	118705
200082	SB	1200082	118751	118752
200052	SB	1200052	118741	119989
200042	SB	1200042	122802	119994
210312	SB	1210312	120057	122036
210362	SB	1210362	119140	120060
210442	SB	1210442	121604	121925
210632	SB	1210632	119151	119152
210692	SB	1210692	119154	119155
210711	NB	2210711	121013	120788
210511	NB	2210511	119133	119136
210371	NB	2210371	119119	119120
210211	NB	2210211	119122	119123
210171	NB	2210171	119147	121602
210041	NB	2210041	121457	118668
200091	NB	2200091	118674	118676
200141	NB	2200141	118706	118677
200201	NB	2200201	118680	118681
200242	NB	2200242	121466	118718

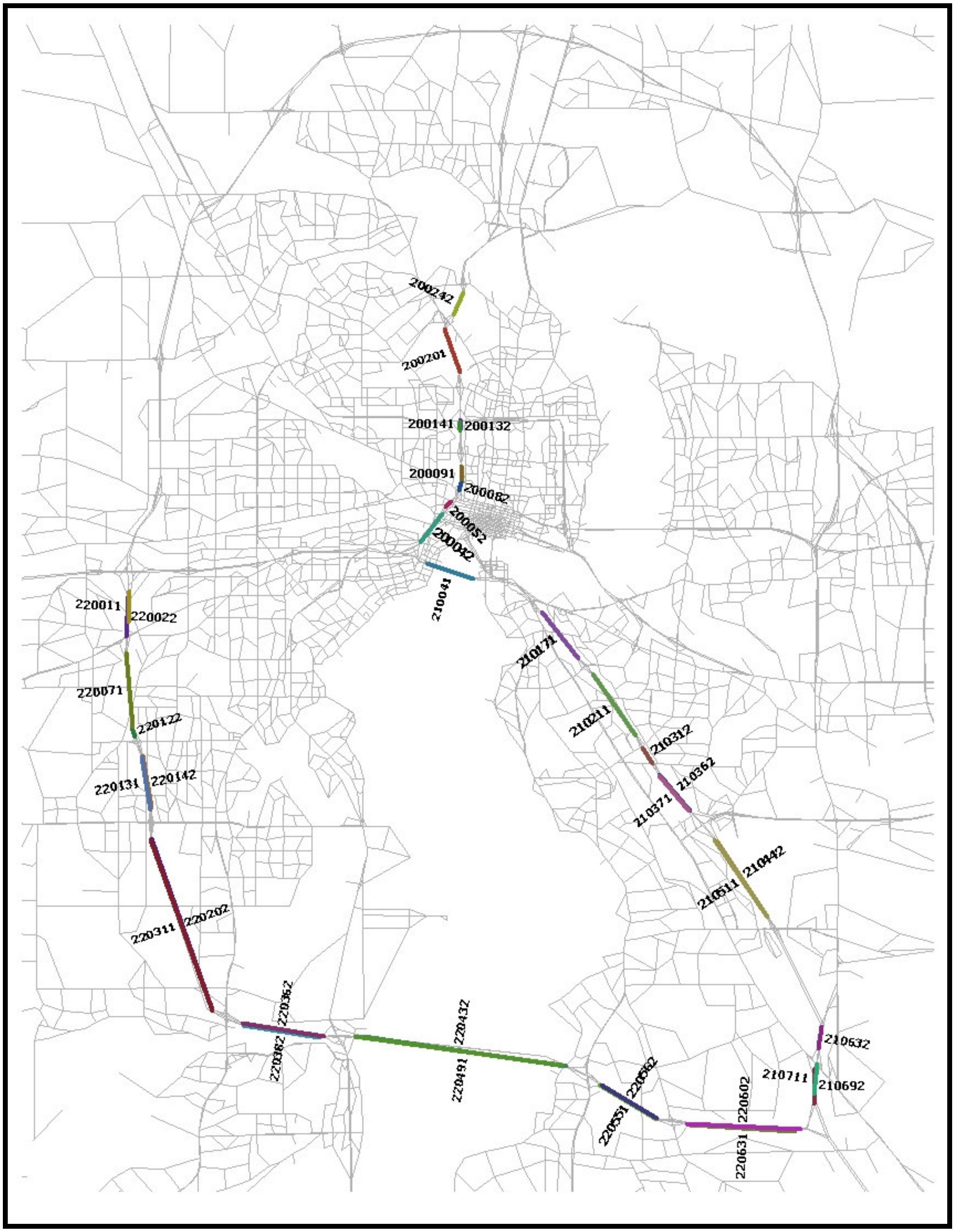


Figure 3-11. Links Associated with Detector

Table 3-3. Detector Traffic Counts (15-min. intervals)

DETECTOR	DIR	N3	N4	N5	N6	N7	N8	N9	…….	N98
220022	SB	188	198	169	125	99	83	80	…….	237
220122	SB	147	161	128	109	84	70	64	…….	181
220142	SB	151	166	135	115	89	73	68	…….	195
220202	SB	89	92	79	65	57	54	51	…….	139
220362	SB	107	106	91	82	67	62	56	…….	131
220432	SB	91	92	86	60	55	54	54	…….	147
220562	SB	106	100	86	75	67	61	58	…….	149
220602	SB	100	93	80	68	64	59	53	…….	145
220631	NB	177	172	136	115	112	91	76	…….	203
220551	NB	146	152	111	91	89	76	63	…….	174
220491	NB	165	196	150	125	119	98	88	…….	217
220382	SB	94	97	81	73	59	57	47	…….	127
220311	NB	82	86	67	55	54	48	43	…….	124
220131	NB	99	93	80	71	62	58	53	…….	146
220071	NB	110	108	98	89	77	69	66	…….	165
220011	NB	105	105	89	90	75	70	66	…….	168
200132	SB	281	187	152	142	130	114	128	…….	258
200082	SB	202	149	126	104	90	80	84	…….	178
200052	SB	270	205	176	145	125	104	108	…….	239
200042	SB	313	253	209	177	161	134	139	…….	269
210312	SB	208	192	166	145	127	106	99	…….	178
210362	SB	224	207	172	153	136	113	103	…….	200
210442	SB	198	188	155	143	126	109	97	…….	190
210632	SB	183	177	155	136	127	108	97	…….	173
210692	SB	213	194	163	144	134	112	98	…….	202
210711	NB	147	130	103	99	95	93	85	…….	175
210511	NB	108	104	80	73	76	65	66	…….	142
210371	NB	187	165	138	117	121	109	100	…….	238
210211	NB	131	118	99	81	82	76	66	…….	165
210171	NB	125	114	92	77	81	73	65	…….	163
210041	NB	138	134	109	88	82	82	75	…….	174
200091	NB	148	147	122	103	89	85	80	…….	183
200141	NB	158	146	123	102	89	82	81	…….	189
200201	NB	182	159	136	113	95	90	85	…….	187
200242	NB	123	105	94	77	72	62	64	…….	129

Note: N in this table shows the time intervals for traffic count measurements. For example N-0:00, N4-0:15, N5-0:30, N6-0:45, N7-1:00, N8-1:15…, N98-23:45.

4. Transportation Network Input Preparation

As described in Section 1, the developed modeling environment integrates the statewide FSUTMS demand model with a dynamic traffic assignment/mesoscopic simulation modeling tool. The tool used in this project is DynusT, which is a version of the Dynasmart Tool. As with travel demand forecasting models, one of the important inputs of advanced modeling tools is the network physical attributes. However, more detailed attributes are required as the associated traffic models move from macroscopic (as in demand forecasting models) to mesoscopic (as in many DTA tools) to microscopic simulation. Considering that many of the attributes required as inputs to DTA tools like DynusT are also required inputs to demand forecasting models, this study developed a utility in the Cube script language, combined with a Visual Studio program, to convert sub-networks extracted from the statewide demand model to a Dynasmart/DynusT network. The Visual Studio programming was necessary to complement the Script language programming to create a more efficient code which utilized the additional capabilities available in the VB programming.

Once the automatic conversion is performed using this tool, the analyst can refine the network and add additional details, as needed, to satisfy the requirements of the more detailed modeling of the DTA tool.

4.1. Extraction of Subarea Networks

Before converting the network from the TDM model format to DynusT model format, the analyst must extract a subarea network for the analysis. If DynusT cannot accommodate a large network of the size of the statewide model, a “memory exceeded error” will be reported by the program. In addition, even if this was possible, modeling the whole statewide network would not have been advisable unless there was a good reason to have the whole network modeled due to the considerable amount of required data and required calibration effort. The Integrated Florida Statewide Model (FLSWM) network is shown in Figure 4-1. In this network, there are a total of 90,767 links and 4,008 zones.

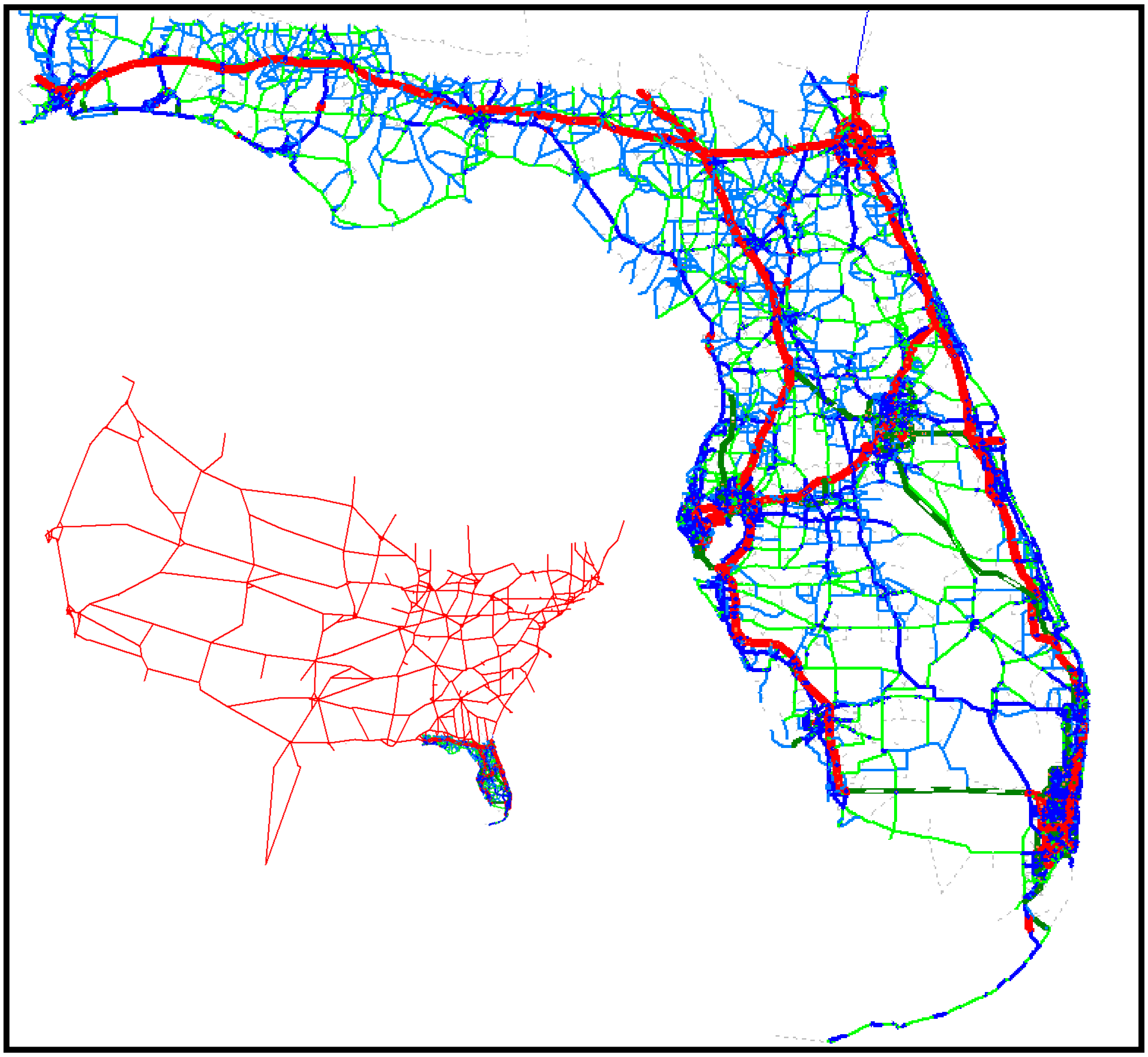


Figure 4-1. FLSWM Model Network

The boundary of the subarea network of interest must be specified first. The subarea boundary can be specified using the Cube voyager Polygon feature or using a GIS tool. Cube can then be used to extract the subarea network from the statewide model network using this predefined subarea boundary. The result of this extraction is a subarea network with new node and zone numbers which are different from the original numbers. Cube stores the association between the old numbers (in the whole network) and the numbers in the new network (in the subtracted network) in two new node features in the subtracted network. These two features are OLD_NODE and SUB_TYPE. The OLD_NODE attribute gives the old node number used in the whole network representation. The SUB_TYPE can have one of four values as explained below:

- Code 0 indicates that this is an existing node in both the whole model network and the extracted subarea network, and that the location of the node is the same in the two networks.
- Code 1 indicates existing zone centroid in both the whole model network and the extracted network; location of the zone centroid does not change in the two networks.
- Code 2 indicates a zone centroid that does not exist in the whole model network, but is created in the subarea network as a new zone centroid at the subarea boundary to account for the demand that is entering or exiting the subarea network.
- Code 3 indicates a node that is connected to a new zone centroid created for the subarea network (i.e., connected to a zone centroid with SUB_TYPE "2").

As mentioned in Section 1, a subarea in the Jacksonville region was used to illustrate the tools developed in this study. This subarea was extracted from the statewide model, as described above, and is depicted in Figure 4-2. It includes 1238 links and 143 zones.

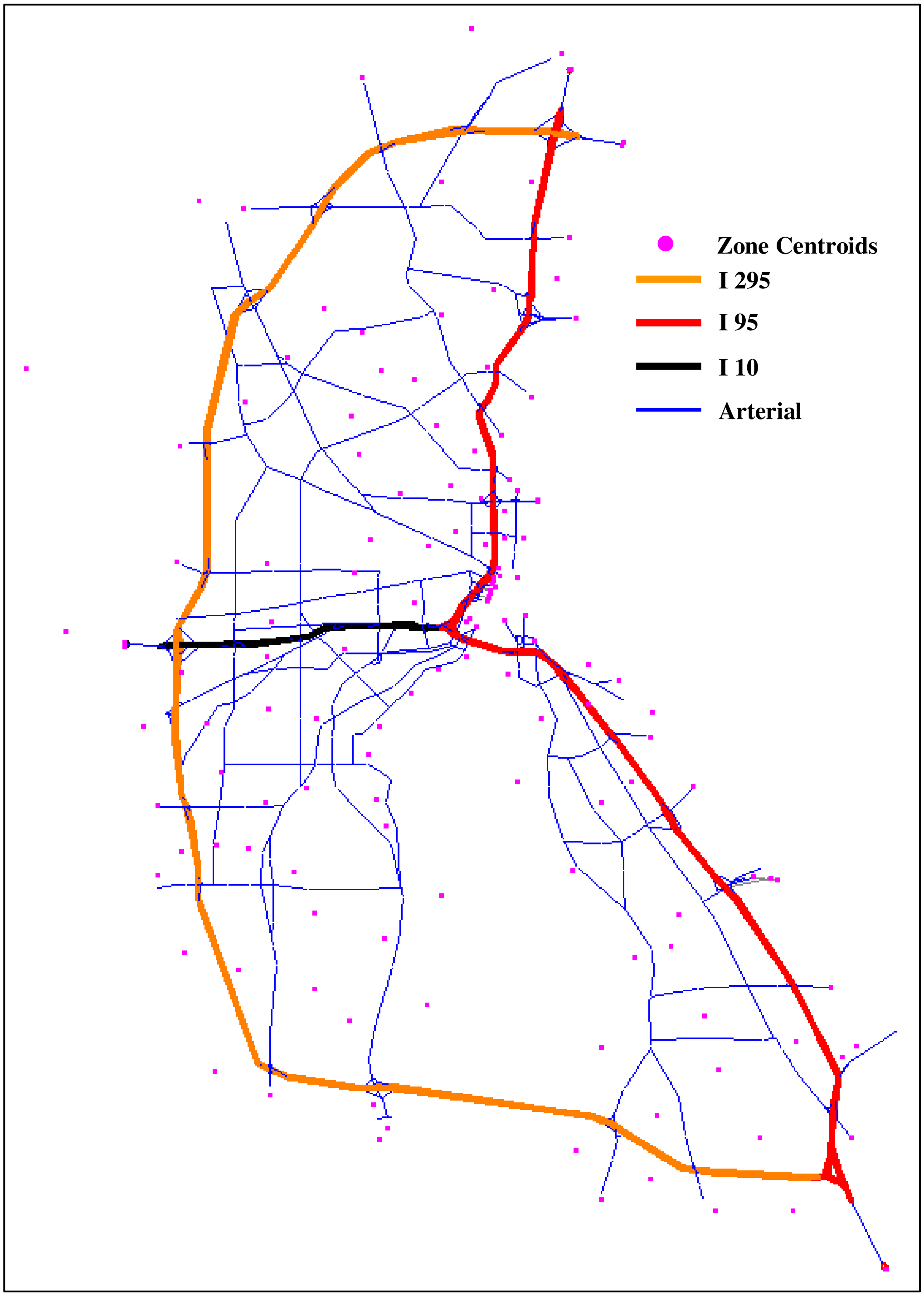


Figure 4-2. The Subarea Network in the Jacksonville Region Studied

4.2. Considerations in Converting Networks

Before describing the utility developed in this study to convert the extracted network from the statewide model to DynusT network format, the following important considerations should be mentioned:

- The FSUTMS model network and the Dynasmart/DynusT network consist of links and nodes. In the Cube/FSUTMS network, there are built-in attributes associated with network links and the user can specify new attributes as required. Some, but not all, of these attributes are needed as inputs to DynusT. Additional attributes cannot be added in DynusT.
- DynusT requires additional data not used as inputs to the demand forecasting model. The need for this additional data increases in proportion to the detail required for modeling. For example, if the operation on the arterial is important to the analysis and a high level of signalized arterial modeling is required, then detailed intersection geometry features, such as turn bay lengths, will be needed.

Table 4-1 presents the link attributes required by DynusT that are either not available in the TDM model (Figure 4-4) or must be converted to account for the difference in attribute definitions.

Table 4-1. TDM Link and Node Attributes Redefined as Dynasmart Inputs

Data Type		TDM	Dynasmart	Comment
Network	Link	Link facility type can be defined for the model under consideration	Ten predefined facility types	Need to convert the facility type to account for the difference in definition
		Free flow speed	Required posted and adjustment speed margin data	Additional data or estimation based on free-flow speed
		No turn bay information unless intersection modeling is needed	Left and right turn bay information are needed if intersections are modeled in detail	Additional data if intersections are modeled in detail
		Capacity	Service rate and saturation flow rate	Additional data or estimation based on capacity
		BPR curve parameters	Modified Greenshields Traffic flow model parameters	Calibration of the modified Greenshields model or use default values of the model in Dynasmart or DynusT
		Link grade is not needed	Link grade	Additional data if truck impacts on performance are affected significantly by grades
	Node	Turning movement is not defined explicitly, unless intersection modeling is required	Requires turning movement data for each node and link	Requires a tool to obtain movement data
		Signal control is needed only in the case of detailed intersection modeling in Cube	Intersection control type and definition of major and minor roads	Additional data if intersection control is to be modeled
		Detailed intersection geometry is needed in the case of detailed intersection modeling in Cube	Detail intersection geometry	Additional data if intersection control is to be modeled
		Signal timing is needed in the case of detailed intersection modeling in Cube	Signal timing	Additional data if intersection control is to be modeled

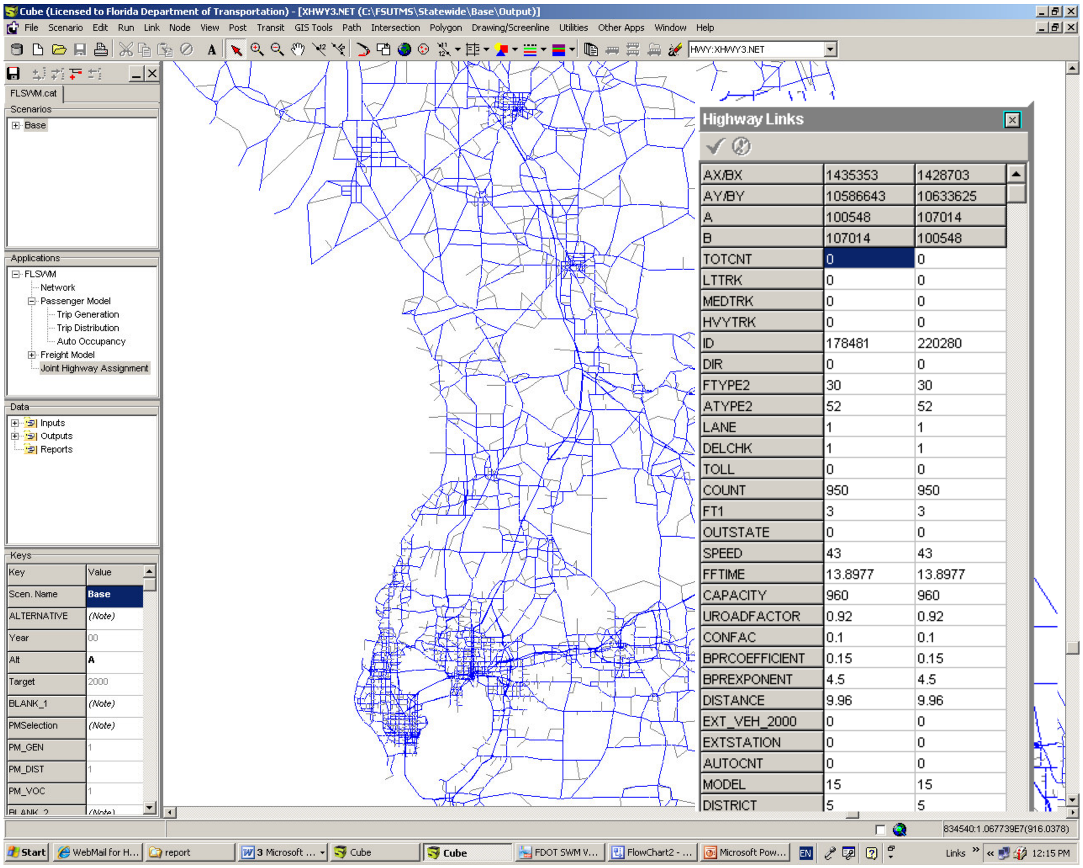


Figure 4-3. Statewide FSUTMS Model Network Link Features

- Another important issue with statewide model network conversion to Dynasmart/DynsuT model format was that these two tools have different definitions for facility types. The FSUTMS model allows up to 99 facility types. The statewide model uses the following types:
  - 10-19: Freeway
  - 20-29: Divided arterial
  - 30-39: Undivided arterial
  - 40-49: Collector
  - 50-59: Centroid connector
  - 60-69: One way facility
  - 70-79: Ramps
  - 80-89: Exclusive HOV lanes
  - 90-99: Toll facilities

- In Dynasmart/DynusT, there are 10 facility types as follows:
    - 1: Freeway
    - 2: Freeway segment with detector (for ramp metering)
    - 3: On-ramp
    - 4: Off-ramp
    - 5: Arterial
    - 6: HOT
    - 7: Highway
    - 8: HOV8
    - 9: Freeway HOT
    - 10: Freeway HOV

There is thus a need for a conversion scheme to convert the FSUTMS link facility types to the DTA tool facility types. This scheme is shown in Table 4-2.

Table 4-2. Association between Statewide FSUTMS Model and DynusT Model Network Features

DTA model code	DTA model definition	TDM model code
1	Freeway	10-14, 90-94
2	Freeway segment with detector (for ramp metering)	-
3	On ramp	70-74
4	Off ramp	75-79
5	Arterial	15, 20-49, 60-69, 95-99
6	HOT	-
7	Highway	15-20,
8	HOV	-
9	Freeway HOT	-
10	Freeway HOV	80-89

4.3. Network Conversion Process

As stated above, a utility was written to convert the TDM network to the DTA tool network, considering the issues described in the previous section. A flow chart representing the network conversion process is presented in Figure 4-4. The following subsection discusses this process in detail.

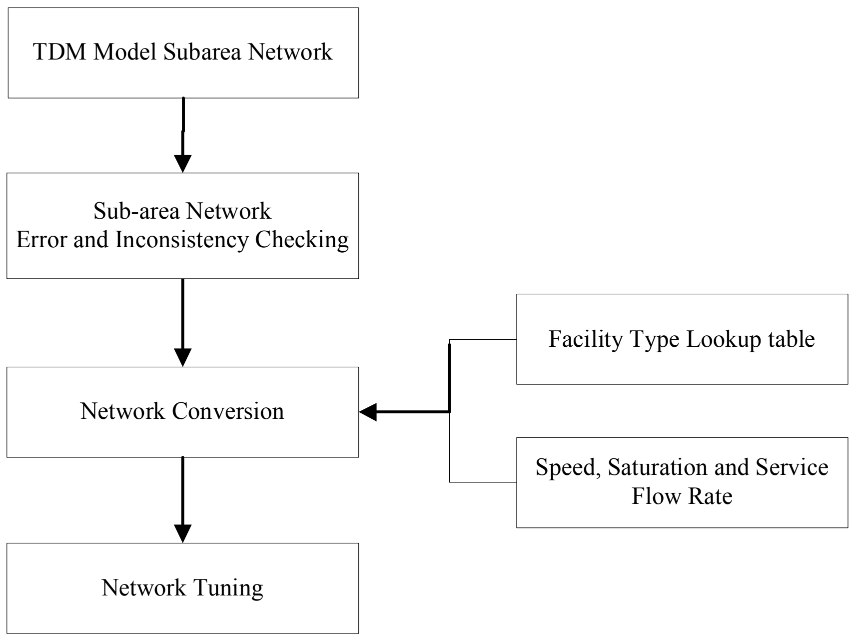


Figure 4-4. TDM Network Conversion Flow Chart

4.3.1. Error and Inconsistency Check

The first step in the network conversion process is to check the FSUTMS model network for potential problems that will create errors and inconsistencies when the network is converted and used as input to DynusT. Due to the differences between the FSUTMS and DynusT specifications, inputs that are acceptable in the FSUTMS model may not be acceptable when used with the DynusT model.

The checks converted in the developed network conversion utility are listed below:

- **Zone connections to network.** In the FSUTMS/Cube environment, it is possible to have a zone that is not connected to a network. However, this condition creates an error when the network is converted and used as an input to DynusT. A routine that checks zone and link network connections automatically was developed in this study to identify the unconnected zones and warn the analyst of their existence.

- **Zone connection to Freeway.** Dyansmart warns the user if any zone is directly connected to the freeway network. A routine was developed in this study to check for this condition and warn the user of its existence.

- **Destination node.** In Dynasmart, the user is allowed to specify the same destination node for up to two zones. In Cube, more than two zones are allowed. Thus, this condition is also checked and a warning message is given to the user.

A utility was written in the Cube script language to check the network based on the above conditions and a program was written Visual Studio to provide the user interface for this utility. If a problem is found in any of the above, a warning is given to the user to fix the problem. No further processing is done until the problem is fixed.

In addition to the above checks, the produced utility checks the minimum link length acceptable by Dynasmart/DynusT as follows:

$$L_m \geq \frac{V_m * 528}{60}$$

Where:

L_m = minimum link length (feet), and
V_m = free-flow speed of the link (mph).

This type of error is checked by the program and is corrected automatically based on the above equation during the conversion process.

4.3.2. Network Data Conversion

Once the network is checked by the utility described in the previous section and all the warnings are addressed, the analyst can run another utility developed in this study to convert the FSUTMS statewide sub-network to a Dynasmart/DynsusT network. The network node, link, and zone geometrical data information are converted to the input format of the DTA tool.

The network features are defined in node, link, and zone attribute files in the FSUTMS. On the other hand, the network parameters in Dynasmart are defined using the input files as seen in Table 4-3.

Table 4-3. Required Data to Model the Traffic Network in DYNASMART/DynusT

Type	Required Data	Input File
Node data	Node number	network.dat
	Total number of nodes	network.dat
	Node coordinates	xy.dat
	Link coordinates	linkxy.dat
Traffic Flow Model data	Parameters for modified Greenshields model	TrafficFlowModel.dat
Link data	Total number of links	network.dat
	Link horizontal alignment	linkxy.dat
	Saturation flow	network.dat
	Speed limit	network.dat
	Free-flow speed adjustment parameter	network.dat
	Traffic flow model type	network.dat
	Link type	network.dat
	Link name	linkname.dat
	Link grade	network.dat
Movement data	Allowed movements from each link	movement.dat

Below is a discussion of how the required input files were generated based on the FSUTMS model data.

Network.dat File

The network.dat file in the DTA tool includes information regarding traffic network configuration, as follows:

- Basic information that includes the number of zones, nodes, links in the network and number of shortest path to be calculated.
- Node data that associates each node with a zone.
- Link data that includes the link length, number of lanes, turn bay configuration, maximum service flow rate, saturation flow rate, posted speed limit, speed

adjustment (for driving above the speed limits), grade, facility type, and the specific traffic flow model (TFM) to use for the link

Some of the above information is available from the FSUTMS model. Default values for the other variables had to set as described below. The user can change these defaults using the Dynasmart input interface.

Initially, the default posted speed limit coded in Dynasmart was set to 5 mph lower than the free flow speed coded in the FSUTMS model. The speed limit adjustment margin (which is used to reflect the free flow speed) is set to be +5 mph (5 mph higher than the posted speed limit, which has been reported in previous studies). However, it was found in this study that coding a free flow speed that is different from what is implied by the Greenshields traffic flow model will result in inconsistencies. Thus, it was decided that the free flow speed value in the traffic flow model should be used as the posted speed limit and adjustment limit margin was set to 0. The developers of the DynusT model were contacted about this finding to fix this problem in future versions of the model.

The default grade of the link was assumed to be 0. The default values for the maximum service flow rate and saturation flow rate were borrowed from a case study of Dynasmart used in Knoxville, TN. These values are given in Table 4-4 but the user can change these default values using Cube input key files by facility type. If the user wants to change the values by link, this is also possible using the Dynasmart/DynusT user interface. The findings of this study also suggests that the capacity defined for a facility type and those implied by the associated traffic flow theory model should be consistent. Thus, in this study a traffic flow theory model is provided for different capacity (maximum service flow rate) values. The user will also have the option to use the capacities implied by these models rather than those in

Table 4-4.

Table 4-4. Maximum Service and Saturation Flow Rate[26]

Link Type	Free Flow Speed (mph)	Maximum service Flow Rate (pc/hr/ln)	Saturation Flow Rate (veh/hr/ln)
Freeway	70	2200	1800
Highway	70	2200	1800
On-ramp	30	1600	1400
Off-ramp	30	1600	1400
Arterials	45	1800	1600

As described earlier, the number of facility types in FSUTMS could be large. However, the facility types from the statewide model can be categorized as one of three facility types: freeway, arterial, and ramps. Dynasmart allows the coding of a limited number of facility types and associates each link with a specific TFM model in the network.dat file. To identify the links as one of three link types, a new link attribute was added in the FSUTMS statewide model. This new attribute is referred to as L_I_N. The default value of the "L_I_N" variable was set using the Cube Script language, based on the link facility types defined by the "FTYPE" attribute of the link in the statewide model.

A lookup table (see Table 4-5) was used in this study to associate a TFM number with each facility type. The association between the link-type and the TFM number, and the parameters of each TFM model, can be changed by the user. The default TFM parameters will be used for all links of a given facility type, as defined by "L_I_N," unless the user explicitly requests a different TFM subgroup of these links. As seen in the example in Table 4-5, the user is interested in specifying different TFM parameters for different freeway segments (I-95, I-10, and I-295). In this case, the user can use a new variable "STATENO" that was added to the link attributes to identify subgroups with different TFM (Figure 4-5). For example, the user can use 95, 110, 295, or 999 as values of the "STATENO" attribute to represent the I-95, I-10, I-295, and "other" corridors, respectively. Otherwise, if the STATENO is coded 0, then the model will use the default TFM using the lookup table based on the L_I_N number, as shown in Table 4-5.

Table 4-5. Link Index Number in Model Network

Association Type	Facility Type Code	TFM	FLSWM Facility Types	Definition
Default based on the L-I-N attribute	1	1	1	Freeway
	5	11	5	Arterial
	3 or 4	12	3 or 4	On/Off-Ramp
User Extension using the STATENO variable	95	1	1	I-95
	110	1	1	I-10
	295	2	1	I-295
	999	12	N/A	Other

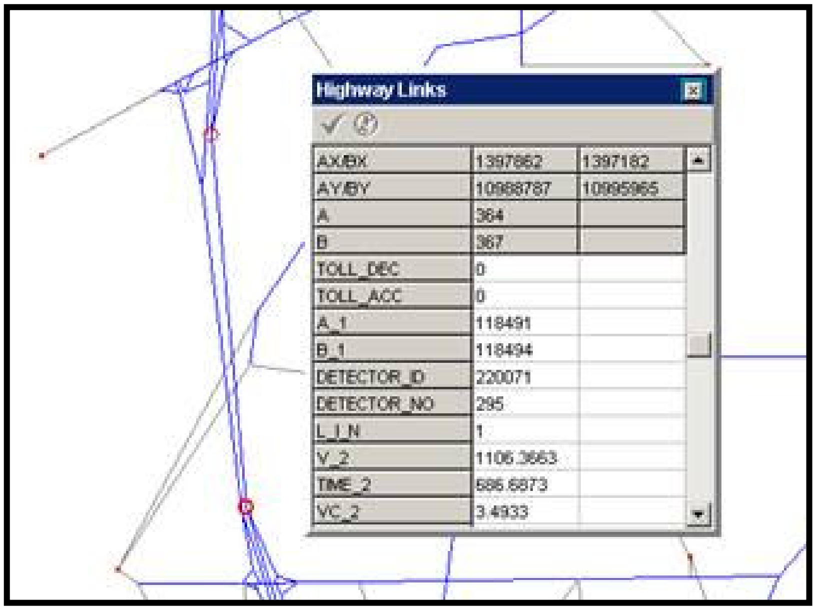


Figure 4-5. TFM and Model Network Indexing

Traffic Flow Model File

This file provides parameters of the traffic flow model (TFM) types specified in the network.dat file, as described above. As will be discussed later, DYNASMART-P uses a modified Greenshields model for macroscopic traffic parameter estimation. The TFM was calibrated in this study for the freeway facilities in the Jacksonville area utilizing ITS detector data, as explained in Chapter 6. For arterial streets, the default parameter of the TFM were those used as default values in Dynasmart due to unavailability of detector data on arterial streets to allow the derivation of a model for Florida conditions. User should change or add new TFM into the file to use in the network.

Movement.dat File

This file specifies the turning movements at each node. For each link approaching the node, the downstream nodes of the left-turn, through, right-turn, U-turn, and two other movements can be specified in this file (Figure 4-6). This means that the user can define up to five movements for each link. This information is not available directly from the FSUTMS statewide model. Thus, a method was developed in this study to determine this information based on other available information in the statewide model data. By examining node numbers and coordinates for each movement upstream and downstream, the relative angels between the upstream and downstream links could be obtained. Identifying the angles allows the determination the turning movements at this node. In the case that the FSUTMS model has turning prohibitions or high turning penalties, then the conversion tool must exclude the associated movements from being coded as inputs to Dynasmart.

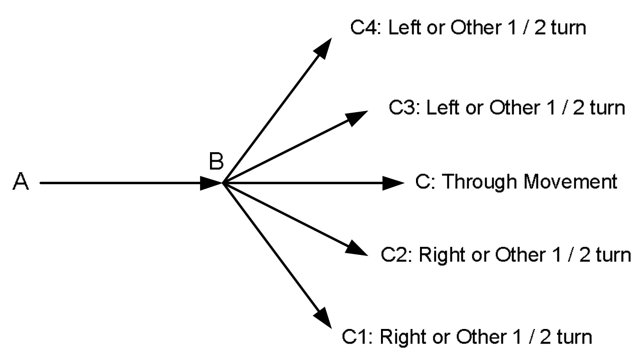


Figure 4-6. Turning Movement Definition in Dynasmart/DynusT

Other Files

Three other files are required to define the network attributes in the inputs to Dynasmart. These files include basic information and are listed together, below, with the explanation of how they were created in this study:

- The xy.dat file includes the node coordinates. This file is produced based on the network node coordinates in the FSUTMS statewide model.
- The Linkxy.dat file provides the horizontal alignment of a link by specifying the coordinates of points on the link. This file is produced based on the beginning and ending point of these links. No intermediate points are coded on the link in the produced file. This implies that the links are assumed to be straight. However, the analyst can enter these intermediate points, if the representation of the horizontal alignment is desirable.
- The LinkName.dat file specifies the name of the link and is left blank in the conversion.

4.3.3. Fine-Tuning of the Converted Network

Once the network is converted, there may be a need for further editing of the network to ensure an acceptable level of detail for the input data, and for the corrections of errors when running Dynasmart. For this purpose, the user can edit Dynasmart input text files or use the Dynasmart graphical editing tool. In this study, aerials from Google earth were examined and compared to the converted network to determine any modifications needed.

5. Zone Connection and Matrix Conversion

Compared to the FSUTMS, the types of connections to the network at the origin and destination zones are different in Dynasmart/DynusT. In addition, the FSUTMS trip matrix format needs to be converted to the Dynasmart format. This chapter describes the utilities developed to convert the FSUTMS zone connections and trip tables to representations that are acceptable by the Dynasmart/DynusT tool.

5.1. Zone Connection Conversion

Dynasmart loads vehicles into the network using generation links and unloads vehicles at destination nodes. The generation links data are specified in the origin.dat file (see Figure 5-1). Unlike zone connectors in Cube, these generation links have limited physical capacities that depend on the number of lanes specified. The user can use real-world links as generation links, but can also use dummy links that are connected to the network for this purpose. On the other hand, Cube uses centroids and connecter links that connect these centroids to the network. The connection links in Cube have infinite capacity. The above discussion indicates that the zone generation connections are represented differently in Cube and Dynasmart, and that a conversion utility is needed which considers this difference.

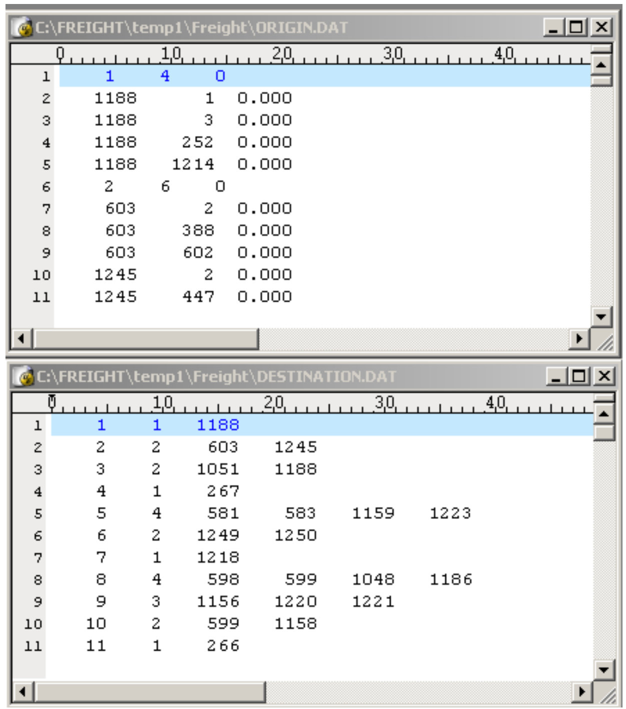


Figure 5-1. DTA Model Origin and Destination File

There are a number of issues that require addressing when defining the generation links in the conversion process, as described below:

- If vehicles are generated on links that are in the opposite direction of the intended path to their destination in the DTA tool, unrealistic U-turns or paths will be made by the vehicles, which can cause congestion in the network. To illustrate this problem, in Figure 5-2, if links 2-3 and 2-4 are defined as generation links for Zone 2. For the demand from Zones 2 to 1, some of the vehicles may be assigned incorrectly to link 2-3 by the DTA model. These vehicles will need to make a U turn on Node 3. This will result in higher than expected volume on link 2-3 and on the U-turn movement at node 3.

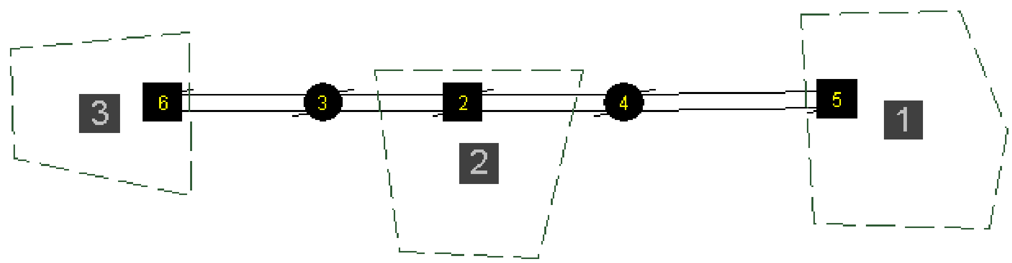


Figure 5-2. Generation Links

- To prevent the situation in this study, instead of specifying the generation links as physical network links, additional dummy nodes were created in the FSUTMS model to represent generation nodes in Dynasmart, which act in a similar manner to the zone centroids in FSUTMS. The connections of these dummy generation nodes to the actual physical network were then defined as the generation links for the zone.

- In Dynasmart, the number of vehicles generated on each link is proportional to its lane-miles. Alternatively, the user may specify the share of demand that each generation link within a TAZ will generate. In this study, the vehicles are generated based on generation link lane-miles, but the user can modify this by specifying the demand share as stated above.

- If the generation link capacity is less than the demand, the vehicles generating on the link will experience unrealistically high travel time to access the network. Thus, careful examination of the congestion level at the access points should be made and generation link locations and/or capacities should be added and/or modified. Additional generation nodes were added to the network to create additional capacity for vehicle generation from the zones to prevent unrealistic congestion.

- The vehicles are unloaded off the network using destination nodes where vehicles exit the network after reaching the destination zone. These nodes are specified in the destination.dat file. The destination nodes in this study were defined as the downstream nodes of the zone connectors in the FSUTMS model, in the direction of the zone centroid.

5.2. Demand Input Format

DYNASMART-P has two methods for loading vehicles on the network: (1) using a time-variant O-D demand matrix notation, albeit a dynamic one; and (2) using a predefined vehicle-path dataset, which provides a controlled environment for assessing the impacts of traffic management strategies.

There are applications in which the use of vehicle and path files instead of trip matrices is preferred, as described later in the application part of this document. However, even in these cases, the vehicles and path files will have to be generated from initial runs in which trip (O-D) matrices were used to specify the demands.

In Dynasmart, the user can input a maximum of three matrices, as follows:

- Combined demand matrix that can be used to specify passenger car trips or total trips if the fraction of the trucks and HOVs are specified
- Truck demand matrix
- High Occupancy Vehicles (HOV) demand matrix

This is a major limitation of Dynasmart. In many modeling applications, the analyst may want to separate the demand into a larger number of matrices to account for different vehicle characteristics and driver behaviors. For example, for the specific analysis of freight corridor management, the analyst may want to categorize the truck demand by commodity or at least separate the truck demand into freight and service trucks, or into heavy, medium, and light trucks. Cube allows the user to code a large number of trip matrices and is much more flexible in this regard.

Table 5-1 shows the trip matrices in the FSUTMS model and how these were mapped to the three Dynasmart matrices. As stated above, since freight corridor management is the goal of this study, it was desirable to have as many matrices as possible that represent different truck types; ideally, this would have been done by commodity. However, even the FSUTMS statewide model does not have this level of detail.

Table 5-1. Statewide Model and Dynasmart Model Matrix Association

Statewide Model		**Dynasmart File**
Passenger	ODUR : Urban and Rural Trips ODLDB : Long Distance Business Trips ODFLRES : Florida Residence Trips ODSHORTEI : Short E-I Trips ODFLUSCAV: Florida US and Canada Visitors Trips	demand.dat
Truck*	LIGHT TRUCKS : Four tired vehicles MEDIUM TRUCKS: Single Unit Trucks with 6+ Tires HEAVY TRUCKS : Combination Truck	demand_truck.dat demand_HOV.dat
Freight*	FREIGHT	demand_truck.dat demand_HOV.dat
*Depending on strategy, the user can request converting Truck or Freight matrix to Dynasmart matrix format as a truck or HOV matrix.		

As indicated in Table 5-1, the statewide model has four different matrices that represent truck traffic: light trucks, medium trucks, heavy trucks, and freight. Dynasmart does not allow for this level of detail since it accepts a total of only three matrices, as stated above. Fortunately, there are no HOVs in the statewide model. Thus, two matrices could be used to represent trucks. In this study, the Truck matrix was used to represent the freight matrix, while the HOV matrix was used to represent light, medium, and heavy trucks combined. This approach, however, has a limitation that is described below.

Dynasmart applies Passenger Car Equivalency (PCE) factors on a link-by-link basis to vehicles from the truck matrix to account for the additional impacts of trucks on traffic, as a function of link grades. The default values of these PCE factors are those presented in the Highway Capacity Manual (HCM). If a portion of the truck demand is coded using the HOV matrix as described above, Dynasmart will not apply the PCE factors to these vehicles. One possible approach to address this is to apply the PCE factors at the matrix level. This implies that the freight demand input using the HOV.dat file is multiplied by a factor to account for the PCE. In this method, the PCE factor used in the multiplication must be calculated assuming 0 percent link grade, since this multiplication is done at the matrix level and not the link level.

5.3. Matrix Format Conversion

In Dynasmart, each of the three allowable trip demand types (combined, truck, and HOV) is coded in one file. If more than one interval is to be coded for the demand, then the demands for all of the intervals will have to be coded in separate matrices in the same text file. A utility was written in this study to read the demand matrices from the FSUTMS files and write them in the Dynasmart input format. Chapter 7 will discuss how the daily trip matrices in the statewide model were converted to dynamic (time-variant) matrices for use in DTA applications. The conversion from the FSUTMS to the Dynasmart format is performed just after the static O-D estimation step, and before the dynamic O-D estimation step, as described in Chapter 7 of this document.

5.4. Other Optional Data

It is worth mentioning here two additional input files related to zone definitions. The zone.dat file in Dynasmart contains the zone coordinate information required to display zone boundaries. The zones are represented as points at the center of the zones. This file can be left blank if the zone display is not needed. The approach used by the conversion tool developed in this study is to leave this file blank.

Another optional data is the *zone aggregation* data specified in the SuperZone.dat file. This data is used to aggregate a number of zones in a single SuperZone to reduce memory requirements and facilitate faster computation, resulting in a number of origins or destinations that are linked to the same centroid. This feature is optional and was not used in this study, but may be implemented by the users of the software if so desired.

6. Calibration of Traffic Flow Model

6.1. Model Description

The macroscopic traffic flow model used in Dynasmart is the Modified Greenshields model. The original Greenshields model was developed more than 75 years ago by Bruce Greenshields. The model is based on the assumption of a linear relationship between speed and density. Since then, macroscopic traffic models with different formats have been proposed[27]. One of these models is the Drew modification of the Greenshields' model. This modification introduced a shape parameter that changes the linear relationship between density and speed to a non-linear relationship that depends on the specified shape-factor. This modified version of the Greenshields model is used in Dynasmart, with the parameters of the model including the shape factors that are to be specified by the user (although default values are also provided). DynusT uses different sets of these parameters, as described later in this document.

The mathematical form of the modified Greenshields model is as follows:

$$v_i^t = (v_i^f - v_i^o)\left(1 - \frac{k_i^t}{k_i^j}\right)^{\alpha} + v_i^o \qquad (1)$$

Where:

$v_i^t =$ The average speed on link *i* at time *t*.

$k_i^t =$ The average density on link *i* at time *t*.

$v_i^f =$ The free flow speed on link *i*.

$v_i^o =$ The minimum speed on link *i*.

$k_i^j =$ The jam density on link *i*.

$\alpha =$ Parameter for sensitivity of speed to density (the shape factor).

Dynasmart uses two variations of the traffic flow model. Type 1 is a dual-regime model that assumes the speed to be constant at the free-flow speed (Regime 1) until a breaking point beyond which the modified Greenshields model is used. In the single regime model, the Greenshields model is applied for all traffic conditions. In Dynasmart, the Type 1 model is used for freeways, while the Type 2 model is used for arterial streets. These two types of models are depicted in Figure 6-1.

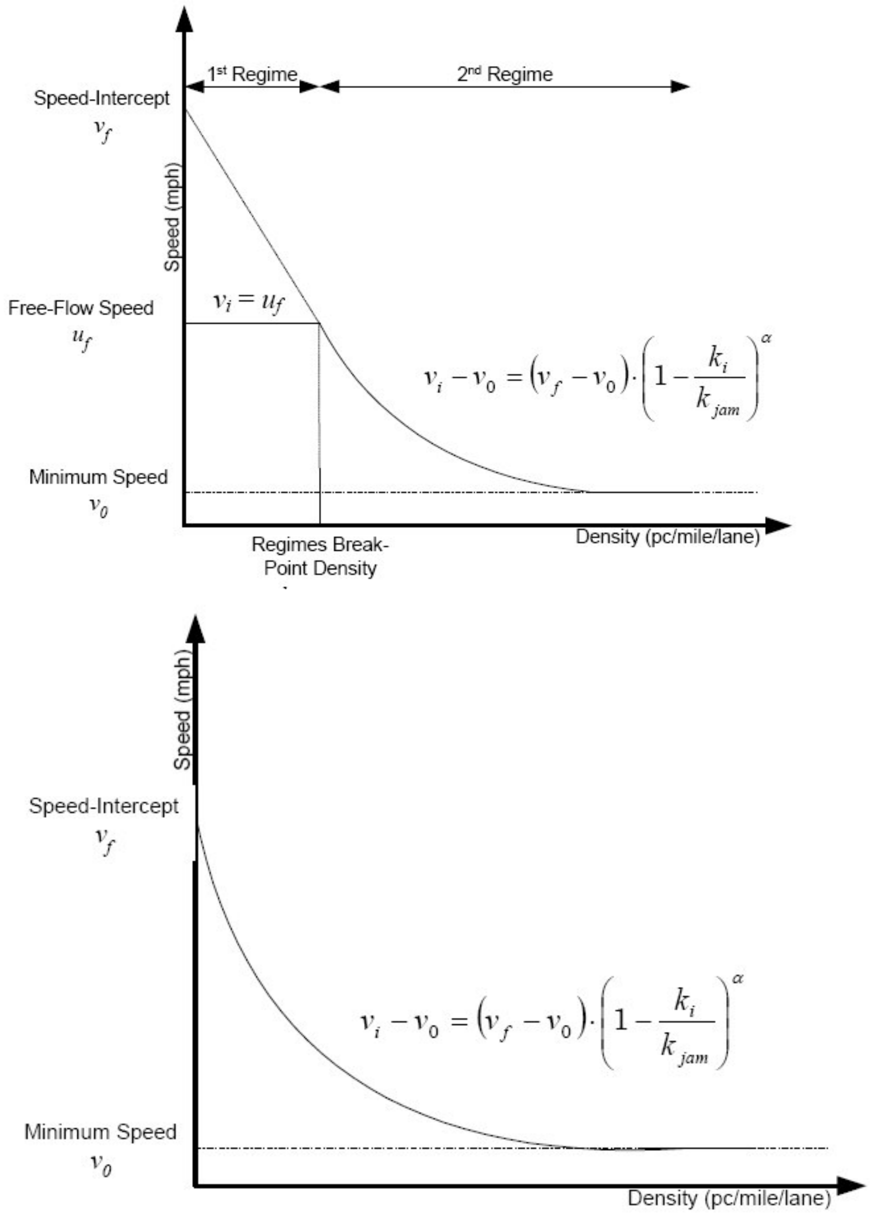


Figure 6-1. The Two Regimes and One Regime Traffic Flow Models

In this study, the parameters of the modified Greenshields model were calibrated for freeways. The availability of detailed ITS data on the I-95 and I-295 in the Jacksonville area allows the calibration of the model parameters for freeways, as described below. However, for arterial streets, the default values of the parameters were used due to the unavailability of detector data on the arterial segments in the study area.

The calibration of the Greenshields model in Dynsmart was done using an approach used by Mahmassani et al[26]. A linear regression analysis was used for this purpose. The Greenshields model is not linear. However, it can be converted to a linear relationship to allow the use of linear regression by taking the natural logarithm of both sides of the equation, as in Equation (2) below.

$$\ln(v_i^t - v_i^o) = \ln(v_i^f - v_i^o) + \alpha\left(1 - \frac{k_i^t}{k_i^j}\right) \tag{2}$$

The parameters that need to be determined in the above equation are the mean free flow (v_i^f), minimum speed (v_i^o), Modified Greenshields model shape parameter (α), and jam density (k_i^j). v_i^t and k_i^t are the speed and density for location *i* at time *t*.

For the two regime model, which is used to model freeway flows, Equation (2) is only applicable to densities above a certain threshold. Below this threshold, the speed is assumed to be constant and equal to the mean free flow speed (v_i^f), as in Equation (3) below.

$$v_i^t = u_f \qquad k_o \le k_i^t \le k_j \tag{3}$$

Where:

v_i^t = Mean speed in section *i* during time interval *t* (mph).

u_f = Mean free speed for the first regime (straight portion) (mph).

k_i^t = Density in the lane in the time *t* (veh/mile/lane).

k_o = Optimum density (veh/mile/lane).

The procedure described in the DYNASMART-P calibration and evaluation document is used to estimate all the necessary parameters. The regression analysis cannot be done unless the minimum speed (v_i^o) and the jam density (k_i^j) are fixed[32]. However, as stated previously, these two parameters need to be estimated based on the analysis. Thus, it was necessary to use an iterative analysis that involved running the regression for different combinations of the fixed values of these two parameters. In this analysis, variables v_i^o and k_i^j were varied between 4 to 20 mph and 120 to 250 vehicles/mile/lane, respectively. The final model selected was produced by using the combination that yielded the highest coefficient of R^2 value.

The calibration was done based on the data collected from ITS detectors in the Jacksonville area. To perform the analysis, there is a need to first identify the appropriate location(s) for which the model will be calibrated. This is an important step that needs careful and detailed analysis to ensure that the variation of the flow at a selected location covers all levels of flow, from light to very congested conditions; that the congestion is not caused by a downstream link; and that the congestion is not a result of unusual conditions which impact capacity and speed (such as bad weather, incidents, and construction). Another criterion was that the section should have a maximum throughput close to the HCM[28] capacity which corresponds to the free flow speed of the segment. The free flow speed for the segment was also determined based on ITS data. The details of the method used in this study to identify the calibration location(s) are described below.

6.2. Regression Analysis

As indicated in Section 6-1, the modified Greenshield models for the freeway segments are two regime models, with one regime representing uncongested conditions with a constant speed at free flow speed, and another regime representing congested conditions with falling speeds and increasing demands. The first step in the calibration process is to divide the measurements in the speed-density diagram into these two regimes. This was accomplished by dividing the data into two clusters. The data from the first cluster was used to estimate the free flow speed (based on the median value of speed measurements). Measurements in the second cluster were used in the regression analysis to determine the values of the parameters of the modified Greenshields model.

Table 6-1 presents a comparison between the calibrated and the default model parameters in Dynasmart and DynusT for freeway segments. Table 6-1 also presents the default model parameters for arterials and ramps.

Table 6-1. Modified Greenshield TFM Parameter

Model	Type	Density Breaking Point	Intercept Speed	Minimum Speed	Jam Density	Shape Term
Freeway Models						
Calibrated	1	31	119	6	200	4.130
DynusT	Default	25	92	6	200	4.500
Dynasmart	Default	30	92	6	200	2.000
Arterial Model						
11	2	0	0	15	85	1.250
Ramp Model						
12	2	0	0	15	100	1.250

7. Trip Matrix Estimation and Calibration

Dynamic traffic assignment requires trip matrices specified for short time intervals (e.g., 15 minutes or 30 minutes). These matrices are sometimes referred to as *time-variant* or dynamic. The derivation of these matrices is one of the most challenging aspects of dynamic traffic assignments. These matrices must be derived based on demand matrices that had been estimated for longer periods of time by demand forecasting models. At present, a large proportion of demand forecasting models in Florida are daily models which estimate the trips at the daily level. However, some models are time-of-day models that produce trip matrices by peak periods. Both daily matrices and peak-period matrices have to be converted to time-variant trip matrices. However, it is expected that the peak-period matrices provide for a much better estimation of the time-variant matrices than that of the daily matrices.

This study used a multi-step procedure for matrix conversion and estimation, as described in this section (see Figure 7-1). The first step is to convert the daily matrices or peak-period matrices to hourly matrices using hourly distribution factors which reflect the proportion of the trip tables for each hour of the day. Second, these matrices are adjusted using the Cube Analyst matrix estimation program. This matrix estimation process performs the estimation by considering a number of input parameters based on the static assignment of Cube. Finally, an optimization procedure is used to derive the time-variant trip matrices based on minimizing the differences between the measured volumes and the volumes produced by the DTA, with consideration to initial trip tables resulting from the Cube Analyst estimation. More details about this procedure are presented in the remaining parts of this section. Further refinement, implementation, and testing of this procedure are expected as parts of a newly launched research project on dynamic traffic assignment. It should also be mentioned that there is a Matrix Estimation program included as part of the Turnpike Model (the TRANPLAN version) and has been reported to be more suitable than Cube Analyst for extremely large networks. A Cube Voyager version of this program is being produced and could be used in lieu of Cube Analyst.

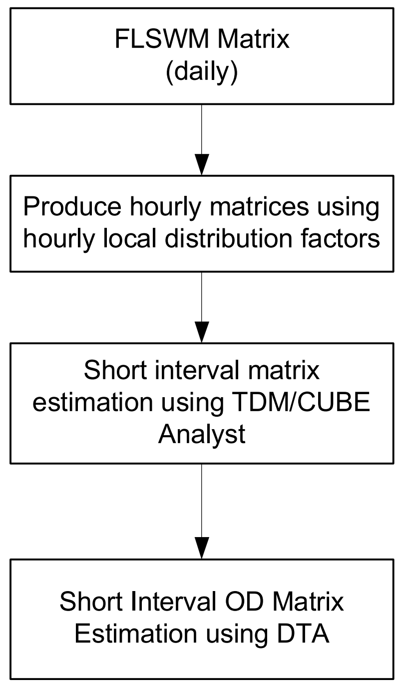


Figure 7-1. Matrix Computation Process

7.1. Subarea Matrix Extraction

As stated earlier in this document, the analysis method proposed in this study is to be conducted on a subarea basis, as opposed to the whole statewide network. The statewide network is too large to be run in its entirety in Dynasmart or DynusT. Thus, in the proposed method, the analyst must define a subarea network to be extracted from the statewide network.

The details of the network extraction procedure are presented earlier in this document in Chapter 4. When extracting this network, the associated subarea trip matrices are also produced by Cube based on the initial whole area (statewide) trip matrices, utilizing the results from the Cube trip assignment procedure. A Cube script language procedure is then used to compute the matrices. The generation of this subarea matrix need be done only one time at the beginning of the trip matrix generation process.

As explained previously, the statewide model utilizes nine trip tables. These trip tables are stored in three different files in the statewide model. For ease of subsequent processing of the matrices in the time-variant matrix estimation process, the nine subarea matrices resulting from the subarea network extraction, as described above, are saved in one file rather than in three files.

7.2. Factorizing the Matrices

The first step in the fine-grained matrix estimation process is to factorize the daily trip matrices or peak-period matrices produced by the demand forecasting models to hourly trip tables based on hourly distribution factors. The factors in this study were calculated based on traffic counts obtained from the Statistical Bureau TTMS (permanent) count stations. However, it should be mentioned that an on-going FDOT study has been conducted to support time-of-day modeling in Florida at the same time that this project was enacted. Factors derived in this time-of-day study could be used for the factorizing of the matrices, instead of the steps listed below.

The steps used to calculate the factors in this study are the following:

1. A subset of the TTMS stations is first defined for use in providing the data for the calculation of the factors.
2. The average hourly weekday and weekend volumes are then estimated for the subarea as a whole.
3. Based on the average hourly volumes, hourly volume distribution factors are then calculated separately for passenger cars, service trucks, and freight movements. The factors can be derived for weekday or weekend traffic and can be for a

particular month of the year or the whole year. The produced trip matrices will represent the days for which the data was collected for use in the calculation.

4. The nine daily statewide matrices are aggregated in to the three matrices used as inputs to Dynasmart. These three matrices represent passenger cars, service trucks, and freight demands, respectively.
5. Finally, the hourly distribution factors are applied to the daily trip matrices to find the hourly factorized matrices for passenger car, truck, and freight trips.

Since the hourly distribution factors are calculated based on TTMS traffic counts, it was necessary to associate the 15 vehicle classes in the traffic counts with the three categories for which the trip matrices were calculated, as explained above. This association is given in Table 7-1. The vehicle classes are presented in Table 7-2 for ease of reference.

Table 7-1. Conversion of Traffic Count Vehicle Class

Factorized Vehicle Class	Traffic Count Vehicle Class
Passenger Car	1-5
Truck	6-8
Freight	9-15

Table 7-2. FHWA Classification Scheme

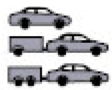
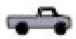
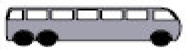
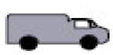
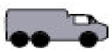
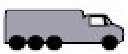
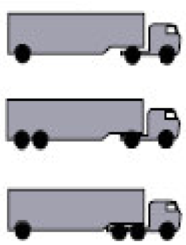
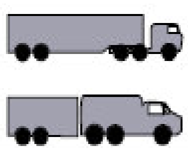
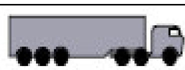
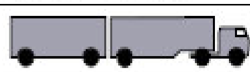
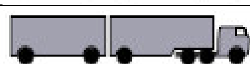
Class Group	Description		No. of Axles
1		Motorcycles	2
2		All Cars Cars w/ 1-axle trailer Cars w/ 2-axle trailer	2 3 4
3		Pickups & Vans 1&2 Axel Trailers	2,3, &4
4		Buses	2&3
5		2-Axle, Single Unit	2
6		3-Axle, Single Unit	3
7		4-Axle, Single Unit	4
8		2-Axle, Tractor 1-Axle, Trailer (2S1) 2-Axle, Tractor 2-Axle, Trailer (2S2) 3-Axle, Tractor 1-Axle, Trailer (3S1)	3 4 4
9		3-Axle, Tractor 2-Axle, Trailer (3S2) 3-Axle, Truck w/ 2-Axle, Trailer	5 5
10		Tractor w/ Single Trailer	6&7
11		5-Axel Multi-Trailer	5
12		6-Axel Multi-Trailer	6
13		Any 7 or More Axles	7 or More

Table 7-3, presents the calculated hourly distribution factors for passenger car (PC), truck, and freight vehicles for the Jacksonville subarea network used as a case study in this project.

Table 7-3. Calculated Hourly Distribution Factors

HOURS	PC	TRUCK	FREIGHT
1.00	0.49	0.49	0.50
2.00	0.28	0.00	0.36
3.00	0.22	0.00	0.29
4.00	0.24	0.00	0.36
5.00	0.45	0.97	0.43
6.00	1.53	1.46	0.78
7.00	4.84	4.37	4.78
8.00	14.84	7.77	14.84
9.00	10.08	8.74	12.34
10.00	3.21	8.74	1.85
11.00	2.99	8.74	1.78
12.00	3.18	8.25	1.85
13.00	3.46	7.77	2.21
14.00	3.41	7.28	1.71
15.00	3.83	8.25	1.78
16.00	6.54	8.25	6.99
17.00	10.22	6.31	13.62
18.00	16.99	4.85	27.82
19.00	4.12	2.91	1.71
20.00	2.79	1.46	1.07
21.00	2.26	0.97	0.93
22.00	1.82	0.97	0.71
23.00	1.33	0.97	0.71
24.00	0.88	0.49	0.57

When using the factors derived in this study, the trip matrices are calculated as described above for each hour of the analysis period. For example, if the analysis period is the A.M. peak between 7:00 A.M. and 9:00 A.M., then two matrices are computed (one for each of the two hours) for each vehicle types (passenger car, truck. and freight).

Once the factorized hourly trip matrices are calculated based on the above factors, it is possible to estimate the average proportion of passenger cars, trucks, and freight vehicles in the traffic stream, for each hour of the day, based on the trips in these matrices. These proportions are needed for use in subsequent steps of the trip matrix estimation process, as explained in the next section.

7.3. Static O-D Matrix Estimation

The factorized hourly matrices derived in the previous step are based on average regional values and do not represent the directional distributions and other specific conditions for each O-D pair in the trip matrix. The use of numbers from the ongoing FDOT time-of-day study may produce better results. However, in any case, using the resulting matrices in the assignment process may not be able to produce realistic demands when compared to real-world traffic measurements.

Thus, there is a need to update these matrices by considering the deviations of the link volumes assigned by the model from traffic count measurements. In this study, the update is performed in two steps. The first step is based on the static assignment of Cube and the second is based on the DTA assignment. This section describes the first step.

The static O-D matrix estimation process is implemented using the Cube Analyst program, which is provided as an optional tool within the Cube modeling environment. Cube Analyst is a tool that estimates trip matrices based on the maximum likelihood technique, coupled with an optimization procedure. The tool utilizes data from different sources and considers the different levels of confidence or reliability inputted by the user from these different sources. The data include not only vehicle traffic or passenger flow counts and prior (old) matrices, but also partially observed matrices, zonal trip end (generation and attraction) data, vehicle routing, travel cost matrices, and even previously calibrated trip cost distribution functions. A further discussion of this tool can be found in the literature review section of this document.

Figure 7-2 shows the procedure of utilization by the Cube Analyst O-D matrix estimation in this study. The procedure slices the factorized matrices calculated as described in the previous section into short sub-interval trip matrices based on traffic volume measurements. For example, if the user wants to analyze the traffic for a two-hour peak period at the 15-minute interval level, the procedure will slice the two hourly matrices into eight (two times four) subinterval matrices.

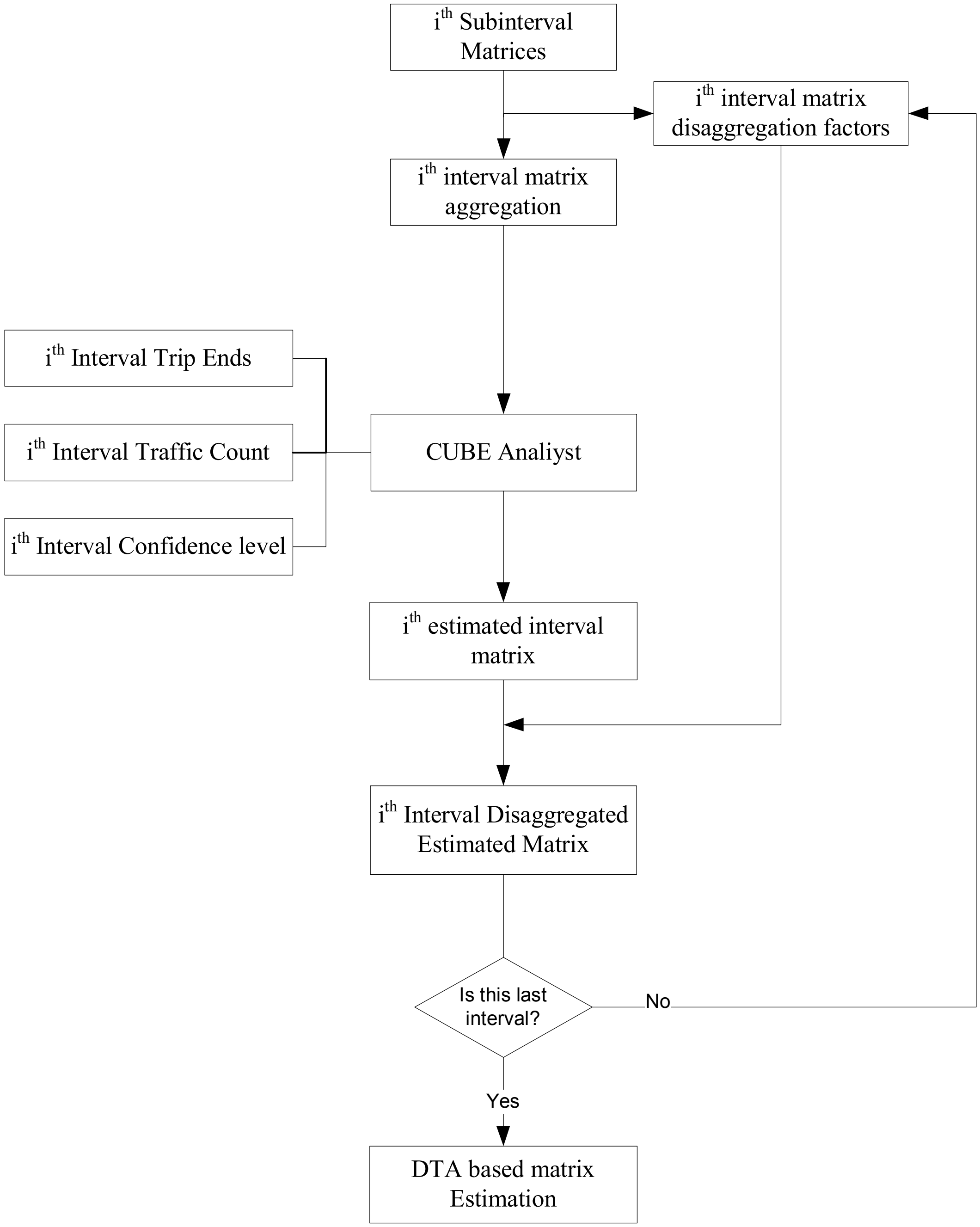


Figure 7-2. Static O-D Estimation Process

In this study, the trip matrix estimation process using Cube Analyst is based on the following inputs:

- An initial 15-minute trip matrix for each of the 15-minute trip matrices to be estimated. To obtain these initial matrices, the trips for each of the two hourly matrices were simply divided by four to obtain four 15-minute matrices within the hour, implying an initial assumption that the demands are equally distributed over an hour.
- Associated trip ends production and attraction calculated based on summing the rows and columns in the trip matrices.
- Traffic counts for each 15-minute interval; these counts were obtained from ITS detectors, TTMS, and PTMS locations in the Jacksonville region.

The Cube Analyst tool requires initial 15-minute trip matrices as inputs. Because Cube Analyst is based on static assignment, it deals with only one matrix at the time. Thus, it had to be run eight times to obtain the eight 15-minute matrices in the above two-hour analysis example. Since there are three matrices for each period (passenger car, truck, and freight), they had to be aggregated into one matrix during the estimation process in Cube Analyst. In this way, Cube Analyst produces one matrix for each 15-minute period. This matrix is disaggregated into passenger car, truck, and freight matrixes using the proportions of these vehicles in each hour.

The user can specify confidence levels for the inputs to the trip matrix estimation of Cube Analyst. Table 7-4 shows the default values of the confidence levels in Cube Analyst. These values are used in the study. However, these values can be changed by the user based on local knowledge.

Table 7-4. O-D Estimation Process Confidence Level

Data Item	Confidence Level
O-D Matrix	20
Trip Ends Production Attraction	20 20
Traffic Count	100

7.4. Dynamic O-D Matrix Estimation

The 15-minute matrix estimation using Cube Analyst is expected to represent better demand estimation than the ones produced from factorized hourly matrices that were used as inputs to the Cube Analyst in the estimation process. However, the Cube Analyst process utilizes demands from the static assignment process and most likely will not produce realistic demand estimation when they are input and assessed using DTA tools. Thus, this study includes another process that uses the output matrices from the Cube Analysts as inputs, and then produces new estimated matrices based on the results of the dynamic traffic assignment. This process is referred to in this study as the Dynamic O-D Estimation process and is illustrated in the flow chart shown in Figure 7-3.

The Dynamic O-D Estimation process needs the execution of a DTA tool to obtain the proportion of the volumes between each O-D pair on each link.

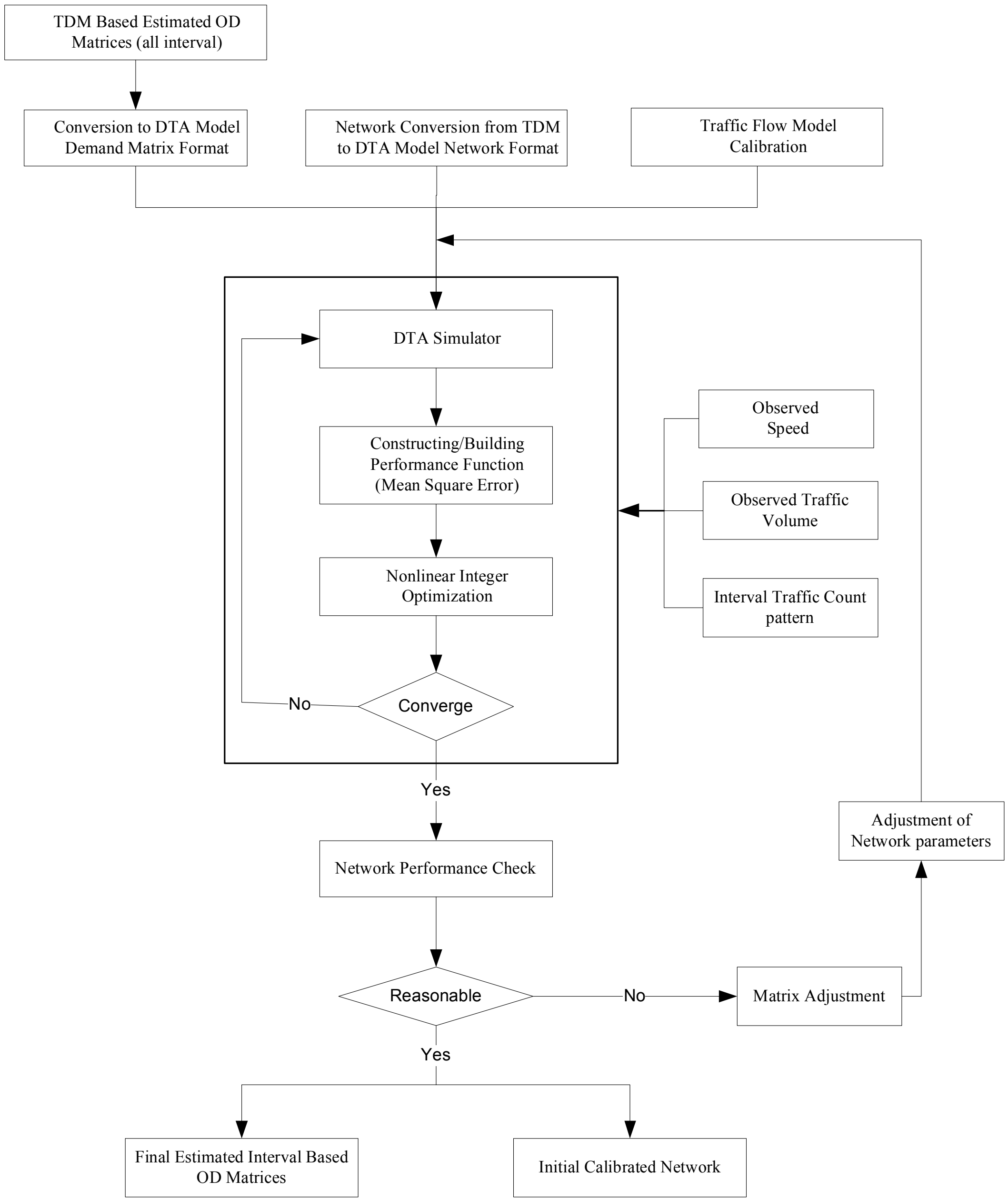


Figure 7-3. Dynamic O-D Estimation Flow Charts

The 15-minute O-D matrices resulting from Cube Analyst estimation were used as initial seed matrices for the estimation of 15-minute demand matrices based on DTA. The dynamic O-D estimation process uses the same set of traffic counts as those used by Cube Analyst as inputs in the static O-D matrix estimation step, described in the previous section.

As stated in the literature review section of this document, there have been several methods developed to estimate trip matrices based on DTA results. However, none of these models has been commercialized to work as a general purpose tool. The developer of DynusT has been working on a new version of the dynamic trip matrix estimation program. This tool, however, was not ready for use in this study. Thus, other methods had to be explored.

At the time of the initiation of this study, a Ph.D. student at FIU was working on his dissertation to develop a new model for trip matrix estimation. This method was used in this study as the basis for Dynamic O-D matrix estimation. However, the application of the model identified several issues with this method and allowed the Ph.D. student, in conjunction with the other researchers of this study, to ascertain and implement the necessary enhancements to the estimation procedure which were required to ensure that it produced acceptable results under different conditions. The procedure was implemented using the Cube/Visual Studio, Fortran programming, and GAMS for optimization. GAMS in an optimization software that provided the deterministic optimization process. Fortran was used for extracting data from Dynasmart output, and was originally written by the Ph.D. student. The Visual studio program was used for the overall control of the process. This method was further developed, tested, and implemented in the new DTA research project mentioned previously.

7.5. Iterative Dynamic O-D Matrix Estimation and Calibration

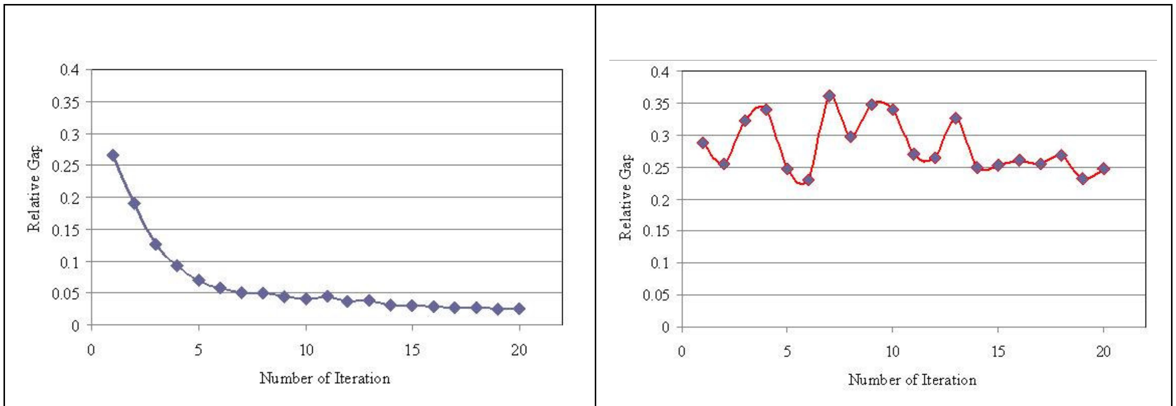
The dynamic OD matrix estimation process, together with the model calibration and identifying any inconsistencies in the model inputs, are the most important factors for successful DTA modeling. Due to the dependency of the O-D matrix estimation process on a well-calibrated DTA model and vice versa, the O-D matrix estimation and DTA/mesoscopic model calibration processes should ideally be performed in an integrated and iterative manner. Although these two components are described separately in this document, these two steps were actually performed in an iterative manner in this study.

During the O-D matrix estimation and DTA/mesoscopic model calibration processes, several outputs from the DTA model for each simulation interval were used. Below is a list of some of the data that were found to be important during these processes (the Dynasmart file names that include the outputs are given parenthetically):

- Network convergence data (Convergence.dat)
- Number of generated vehicles (SummaryStat.dat)
- Total number of vehicles in network (SummaryStat.dat)
- Total number of vehicles out of the network (SummaryStat.dat)
- Vehicle trajectories (VehTrajectory.dat)
- Link counts, travel times, and speed

Below are further details of these variables.

Network convergence data includes a measure referred to as the “Relative Gap.” This measure quantifies how close the current solution is to equilibrium. It is defined in Dynasmart as the difference between the minimum (best) path costs and the average path costs, relative to (divided by) minimum path cost, as a weighted average across all O-D pairs. A plot of the relative gap versus the iteration number should display a pattern of lines converging down to a minimal stable value. The plot will allow the identification of the number of iterations needed and whether the model is converging or not (see Figure 7-4).



(a) Converge	(b) Unconverge

Figure 7-4. Relative Gap Value for Converging and Unconverging Network

Summary Statistics is a main output file of the Dynasmart/DynusT tool. The file reports the network performance statistics by interval based on the operations of all vehicles, whether they are still in the network (did not reach their destinations by the end of the model run period, referred to as the planning horizon in Dynasmart) or are outside the network (reached their destinations by end of the planning horizon). The reported measures include trip times, link travel times, stop times, entry queues, and travel distances. It also includes the number of vehicles in the network, the number of vehicles waiting to enter the network, and the number of the vehicles exiting on the network. These measures are very important to fine-tune the estimated O-D matrix estimation and to calibrate the model. Before more focused calibration, these measures can be used to identify unrealistic congestion levels. A high number of vehicles attempting to enter the network and/or high average times to clear the network indicates incorrect estimation of the O-D matrix, a coding error, and/or unacceptable zone connections to the network. The user can conduct a simple test by coding a period with no demand (zeros in all cells of the input trip matrices) that start at the end of the planning horizon to see how long it takes to empty the network.

Vehicle Trajectory describes the itinerary of each vehicle in the network. The information for all vehicles that exited the network is listed first, followed by information for those vehicles that are still in the network at the end of simulation. The information includes each individual vehicle's path information (nodes on their paths), departing time, link traverse time, cumulated travel time, and origin and destination nodes. Link volumes, travel times, and the proportions of link volumes for O-D pairs can be estimated based on this data. Although link measures can be obtained from other outputs, trajectory based measures are calculated in this study. This provides a more flexible and detailed method of calculating the measures. This is also in accord with the recommendations of HCM 2010 in using trajectory-based measures when utilizing alternative simulation tools.

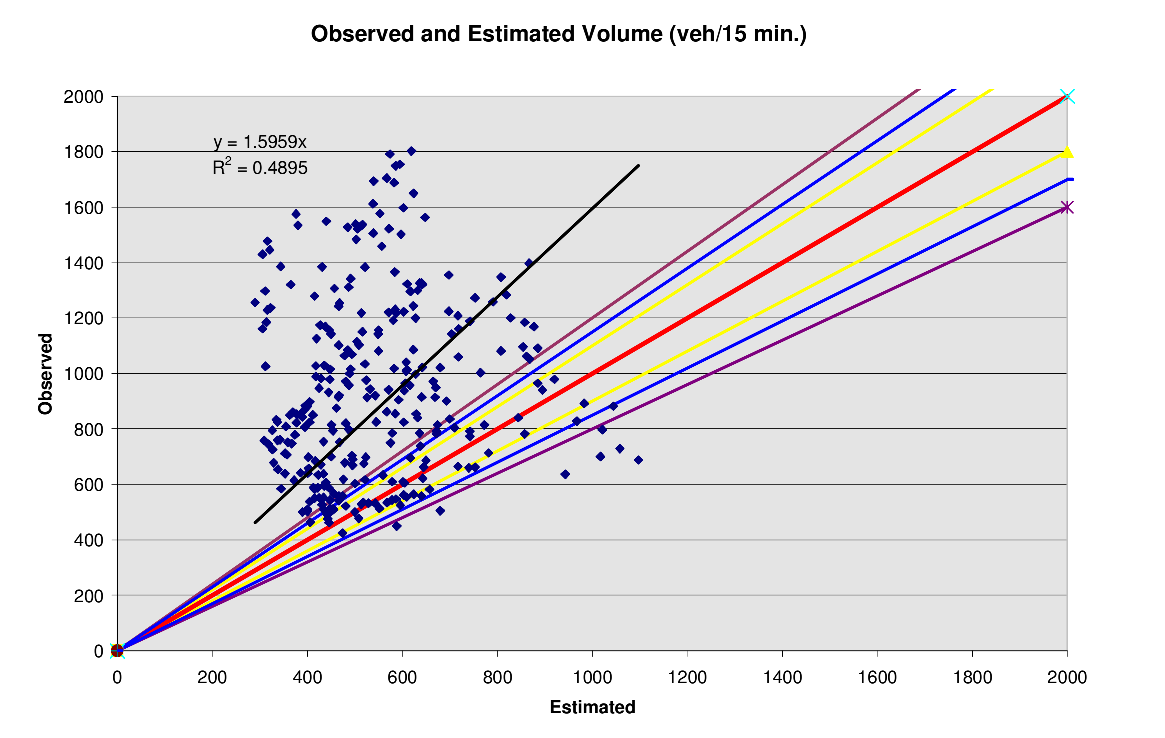
Link Volumes were calculated based on trajectory data. Once the model is brought to a minimally acceptable initial state by eliminating unrealistic significant congestion, as described above, a comparison was made between the observed and estimated link traffic volumes. The comparison was made using an Excel spreadsheet that includes a macro which produces tabular and graphical representations of the comparison. The comparison was done for each analysis interval (15-minute) and each hour of the analysis. The observed traffic counts were collected based on ITS detector measurements, TTMS measurements, and PTMS measurements, as described earlier in this document.

Link travel times, speeds, and densities can also be extracted from DTA model outputs. This can be used to calibrate and validate DTA models in more detail. However, the use of this data in the study, although attempted and investigated, was not extensive due to the limits of the research. Nevertheless, the speed measurements based on ITS data and Google Map displays were used in this study to identify bottlenecks and queue lengths to ensure that the used DTA tool replicates these bottlenecks and queues. The use of speed data will be investigated further in the DTA research project mentioned earlier.

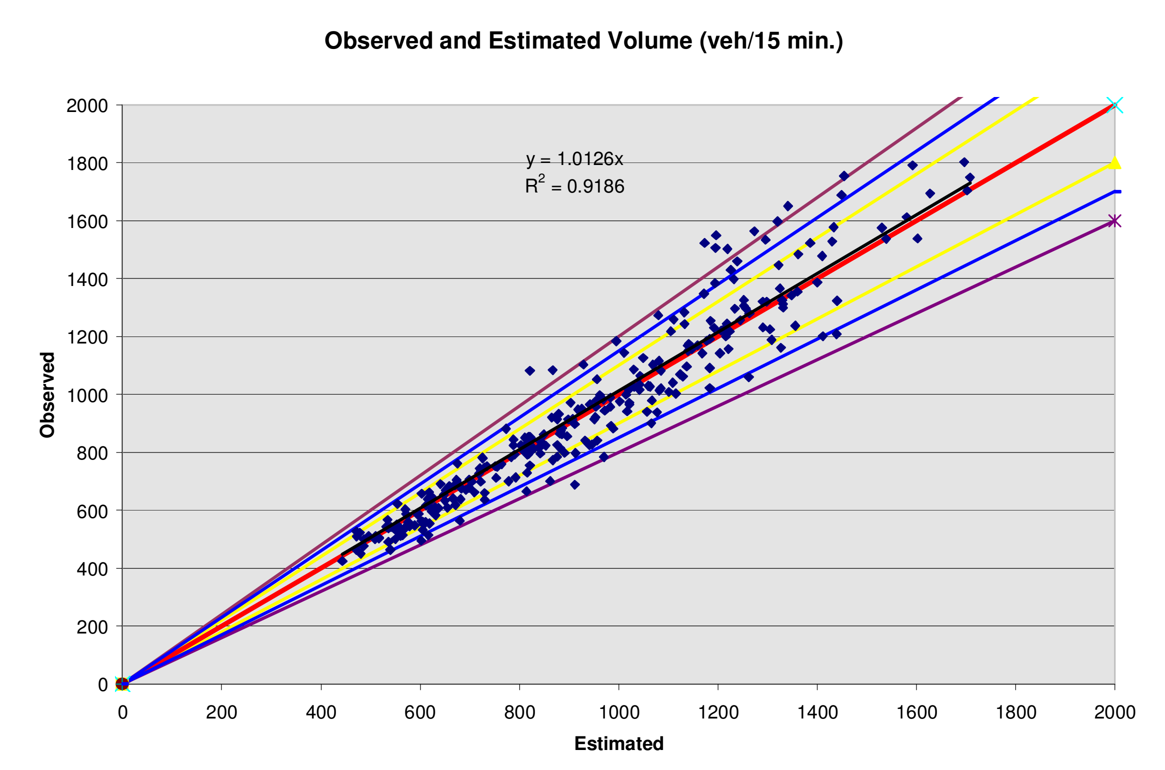
7.6. Application of the Calibration Process

An iterative dynamic O-D estimation and calibration process, described in the previous section, was applied to the Jacksonville network which is used as a case study in this project. Figure 7-5 presents a comparison of the observed and estimated volumes for end of the first and last iteration, for 15-minute and one-hour analysis periods, respectively. In the plots, the closer the points to the 45-degree line (the red line in the plots), the closer the estimated observed volumes. In the figures, additional lines are drawn representing the 10%, 15%, and 20% deviations from the 45-degree line (the yellow, blue, and brown lines, respectively). It is clear that the iterations were able to pull the points closer to the 45-degree line and to distribute them more evenly around the line. The points in the one-hour comparison are even closer than that of the ones for the 15-minute comparison, which is expected due to the smoothing effects of the errors in the comparison based on the one-hour period.

In addition to the above, a linear regression was conducted between the observed and estimated volume. As can be seen in Figure 7-5 and Figure 7-6, the regression coefficients that relate the observed to the estimated values in the last iteration are only slightly higher than one, which is an acceptable result. The regression *R*-squared coefficient improved from 0.49 to 0.91 in the case of the 15-minute comparison, and from 0.50 to 0.96, in the case of the one-hour comparison.

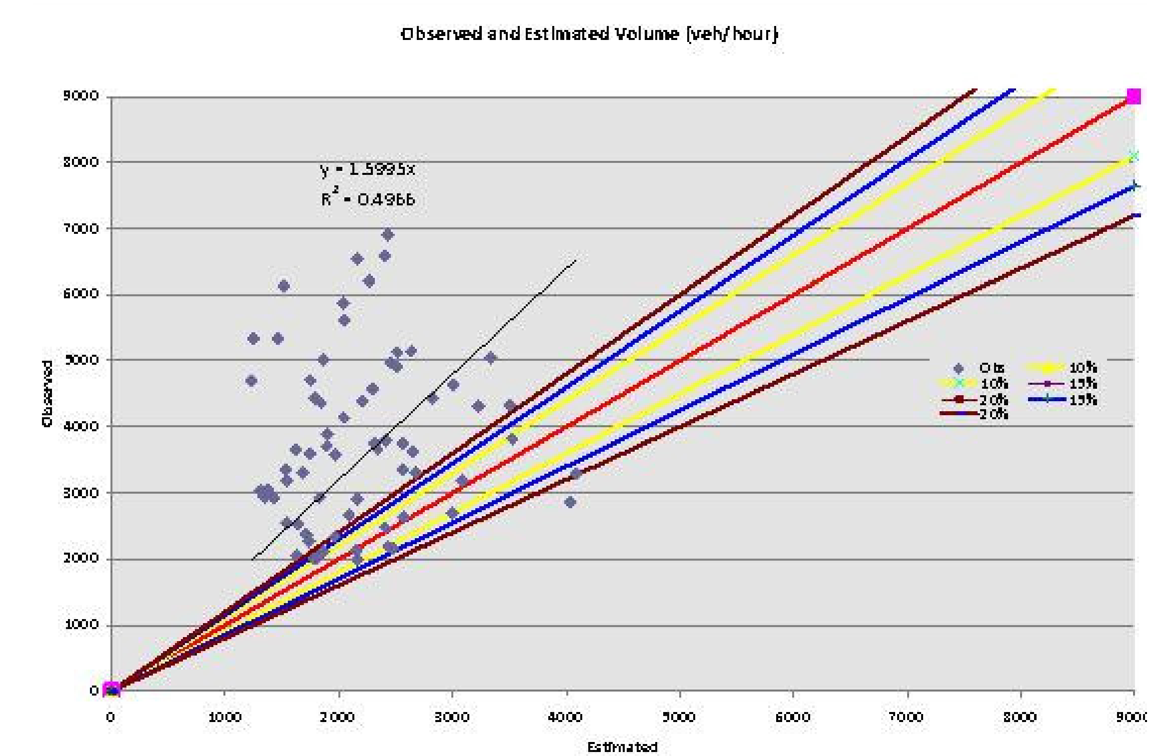


(a) End of First Iteration Result

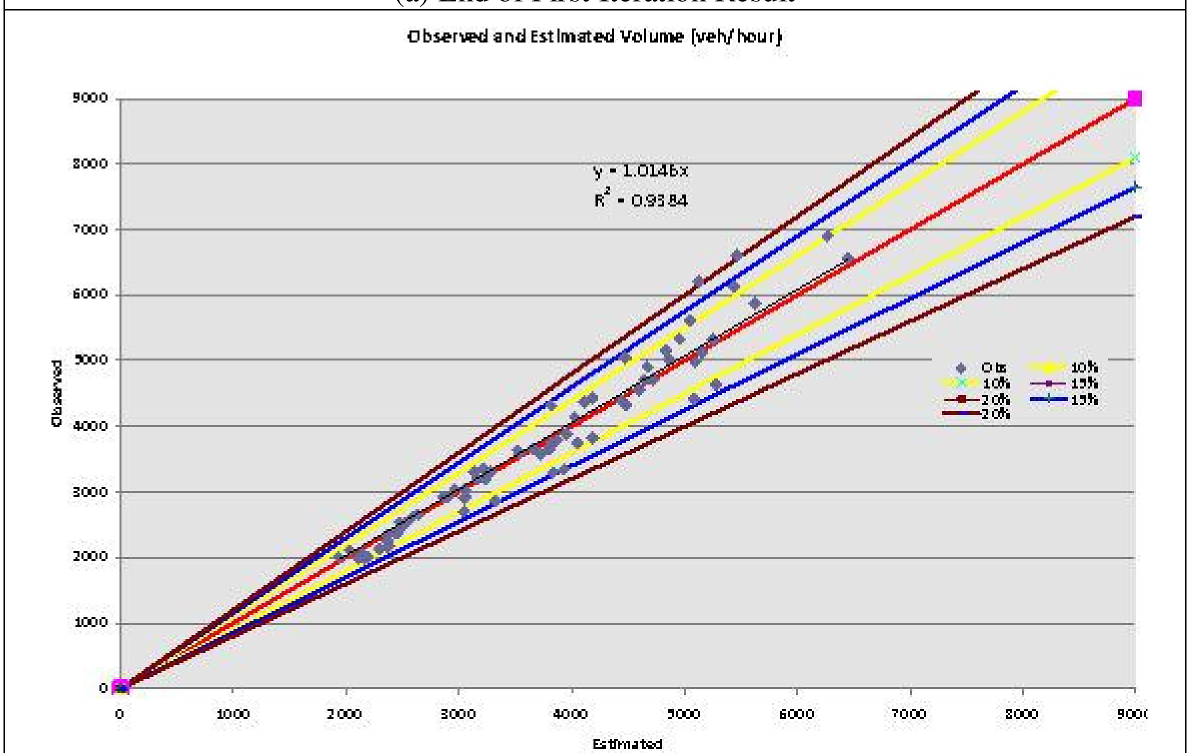


(b) End of Last Iteration

Figure 7-5. 15-Min. Interval Observed and Estimated Volumes



(a) End of First Iteration Result

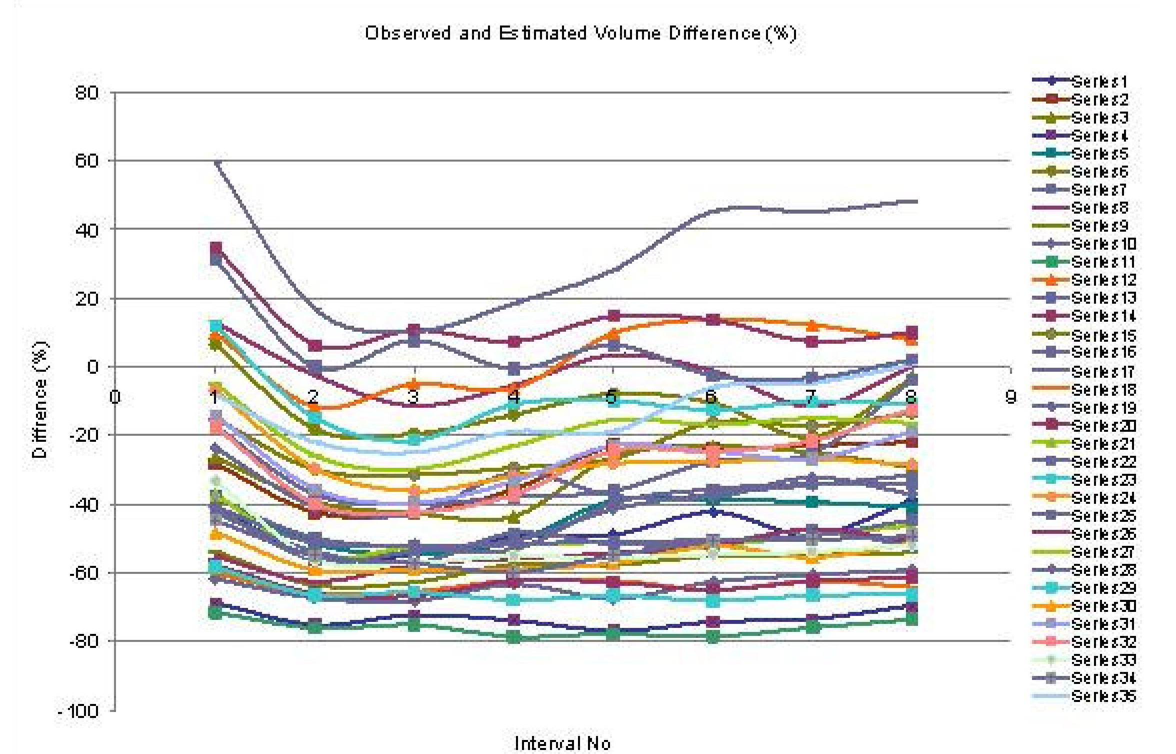


(b) End of Last Iteration

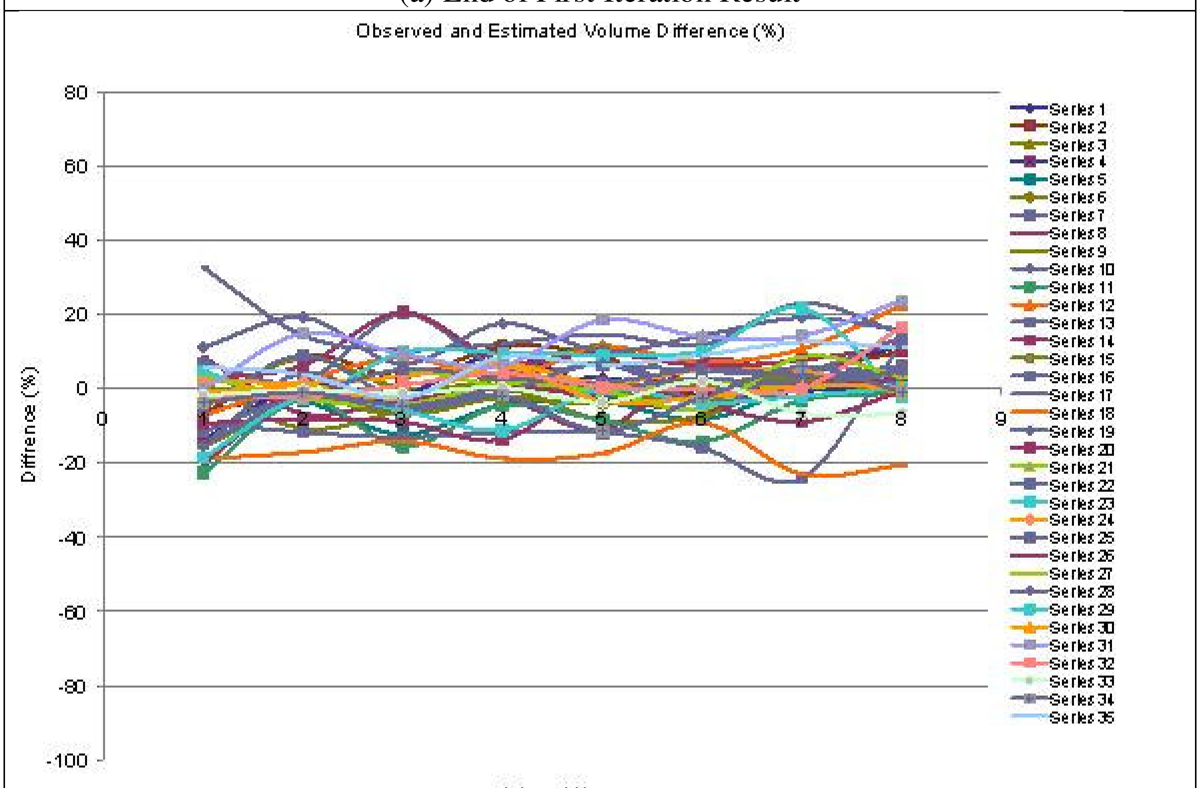
Figure 7-6. Hourly Observed and Estimated Volumes

Another set of useful plots that were used extensively during the calibration and setting of the O-D matrix estimation are shown in Figure 7-7. These figures show the percentage difference between the observed and estimated link volumes for each interval. As an example of the usefulness of these figures, if in a given direction of travel, most of the links have a positive difference of the estimated volumes compared to the observed volumes, then the demand in the trip matrix in the subject direction may need to be reduced.

Between the first iteration and last iteration shown in the figures referenced earlier in this section, additional fine-tuning of the demand matrices, network geometry, and model parameters was done to ensure better correspondence between the observed and simulated link volumes at each interval. One important aspect is to adjust the warming up period and the subsequent period demand levels based on examining the differences between the observed and simulated link volumes in the network. Another critical adjustment made is to then decrease the production and attraction of individual network zones, based on identifying excessive demands on the entry and exit links to the network. Subsequently, new zone connectors were added to better distribute the general demands. Changing the connector link length was also useful to better distribute the generated demands among the zone connectors. These modifications ensure that the dynamic O-D estimation process is able to reach an acceptable solution when using the initial matrices, and that the demands can enter and leave the network as expected. Furthermore, unrealistic congestion on individual links was identified and the associated links were examined to determine and correct any coding problems. Figures similar to the ones presented in this section were very helpful in identifying the adjustments referenced above.



(a) End of First Iteration Result



(b) End of Last Iteration

Figure 7-7. Observed and Estimated Volume Difference (%) Based on Interval

As stated earlier, speed measurements based on ITS data and Google Map displays were used in this study to identify bottlenecks and queue lengths to ensure that the used DTA tool replicates these bottlenecks and queues. In this task, the traffic flow model parameters and inputted capacities were adjusted based on the speed measurements for each modeled corridor. Figure 7-7 shows an example of the comparison between speeds estimated based on Google Map and DynusT during the calibration process in this study.

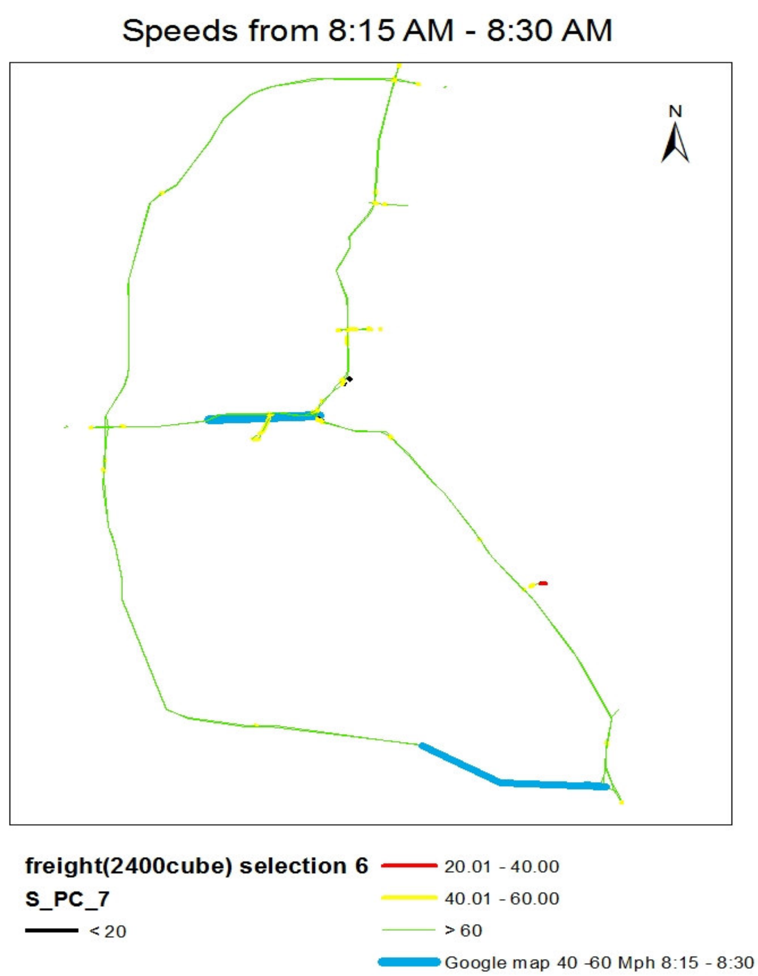


Figure 7-8. Example of the Comparison between DTA Tool and Google Map Speeds Conducted During Calibration

8. Assessment of ATIS Application to Freight Traffic

The provision of information to travelers is one of the most important active management strategies. Advanced traveler information systems (ATIS) involve the collection, aggregation, and dissemination of information to assist surface transportation travelers in moving from their origins to destinations. This information could include travel time, incident, roadway construction, weather, emergency, transit, optimal routes to destinations, and/or traveler service information. Information dissemination involves the use of a number of technologies for disseminating traveler information, such as highway dynamic message signs (DMS), Highway Advisory Radio (HAR), traveler information telephone systems, and web sites.

However, the benefits of ATIS in general, and as they apply to freight in particular, are not easy to quantify. Thus, the use of DTA/mesoscopic simulation tools is ideal to evaluate ATIS benefits. This section describes an illustration of how the modeling environment discussed in previous sections of this report can be used for assessing ATIS alternatives.

8.1. Previous Work

Golob et al.[29] analyzed the preferences for traveler information of the managers of 700 trucking companies to determine how they valued information. This study found that for-hire carriers placed the highest value on ATIS delivered using in-vehicle or handheld, Internet-enabled wireless devices. Providers of high value, bulk, or flatbed services also placed a higher value on general traffic information, but to a lesser extent. Carriers serving rail terminals were found to be most in need of traffic information using wireless devices. Fleet size also affected carriers' perception of the value of the general information bundle. Smaller fleets placed a higher value on a general information bundle.

The impacts of traveler information have been evaluated using field studies, traveler surveys, laboratory experiments, and simulation/evaluation software. Examples of the software utilized for this purpose have included sketch-planning tools such as IDAS, FITSEVAL, SCRITS, and ITSOAM; DTA/mesoscopic simulation models such as DynaMIT and Dynasmart; and microscopic simulation such as VISSIM, AIMSUN, and PARAMICS. However, limited or no work has been done on the use of these tools to assess the benefits of ATIS with consideration to commercial vehicles.

Jung et al.[30] evaluated the ability of ATIS to improve the on-time reliability of urban truck movements in the Los Angeles area through the application of the Heuristic On-Line Web-Linked Arrival Time Estimation (HOWLATE) methodology. This methodology utilized real-world estimates of travel time by link, time-of-day, and across many days. The results indicate that, when assuming a fixed departure time, ATIS can benefit truck operations by communicating the time dependent shortest path. ATIS trucks were estimated to make route changes on 10.8% to 16.9% of days, reducing late arrivals by 14 to 54%. This case study indicated that for trucks that must be on time, and face considerable variability in their trip travel times, ATIS was a useful and highly-valued service. In particular, drivers unfamiliar with the transportation network and congestion receive significant benefits from ATIS. It was concluded that a valuable extension of this research would be to examine the benefits of ATIS for more complex truck operations, such as fleet routing and scheduling.

Pan et al.[31] developed a framework for evaluating dynamic traveler information systems, focusing on incident-induced congestion and taking into consideration different user and vehicle classes, including trucks. This study considered the following influential factors: 1) travelers ability to observe incidents in the absence of information, 2) commercial truck percentages, 3) percentage of diverted truck drivers versus the percentage of the diverted general traffic, and 4) the value of time of trucks versus passenger vehicles. The study concluded that substantial network performance benefits can be obtained from disseminating traveler information. Higher probabilities of truck diversions were found to be associated with a greater total of travel cost savings.

8.2. Market Penetration and Compliance Rates

Market penetration (*MP*) and compliance rate (*CR*) are two critical parameters in the analysis of ATIS impacts. The market penetration is the percentage of travelers that access the information, while the compliance rate is the percentage of these travelers that make changes in trip decisions based on this information.

Khattak et al.[32] used empirical data from a series of travel surveys conducted in the San Francisco Bay Area. The results showed that 100% of the respondents accessed or owned at least one device (and on average, about four devices), that 66.4% of all respondents received travel information either regularly or occasionally, and that 33.1% changed their travel decisions in response to that information. Furthermore, Athena et al.[33] presented a case study on travelers' response to ATIS for the Puget Sound Region. This study found that respondents used some form of information system for only for 4.1% of their total trips. Almost 36.3% of the respondents stated that they used the disseminated information systems on their trips. The three changes that respondents made were as follows: (a) small changes in their regular route in order to avoid congested areas; (b) taking an entirely different route; and (c) changing departure time.

A study by Pierce and Lappin[34] of the Seattle ATIS indicated that travelers acquire information on only about 10% of their trips and change their travel plan during 9% of these acquiring trips. This indicates that the percentage of travelers that may benefit from the system is only 0.09%.

To better determine the benefits, it is also necessary to understand the diversion behavior of travelers (the compliance rate). Several researchers have used the stated preference approach in an attempt to determine the percentage of travelers changing trip decisions in response to information disseminated by ATIS technologies. The studies concluded based on this type of surveys that the disseminated information can result in up to 60% to 70% of the freeway traffic exiting the freeway ahead of a bottleneck, such as at an incident location. However, information about the actual diversion due to traveler information has been limited. Several European field studies have found that dynamic message signs (DMS) compliance rates range between 27% to 44%. Knopp et al.[35] found that for major incidents, up to 50% of the travelers take another route.

Several studies also relate the diversion rate with the delay reductions. Mahmassani[36] assumed that travelers switch routes under information based on a *boundedly rational* switching behavior, with travelers not changing their routes as long as the difference between travel time on the subject route and alternative route is below a certain threshold; for example, a mean of 1-minute or 20% of travel time, as determined empirically from user behavior studies.

8.3. Use of DTA Models to Assess ATIS

INTEGRATION was one of the first DTA-type tools used to assess ATIS. It was utilized as part of the National ITS Architecture to assess different architecture alternatives. In addition, Van Aerde and Rakha[37] utilized INTEGRATION in the evaluation of the TravTek route guidance field operation test in Orlando in the mid-1990s.

Florian [38] assessed the impact of ATIS on transportation network quality of service using the DynaMIT platform. The main conclusion from the study was that the provision of dynamic route guidance can benefit both guided and unguided drivers, thus improving the whole system performance.

Based on simulation analysis, Yang et al. [39] showed the benefits from predictive information compared to the provision of instantaneous information (referred to as Naive ATIS). The results also demonstrated the benefits of predictive ATIS in dealing with the problem of overreaction, in which drivers overcompensate in response to information, causing sub-optimal traffic conditions. Kaysi found based on simulation that overreaction impact becomes significant after 50% market penetration.[40]

Balakrishna et al.[41] investigated the sensitivity of ATIS to three parameters: frequency of information update, penetration rate of information sources, and demand prediction error using the DynaMIT DTA tool.

Srinivasan and Krishnamurthy[42] investigated the spatial and temporal network dynamics induced by variable message sign (VMS) information under non-recurrent congestion, using Dynasmart. The study analyzed the role of incident attributes (number, location, and timing), information characteristics (delay, update frequency, and compliance rates), and alternative operational strategies. The network performance of VMSs was compared with those of in-vehicle devices (IVDs). The findings indicate that VMS performance varies dynamically and depends on the interactions between information lag, diversion rate onto alternative paths, efficiency of reported paths, time-varying interactions between vehicles with VMS information and vehicles without VMS information, residual capacity on alternate paths, compliance rates, and spatial incident characteristics.

Recently, a study[43] in North Carolina selected tools for use in evaluating ATIS in the state based on an investigation of existing tools. Sixteen evaluation criteria were selected based on the functional requirement in the states of North Carolina.

In this evaluation, DYNASMART-P received the highest grade. INTEGRATION and IDAS, and a macroscopic simulation environment referred to as IMAP (which is based on the FREEVAL macroscopic model) also received high grades. Based on the identified functional requirements, DYNASMART-P, IDAS, and extended IMAP (IMAP with extended capabilities) were identified to be appropriate as ATIS evaluation tools for North Carolina. DYNASMART-P was considered the best alternative for the ATIS evaluation tool.

8.4. Assessment Methodology

In this study, the DynusT dynamic traffic assignment tool was used to evaluate the impacts of traveler information. One of the strengths of Dynasmart/DynusT is its ability to account for different types of road users/vehicles and their different responses to the same traveler information. As with other DTA applications, ATIS analysis requires road network, traffic flow demand, calibration parameters, and behavioral parameters; as discussed in previous sections of this document.

Travelers react differently to the provision of information to travelers by traffic management centers (TMC) or private sector information service providers, depending on a number of factors. Two inputs are of particular importance to ATIS analysis: driver strategic behaviors in response to information, and market penetration of various ATIS technologies. A literature review of the type presented earlier in this chapter, analysis of local data, and interviews with regional ITS personnel will assist in identifying these inputs. As mentioned earlier in this document, the most important behavioral change due to ATIS is route diversion. DynusT is able to analyze this behavior, however, it cannot analyze other behaviors such as mode shift and trip time shift.

An important feature in DYNASMART-P and DynusT that allow it to model ATIS is the ability to model multiple user classes (MUC). DYNASMART-P is capable of simultaneously modeling different classes of users with different choices and assignment rules, under different information levels. Currently, DynusT and DYNASMART-P can handle five classes of users, as follows:

Class 1 – Unresponsive: This class of users is not responsive to any type of information. These users receive path assignments at the beginning of simulation, and adhere to these paths throughout the entire simulation. This class only responds to detours; if variable, message sign 2 (VMS Type 2 explained later) is specified in the network.

Class 2 – System Optimal (SO): The users in this class follow the system optimal (SO) assignment rule, in which travel times are minimized from the system's perspective. The general idea of this assignment rule is to force a small fraction of users to follow sub-optimal routes, from their perspective (not UE), for the benefit of the majority. This user class is not responsive to VMS information, except for speed advisory (VMS type 1). The total network-wide travel time resulting from this assignment is less than or equal to that generated from the UE assignment rule.

Class 3 – User Equilibrium (UE): This class of users follows the UE assignment rule, in which travel times are minimized from the user's/traveler's perspective. Such a class is used to model travelers who are familiar with the network. This user class is not responsive to VMS information, except for speed advisory (VMS type 1).

Class 4 – Enroute Info (Boundedly Rational Behavior): The users in this class update their paths at each intersection based on the prevailing shortest path tree. This user class is assumed to receive enroute information. The routing decision is based on boundedly rational behavior. With these behaviors, two criteria are used for route choice, namely the indifference band and the threshold bound for switching decisions. The indifference band is a fraction of travel time improvement above which the user will switch routes. The threshold bound is a time improvement (in minutes) above which the user will switch routes. This class of users is only responsive to detours (VMS type 2), and does not respond to VMS information unless the VMS preemption mode is selected.

Class 5 – VMS Responsive: This class of users responds to VMS information. There are four types of VMS information: congestion warning, optional and mandatory detours, and speed advisory. VMS responsive users receive path assignments at the beginning of simulation, which they adhere to unless they encounter a VMS, and possibly decide to change their paths as a result. Four types of VMS, now more commonly referred to as Dynamic Message Signs (DMS), are supported by DYNASMART, as indicated in Table 8-1 and listed below:

- Type 1: This is the speed advisory VMS that promotes users to increase/decrease speed by a certain percentage when below/above a certain threshold.
- Type 2: This is the mandatory detour VMS that mandates all vehicles to follow some user-specified sub-path in the vicinity.
- Type 3: This is the congestion warning VMS, which allows the user of Class 5 vehicles (VMS-responsive vehicles 5) to evaluate the VMS information and divert their route if a better path exists.
- Type 4: VMS is the optional detour VMS. It is similar to Type 2, however, it gives drivers the option to follow the detour path or keep their original path, based on the boundedly rational decision rule.

It was found that VMS Types 1 and 4 are inapplicable in the DynusT version used in this study, although they are viable in the official version of Dynasmart-P.

Table 8-1. VMS Types in Dynasmart

User Class	VMS Type			
	1: Speed Advisory	2: Mandatory Detour	3: Congestion Warning	4: Optional Detour
1:Unresponsive	√	√		
2:SO	√			
3:UE	√			
4:Enroute Info*	√	√	*	*
5:VMS	√	√	√	√

* Generally does not respond to VMS information unless the VMS preemption mode is selected.

The approach used in this study to model the ATIS in DynusT can be explained using the diagram shown in Figure 8-1. The main benefits of ATIS occur during incident conditions; thus, the assessment of ATIS is done under these incident conditions. In the DTA tool, incidents can be specified to be on any link, and are associated with start and end times. The severity of the incident is specified to represent the fraction link capacity loss due to the incident. Estimates of this fraction can be obtained based on a table included in the Highway Capacity Manual (HCM)[28]. The remaining discussion in this section includes the details of the modeling of ATIS.

The first step is to run the system under consideration in the model with no ATIS. For commuters and travelers familiar with the transportation system, the best method of assigning the traffic to the network in this run is the so-called User Equilibrium (UE) or User Optimal assignment based on "normal" traffic conditions. In such assignment, travelers select their routes such that no travelers can improve their times by shifting to another route between the origin-destination (O-D). DynusT establishes the UE condition through deterministic time-dependent shortest path, and method of successive average (MSA) or route swapping algorithm.

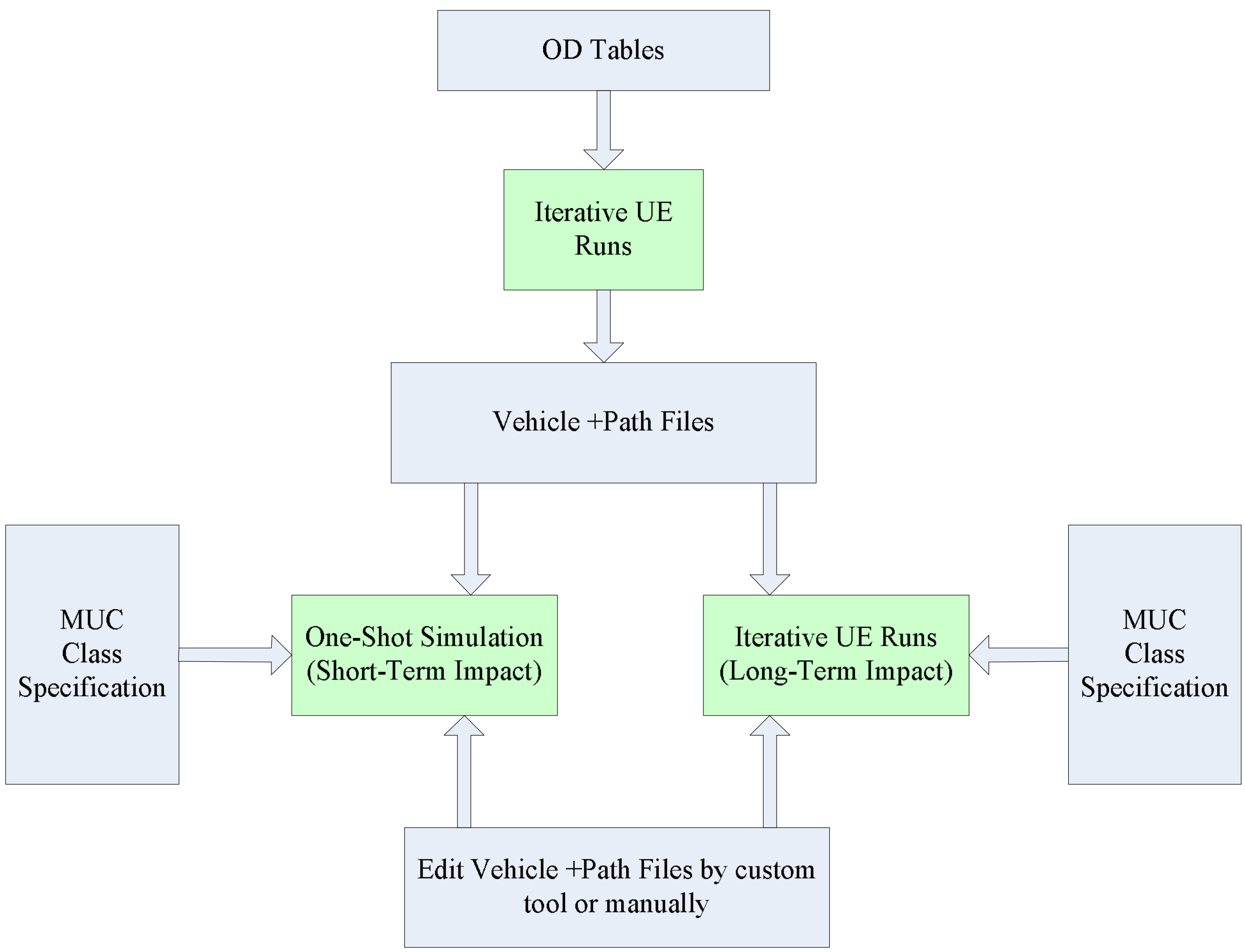


Figure 8-1. Modeling in DyanusT

DynusT generates two files that contain the attributes of all the vehicles at the end of the simulation. These two files are the vehicle.dat and path.dat files, and can be used in subsequent Dynasmart runs as inputs, instead of the trip (O-D) tables, to specify the initial paths assigned to the vehicles. In the subsequent runs, the user can change the proportions of different user classes to allow them to receive information and change routes based on the provided information. This study, however, found a bug with Dynasmart-P that prevented the research team from specifying different user classes when the vehicke.dat and path.dat files were used as inputs. Thus, a custom tool had to be produced to edit the attributes in the vehicle.dat and path.dat files, in order to change the proportions of the vehicles of various user classes. In the subsequent runs, incidents can be introduced into the network, and the impacts of the proportions of different user classes can be assessed in this manner.

As stated above, in the first run, the model is based on trip matrix demands, with all of vehicles classified in the User Equilibrium user group. Furthermore, no incident is coded in this run. This setup is used to model the day-to-day behaviors of travelers who are familiar with the network.

Subsequent to this first run, all runs are made based on the vehicle.dat and path.dat files instead of the trip tables. In these runs, incidents with specific durations and lane blockage characteristics are modeled. The vehicle.dat and path.dat files used as inputs to these runs are those resulting from this run, and will provide the paths that commuters use if they do not get information about the incidents (since these are their “normal” day paths). Using the developed custom tool, portions of the vehicles will be assigned to different user groups. Vehicles assigned to the unresponsive user group will follow the initial paths and will not receive any information about the incident. Other drivers which are assigned to user groups that receive information will change their routes, as described earlier in this section.

8.5. Hypothetical Case Study

The small hypothetical network shown in Figure 8-2 was used to test the methodology described above and the abilities of DynusT to assess ATIS. The small network was run in both DynusT and Dynasmart-P and the results were compared. After the test, a decision was made to use Dynasmart-P to run the simulation since it was found that some of the required features were not working in DynusT. In particular, DynusT had a bug which resulted in the paths of the vehicles to not be fixed when the vehicle.dat and path.dat were used as inputs.

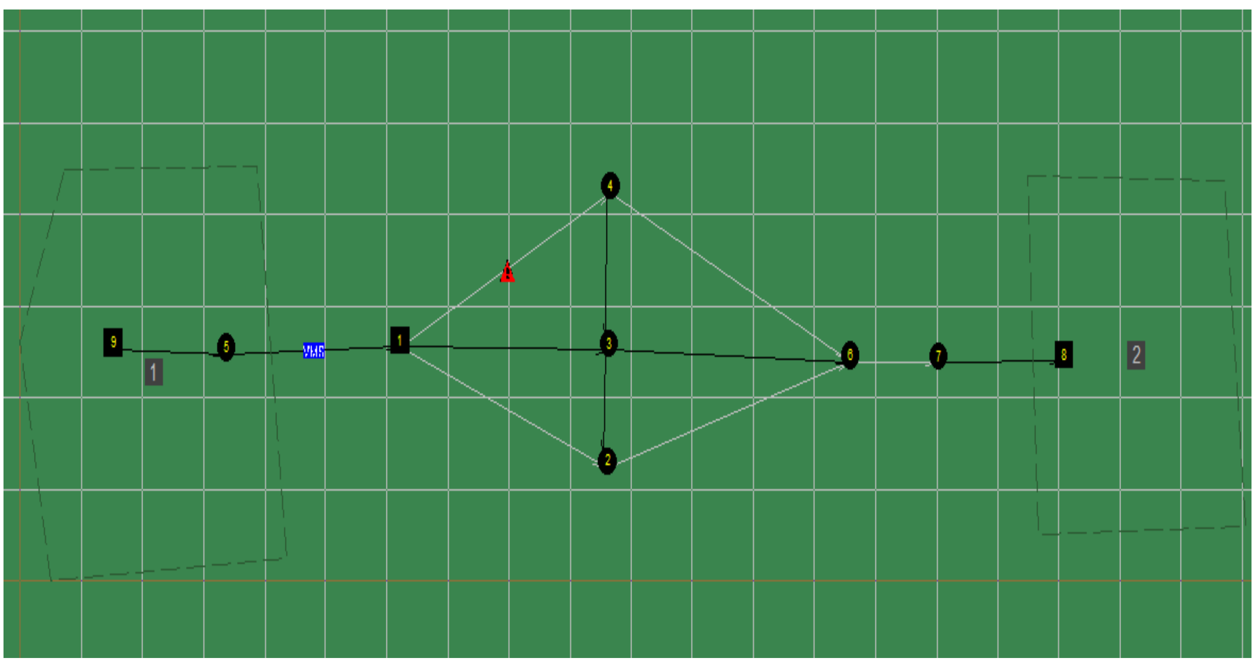


Figure 8-2. The Modeled Hypothetical Network

After the initial run (with 100% user equilibrium), the tool developed in this study was used to change the percentage of UE class from 1% to 100% in a set of runs that use vehicle-path data, as described earlier. The objective of these runs is to determine the benefit of an ultimate ATIS system that provides optimal routes to drivers in the case of incidents. Such systems are not currently available but are expected to be available with systems like IntelliDrive. In the network, the drivers can take one of three paths between nodes 1 and 6. The capacity of each path is 3,600 veh/hr. An incident that lasts from the 30th minute of the simulation to the 60th minute and drops the capacity on the link that connects node 1 to 4 by 25% (this drop is referred to in Dynasmart as severity) was introduced in the simulation.

The results are presented in Figure 8-3 and Figure 8-5. These results show that the delay close to the minimum average delay in the system can be achieved with a mere 30% to 40% market penetration of travelers. The minimum delay for vehicles impacted by the incident can be achieved at 40% to 50% market penetration. The average trip time of all vehicles and the average trip time of the vehicles impacted by the incident could be reduced by 47.4% and 48.6%, respectively. For example, the average trip time decreased from 10.5 veh/min to 5.6 veh/min when the percentage of informed vehicles increased from 1% to 40%. The maximum decrease in travel time for all vehicles and for the impacted vehicles were 46% and 50%, respectively. The volume on the incident link dropped from 31% to 25% of the total traffic when the percentage of UE class increased from 1% to 40% and remained almost constant after that. This indicates a maximum diversion rate of about 19% from the incident link. No further significant increase in volume or reduction in delays could be achieved with higher penetration rates. It should be noted that the above results are for advanced ATIS systems that provide the travelers with perfect knowledge of the best routes. Such systems are not currently available but will become available in the future, for example, as a result of the IntelliDrive system development.

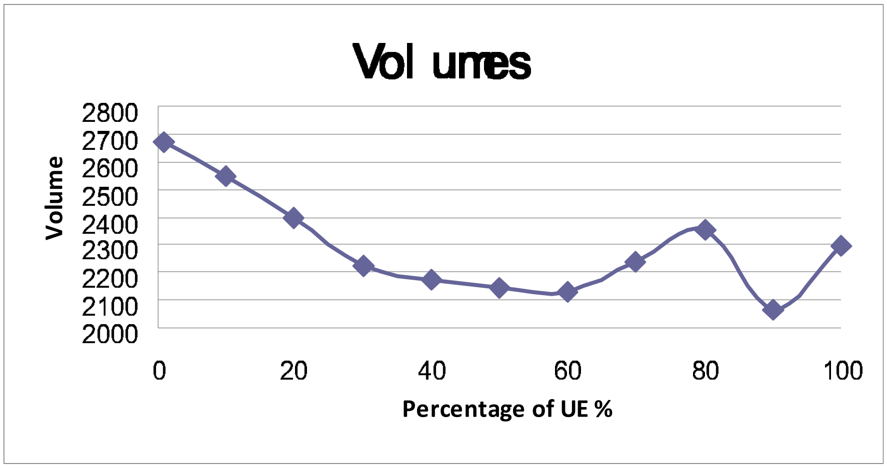


Figure 8-3. Volumes on the Incident Link (incident with ATIS Providing Optimal Route Information)

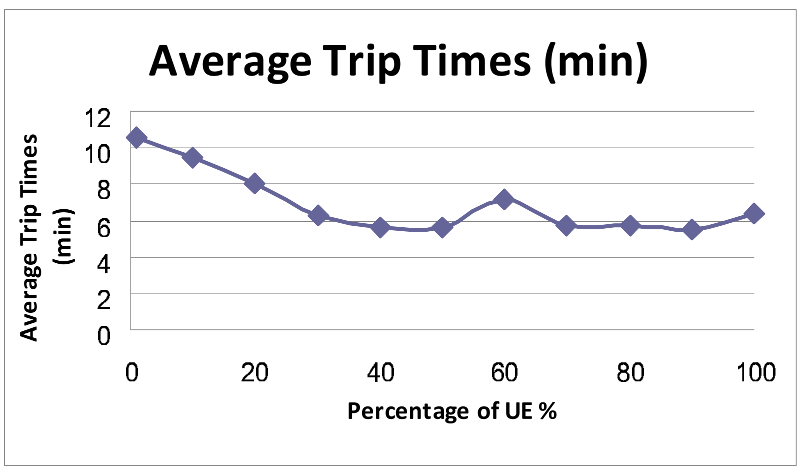


Figure 8-4. Average Trip Time (incident with ATIS Providing Optimal Route Information)

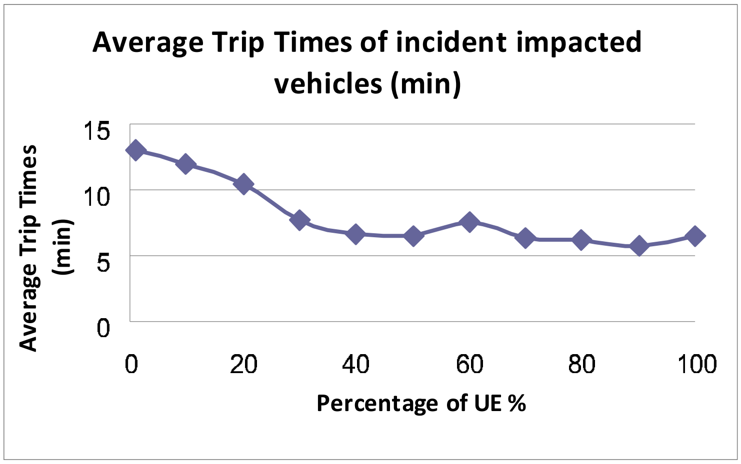


Figure 8-5. Average Trip Times of Incident Impacted Vehicles (Incident with ATIS Providing Optimal Route Information)

An additional set of runs was used to investigate the benefits of dynamic message signs. As with the route guidance system runs discussed above, these runs utilize the path and vehicle data produced from the initial runs. Congestion warning VMS was added to the network with the percentages of VMS-responsive vehicles (user Class 5), and the response rates were varied to investigate the effects of market penetration and compliance rates. The VMS-responsive vehicles divert if and only if a better path exists.

The results from the analysis are shown in Figure 8-6 through Figure 8-8. The results show that the travel time is minimal when 25% to 30% of the drivers responded to the VMS. The volume on the incident link dropped by 11.6% when the percentage of VMS-responsive vehicles increased from 0% to 30%. The corresponding decrease in average travel time of all vehicles and average trip time of incident impacted vehicles were 27.3% and 23.6%, respectively. These are lower than the values for the advanced ATIS system reported earlier at 46% and 50%, respectively. However, when the percentage of VMS-responsive class increased from 30% to 90%, the average trip time of all vehicles increased rapidly and finally surpassed the average trip time of all vehicles without ATIS. One possible reason is that the volumes of the other two links without incident are close to their capacities.

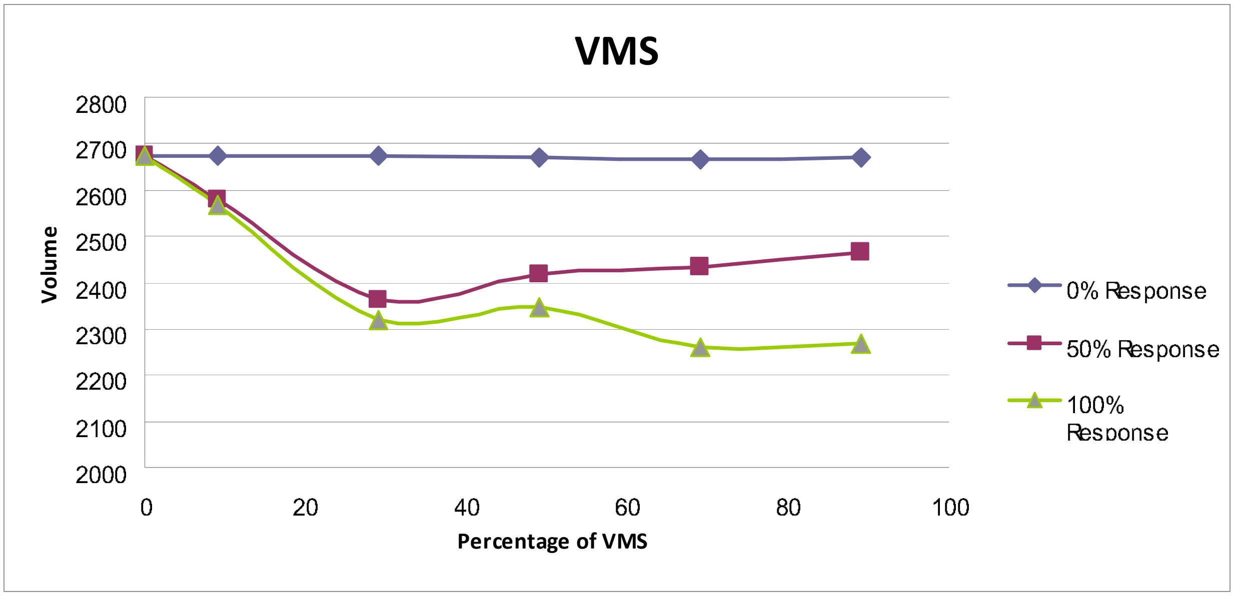


Figure 8-6. Volumes on the Incident Link with VMS Congestion Warning

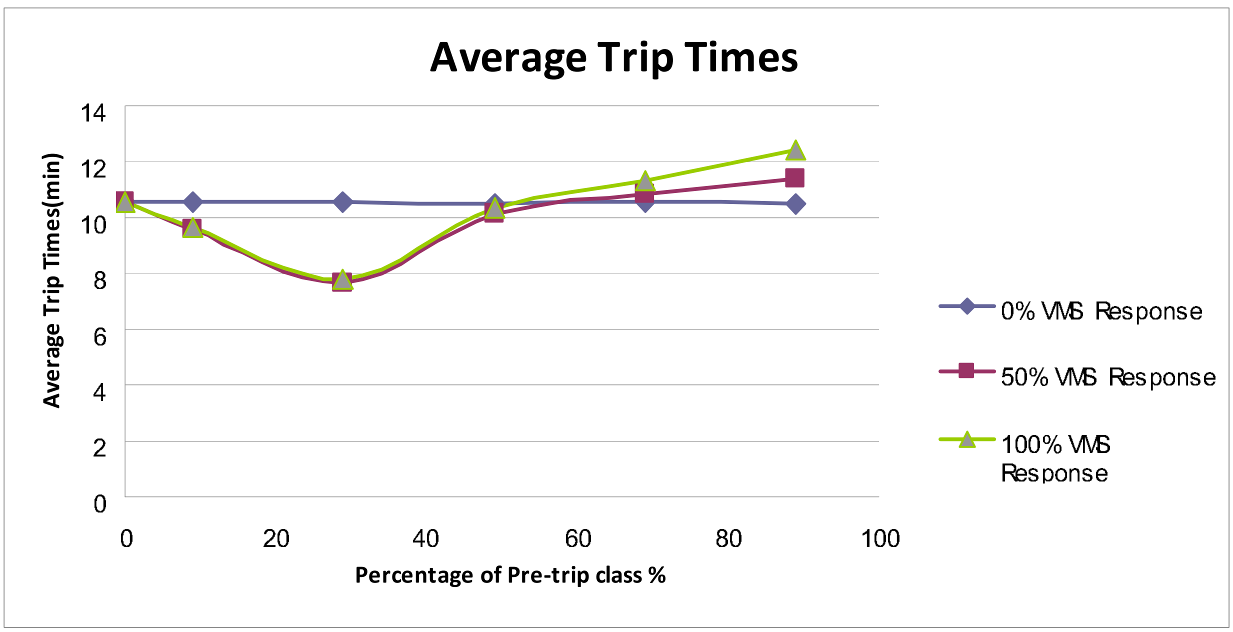


Figure 8-7. Average Trip Times with VMS Congestion Warning

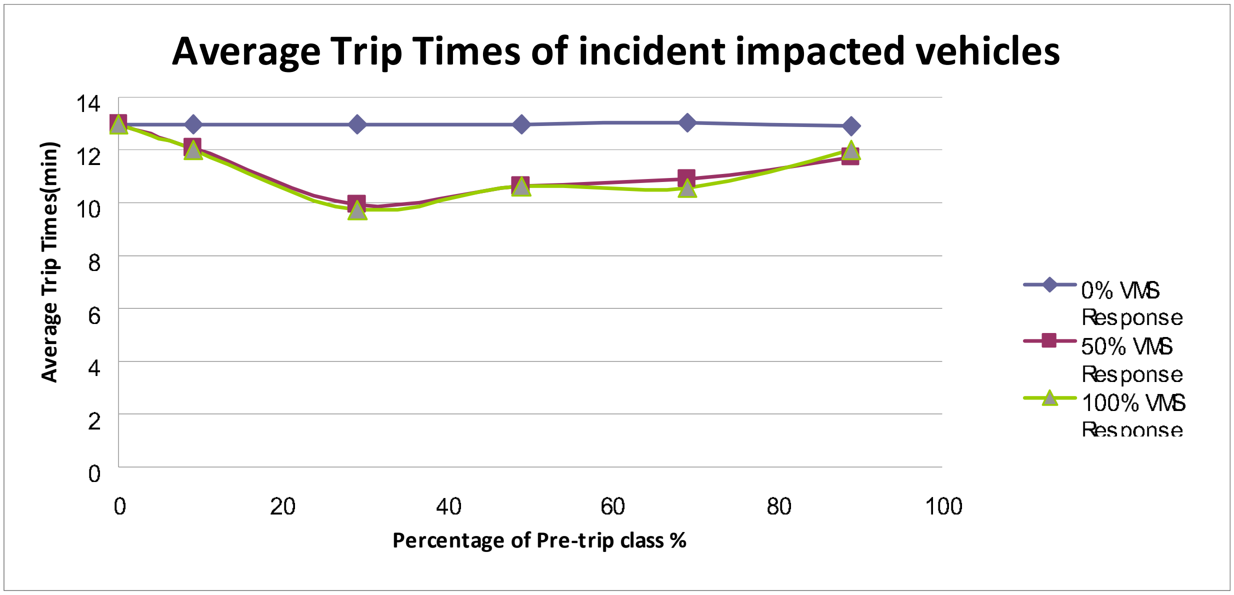


Figure 8-8. Average Trip Times on the Incident Link with VMS Congestion Warning

It can be seen from the results of the hypothetical network that the analysis seems to produce logical trends that confirm the validity of the use of the tool and method developed in this study to assess ATIS. Advanced in-vehicle route guidance systems are shown to produce better performance than VMS-provided information. In addition, the analysis shows an optimal percentage of diversion beyond which diversion is not beneficial due to the excessive congestion on alternative routes.

8.6. Jacksonville Case Study

The next step was to examine the ability of the developed model to assess the effect of ATIS as applied to the Jacksonville network, described earlier in this study. Figure 8-9 shows the location of the incident introduced in the simulated network for the purpose of the investigation. The incident was introduced on the southbound direction of I-95 for a duration of half an hour. The capacity drop was then set to 83%, which corresponds to blocking two of the three lanes.

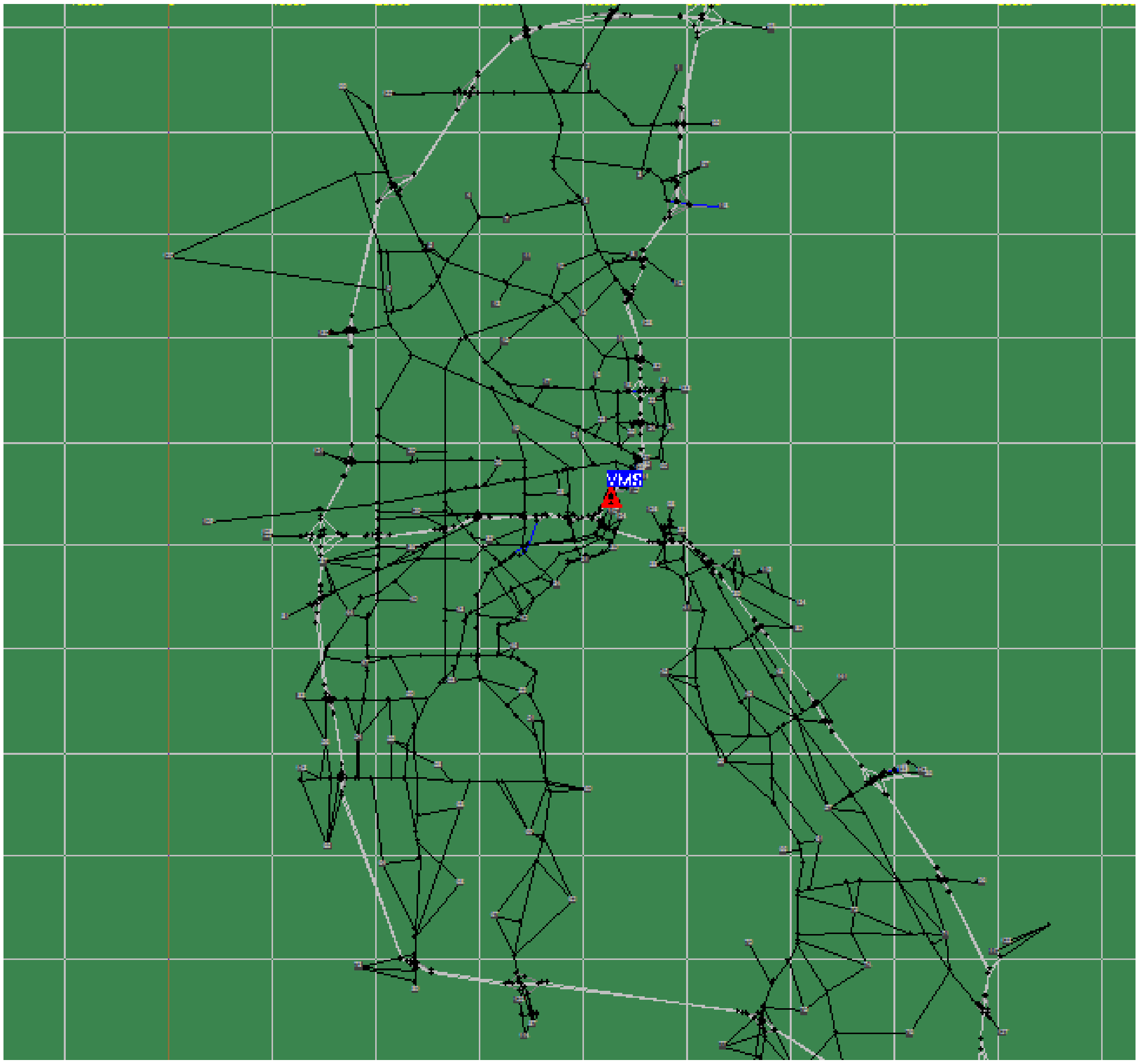


Figure 8-9. Jacksonville Network with the Modeled Incident and VMS Locations

The same method applied to the hypothetical network was applied to the Jacksonville network. Figure 8-10 through Figure 8-11 show the results from varying the percentage of drivers that are routed utilizing UE equilibrium in the case of incident. In the hypothetical network, we mentioned that this setup emulates an in-vehicle advanced route guidance system. In fact, with UE, the routing information is provided as the vehicles enter the network. Since the hypothetical network is small and the distance from the network entry to the diversion point is short, it was acceptable to assume that the routing information is provided en-route. However, for the Jacksonville network, this configuration implies a system that is in between in-vehicle route guidance and pre-trip route-guidance. If the vehicle enters the network close to the incident location, then the information received by these vehicles can be assumed to be en-route information. If the vehicles enter the network far from the incident location and close to their origins, , then the information received by these vehicles can be assumed to be pre-rip information. With the current capabilities of DynusT, the modeling of a pure advanced en-route system that provides optimal routing is not possible.

The results of using user equilibrium assignment in incident conditions are shown in Figures 8-10 and 8-11. From these results, it can be seen that the average travel time of all vehicles and the average travel time of incident impacted vehicles reduced by 7% (from 7.1 min./veh to 6.6 veh/min.) and 13.0% (from 19.5 min/veh to 16.7 min/veh), respectively, when the percentage of User Equilibrium class increases from 1% to 100%.

When VMSs are used to provide travel time, Figures 8-12 and 8-13 show that the average travel time of all vehicles and the average travel time of incident impacted vehicles reduced by 5.6% (from 7.1 min./veh to 6.7 veh/min.) and 18.0% (from 19.5 min/veh to 16.0 min/veh), respectively, when the percentage of VMS responsive class increases from 1% to 100%. The above results indicate that UE assignment at the entry points to the network was not able to produce significantly better results than providing information to vehicles using VMSs.

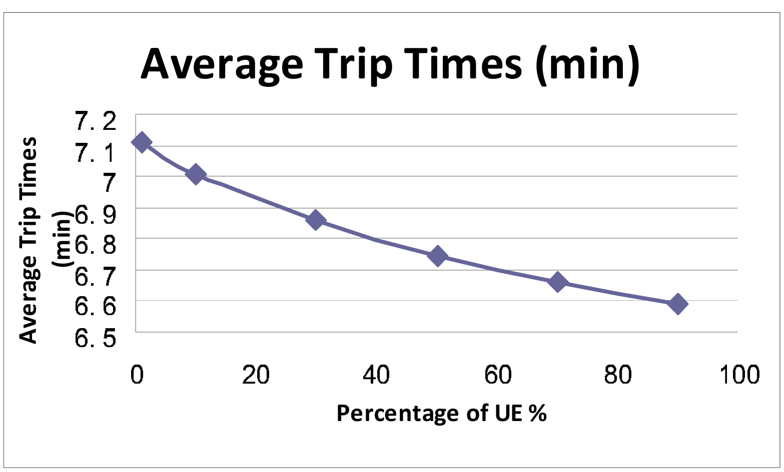


Figure 8-10. Average Trip Times with User Equilibrium for the Jacksonville Case Study

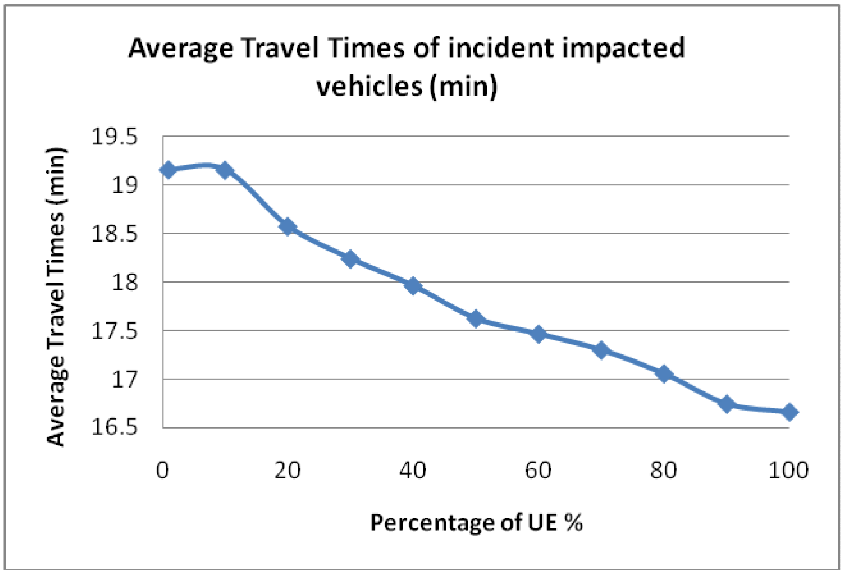


Figure 8-11. Average Trip Times of Incident Impacted Vehicles with User Equilibrium for the Jacksonville Case Study

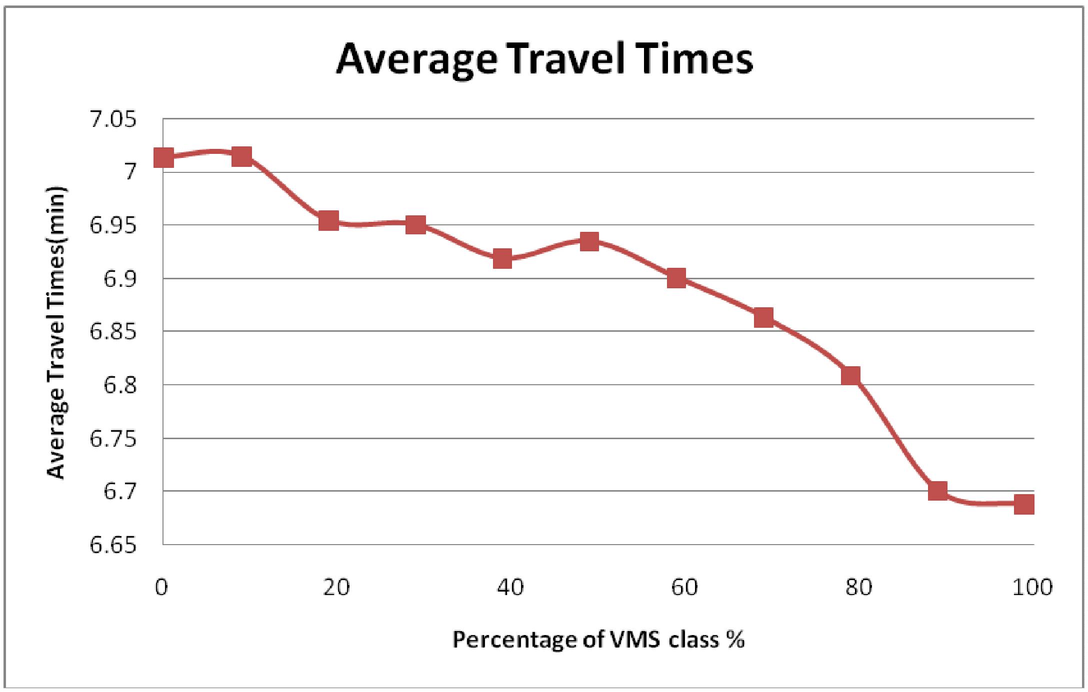


Figure 8-12. Average Trip Times with VMS for the Jacksonville Case Study

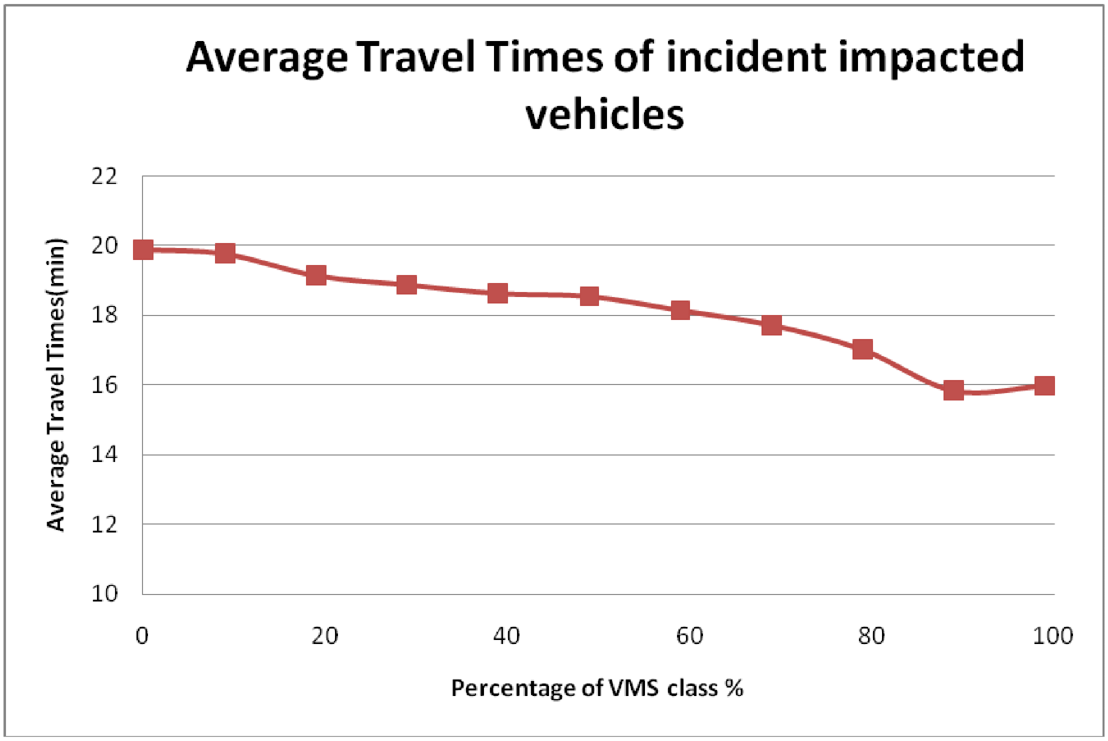


Figure 8-13. Average Trip Times of Incident Impacted Vehicles with VMS for the Jacksonville Case Study

9. Assessment of Truck/Toll Lanes

Another strategy that requires advanced modeling is the implementation of truck lanes, with the possibility of charging tolls for these lanes. The tolls could be either fixed, varied by time-of-day, or dynamically changed in response to network congestion. Truck lanes allow the shifting of trucks from mixed traffic flow lanes (general use lanes), improving the mobility and safety of both trucks and general traffic. Despite the expected benefits of these facilities, a number of issues face truck lanes including political, financial, engineering, safety, and environmental challenges. Thus, there is a need for a methodology to analyze these facilities, prove their benefits, and optimize their design and operations.

This section first presents a review of the current experience with these types of lanes; then, a discussion is included of the evaluation conducted in this study to assess their impacts using Dynamic Traffic Assignment (DTA)/mesoscopic simulation modeling. This assessment is based on both a simple hypothetical network and the Jacksonville network used in other tasks of this task.

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9.1. Past Experience in United States

California, Florida, Georgia, Missouri, Texas, Virginia and Washington have either already implemented, or are considering the implementation of, Truck-Only Toll (TOT) lanes. Below are descriptions of the experiences with these lanes in the United States.

9.1.1. California

California has two TOT facilities lanes on I-5 in Los Angeles County (2.43 miles) and I-5 in Kern County (0.35 miles)[44]. These truck-only lanes have barriers separated from the general purpose lanes.

The Southern California Association of Government in Los Angeles proposed regional toll truck lanes on SR-60, I-710, and I-15 freeways, for a total of 142 miles of tolled truck facilities, to improve both the conditions on freeways and the quality of air in the region. The proposed facilities include two-elevated truck lanes in each direction. The design capacity for these facilities was assumed to be 800 vehicles per lane, per hour. The estimated cost for the proposed 142-mile tolled truck facilities was $16.5 billion. The proposal is that the toll rates be varied based on time-of-day and level of congestion. It is estimated that 30% of the development cost of SR-60 will be covered from the toll revenue, with the toll rates estimated to be 35 to 70 cents/mile. Public-Private partnerships are encouraged to help speed the construction of the toll lanes on SR-60. The proposal also includes that longer combination vehicles will be required to use the toll truck facilities, but other trucks will have the option to choose between truck lanes or free general purpose lanes.

The criteria used in the above study to select corridors for implementing truck lanes are as follows:

- 30% of the total volume should be trucks
- Peak-hour volumes should exceed 1,800 vehicles per lane, per hour
- Off-peak volumes should exceed 1,200 vehicles per lane, per hour

9.1.2. Florida

The Florida Department of Transportation conducted a study to evaluate the feasibility of truck lanes for Florida's state highway system[45]. The study used Geographic Information Systems (GIS) to identify potential sites for exclusive truck facilities based on truck-related crashes, truck volumes, percentages of trucks, highway levels of service, proximity to airports, proximity to seaports, proximity to other intermodal facilities, and availability of right-of-way. Based on the above parameters, the study selected six corridors for implementing TOT lanes. These six corridors are I-95 from Miami to Titusville, I-95 from Daytona Beach to Jacksonville, I-75 from Naples to Ft. Myers, I-4 from Tampa through Orlando to Daytona Beach, I-75 from Venice to the Florida/Georgia State Line, and I-10 from Lake City to Jacksonville.

The above study pointed out that a separate toll-lane facility should provide both for ease of passing and for adequate shoulders on disabled lanes. A four-lane facility of this type was estimated to cost roughly $5 million per mile in 1987 and $9 million per mile in 2002. The study proposed the use of bonds that could be financed by state or private investors with long-term authorization agreements, and that could be repaid through tolls.

Another study [46] investigated the need for additional roadway capacity for goods-movement to and from the Port of Miami. The focus of this study was investigating an east-west truck-only roadway or "truck-way," built mostly along existing rail and roadway rights-of-way. Because the cost of such a truck-way was estimated to be in the billion-dollar range and the conventional funding sources are unlikely to be sufficient, the study made a preliminary feasibility assessment of financing the cost of the truck-way via tolls. Four alternative east-west routes were thus examined. The alternative included a combination of elevated, tunnel, and surface routes. The estimated costs ranged from a low of $1.1 billion to high of $1.3 billion in 2007 dollars. The study suggested that the toll truck-way requires a mix of public and private funds. It was estimated that the average round trip time for the trucks will be reduced from 2.55 to 1.8 hours with the implementation, resulting in an increase of the possible trips from three trips per day to four trips per day. By implementing a $9 toll per trip and realizing that each driver's gross income benefits due to the TOT lane are $147 (as a result of the additional trip made possible by the TOT lane implementation), the driver would have a net gain of $75 per day, if using the lane.

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9.1.3. Georgia

In 2005, Georgia's State Road and Tollway Authority (SRTA) conducted a study of TOT facilities in the Atlanta region[47]. A regional TOT network for the target year 2030 was proposed to improve safety, reduce congestion, and create reliable trips for both trucks and cars in the Atlanta area. This study modeled three scenarios for TOT lanes.

- Alternative 1 includes adding two voluntary TOT lanes in each direction on I-75 (north and south of I-285), on I-85 (north of I-285), and on I-285 west between I-75S and I-85N.
- Alternative 2 is the same as Alternative 1, except that it allows light-duty trucks to share HOV lanes inside I-285 during the off-peak periods from 10:00 A.M. to 3:00 P.M. with tolls.
- Alternative 3 involves converting planned HOV lanes on I-75, I-85, and I-285 to voluntary TOT lanes.

Alternative 3 was recommended because it was estimated to generate the greatest annual revenue of $198 million, incur the lowest construction cost of $578 million, produce the greatest travel time savings, and create the greatest congestion reduction on the general purpose lanes.

The above referenced Georgia study assumed a value of time of $18/hr for light trucks and $35/hr for heavy trucks in the estimation of toll rates. According to the plan, the toll rates would be adjusted according to the congestion level in the TOT lanes to limit the excess truck volumes and maintain TOT lane performance (a minimum level of service D). Public-private partnerships would be considered as a financing approach under Georgia's public-private partnership legislation. Truckers would also not be required to use the TOT lanes under the proposal, as the trucking industry supported the concept of the TOT lanes if and only if use of these lanes was voluntary.

In 2006, the Georgia DOT undertook the I-75 northwest corridor study, in which a TOT facility was one of the alternative[44]. The considered 15-mile TOT lanes would have two lanes in each direction and would be barrier-separated from the inside general purpose lanes and outside express toll lanes. Two scenarios in this corridor, including voluntary use of TOT lanes and mandatory use for through truck trips, were thus proposed. The toll rates on TOT lanes would vary by time-of-day and travel direction, and were estimated in the projected year of 2030 to be 15 cents/mile during off-peak periods to 80 cents/mile during peak periods. Public-private partnerships were to be part of the project financing. Various levels of truckers' willingness-to-pay were tested to reflect the application to different truck trip characteristics. Mandatory TOT lanes showed better performances on the general purpose lanes than did the voluntary TOT lanes because all through heavy trucks are forced to travel in the TOT lanes with this strategy. Implementing voluntary TOT lanes or mandatory TOT lanes on I-285 west will result in increased travel speed, decreased travel time, reduced delay, and reduced truck vehicle miles traveled on the general use lanes. The above study used the following evaluation criteria to identify candidate truck-only lanes on statewide interstate systems: (1) daily truck volume in both directions greater than 30,000, (2) congestion measured by level of service equal to E or worse on general purpose lanes, (3) major truck activity centers, (4) freight bottlenecks, and (5) corridors have already been considered for improvement.

9.2. Hypothetical Case Study

Initially, the official version of Dynasmart was considered in this study to evaluate the efficiency of the TOT lane. It was found, however, that this version is not capable of simulating TOT lanes. Dynasmart does not provide the option to specify toll values for trucks that are different from other vehicle types. Fortunately, enhancements in DynusT overcome this problem. As mentioned before, DynusT is the software used in this study.

As stated earlier, the assessment of the TOT lane was conducted for both a hypothetical network and the Jacksonville network used as a case study herein. The simple hypothetical network is shown in Figure 9-1. Zone 1 is the origin and Zone 2 is the destination in the model. The one-lane segment that connects Nodes 3 and 4 through Node 7 is the coded TOT lane. The two-lane segment that connects Nodes 3 and 4 through Node 8 is the general-use lane. The capacity is assumed to be 1,800 vehicles per hour (vph) per lane.

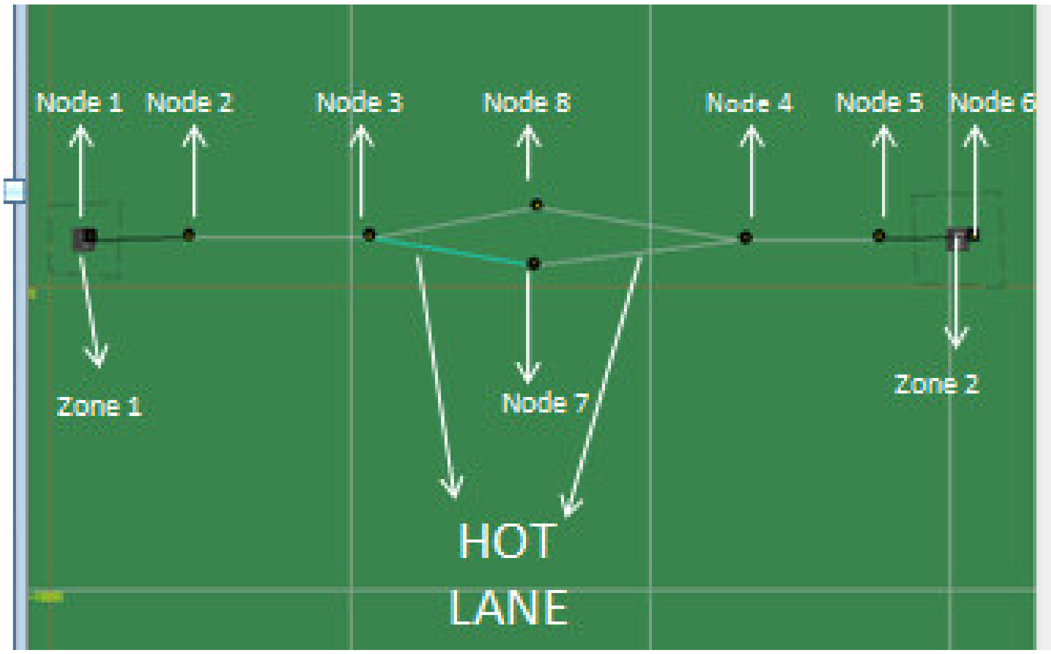


Figure 9-1. Hypothetical Network Used in Testing TOT Lanes

In order to evaluate DynusT's ability to assess TOT lanes, the demand was varied from uncongested to congested conditions. In addition, the value of time and toll values were also varied. All combinations of the following values for the three investigated variables were assessed:

- Demand between Zones 1 and 2: 2,000; 2,500; 3,000; 3,500; 4,000; 4,500; 5,000; 5,500; and 6,000 vph
- Value of time: 15, 20, 25, 30, 35, and 40 dollars per hour
- Toll: 0, 0.25, 1, 3, 5, 7, and 8 dollars

The combinations of the above variables result in a total of 378 different simulation scenarios (nine demands multiplied by six values of time multiplied by seven toll values). By examining these scenarios, it was possible to determine the reasonability of the results produced with DynusT.

Figure 9-2 and Figure 9-3 show examples of the results for congested conditions when the input demand is set to be 6,000 vph, while the combined capacity of the toll and general use lanes is set to 5,400 vph. Figure 9-2 shows that as expected the increase in the value of time and the decrease in toll value increased the utilization of the toll lane. The impact of the value of time on the utilization is even greater at higher toll rates. Figure 9-3 shows that the travel time saved by the vehicles using the toll lanes increases with the decrease in the value of time and the increase in the toll rate. The reason is that when decreasing the value of time and increasing the toll rate, the utilization of the toll lane decreases. This results in a higher congestion on the toll lane, thus increasing the difference in travel time between the toll lane and the general use lane, as indicated in Figure 9-3.

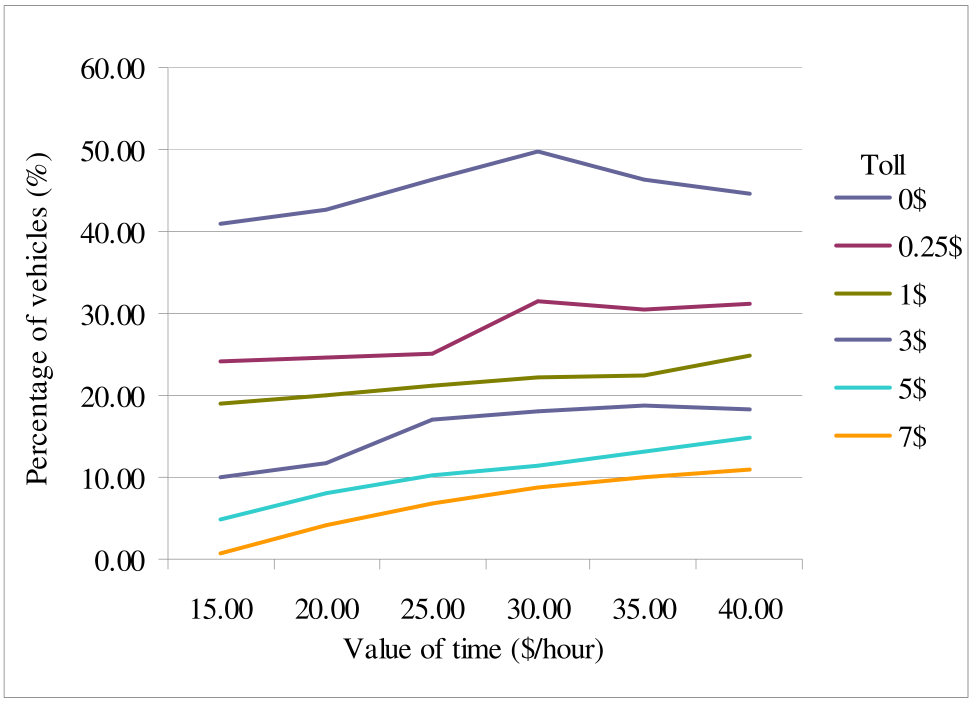


Figure 9-2. Percentage of Vehicles Using the Toll Lane (for 6,000 vph Demand)

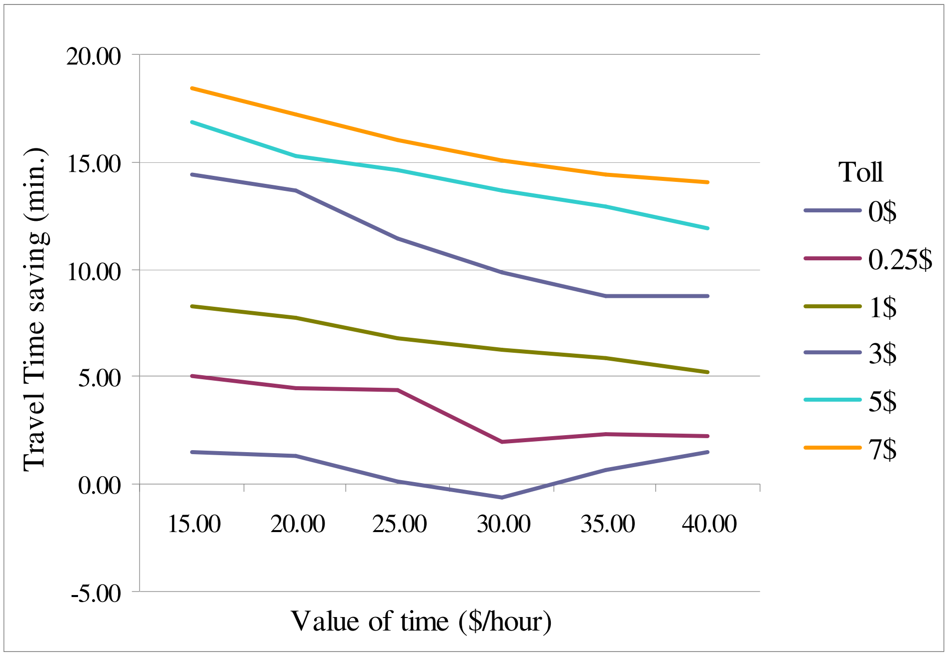


Figure 9-3. Travel Time Saved by the Vehicles Using the Toll Lanes (for 6,000 vph Demand)

9.3. Jacksonville Network Case Study

The Jacksonville network obtained in previous tasks of this project was utilized as a case study to demonstrate the use of DynusT to assess TOT lanes.

The following steps are used in this task:

1. The first task is to screen the network to determine potential segments for TOT lane implementation. The screening criteria used to identify a potential segment include the following:
   a. Low level of service
   b. High truck volume
   c. High truck percentage
   d. High truck related crashes

2. Next, a decision will need to be made regarding the criteria for the setting of the toll rates. Criteria used in the past included toll revenue, level of service, utilization rate, and truck diversion rate.
3. Finally, the developed tools will be used to assess the benefits of the alternatives of TOT implementations based on the criteria set in Step 1, above. Due to the uncertainty associated with the value of time for truck traffic, sensitivity analysis is performed for this value.

9.3.1. Screening for Potential Segments

As stated earlier, the first task is to screen the network to determine potential segments for TOT lane implementation. Below is a discussion of the criteria used.

Level of Service (LOS): The first used criterion is the LOS, as defined in the HCM. The LOS is a qualitative measure of traffic operational conditions, ranging from A to F. For freeway basic segments, the HCM presents relationships between the v/c ratios and LOS categorized by free flow speed. In this study, these relationships are used in determining the level of service for each freeway segment in the Jacksonville area. For basic freeway segments with free flow speed above 70 mph, as in the Jacksonville case study, v/c ratios between 0.74 to 0.9 are associated with LOS D and v/c ratios between 0.9 and 1 are associated with LOS E. Segments operating at v/c ratios greater than 1 are considered to be operating at LOS F. The analysis will have to be performed for each period of the DTA analysis based on DTA model results. For example, if the DTA analysis is performed for every 30 minutes in a 2-hour P.M. peak-period, then four different LOS values are determined for each segment and the lowest LOS is used in the analysis. As seen in Figure 9-4 the LOS values are visualized on maps to identify adjacent segments with LOS D and E as potential segments for the TOT implementation.

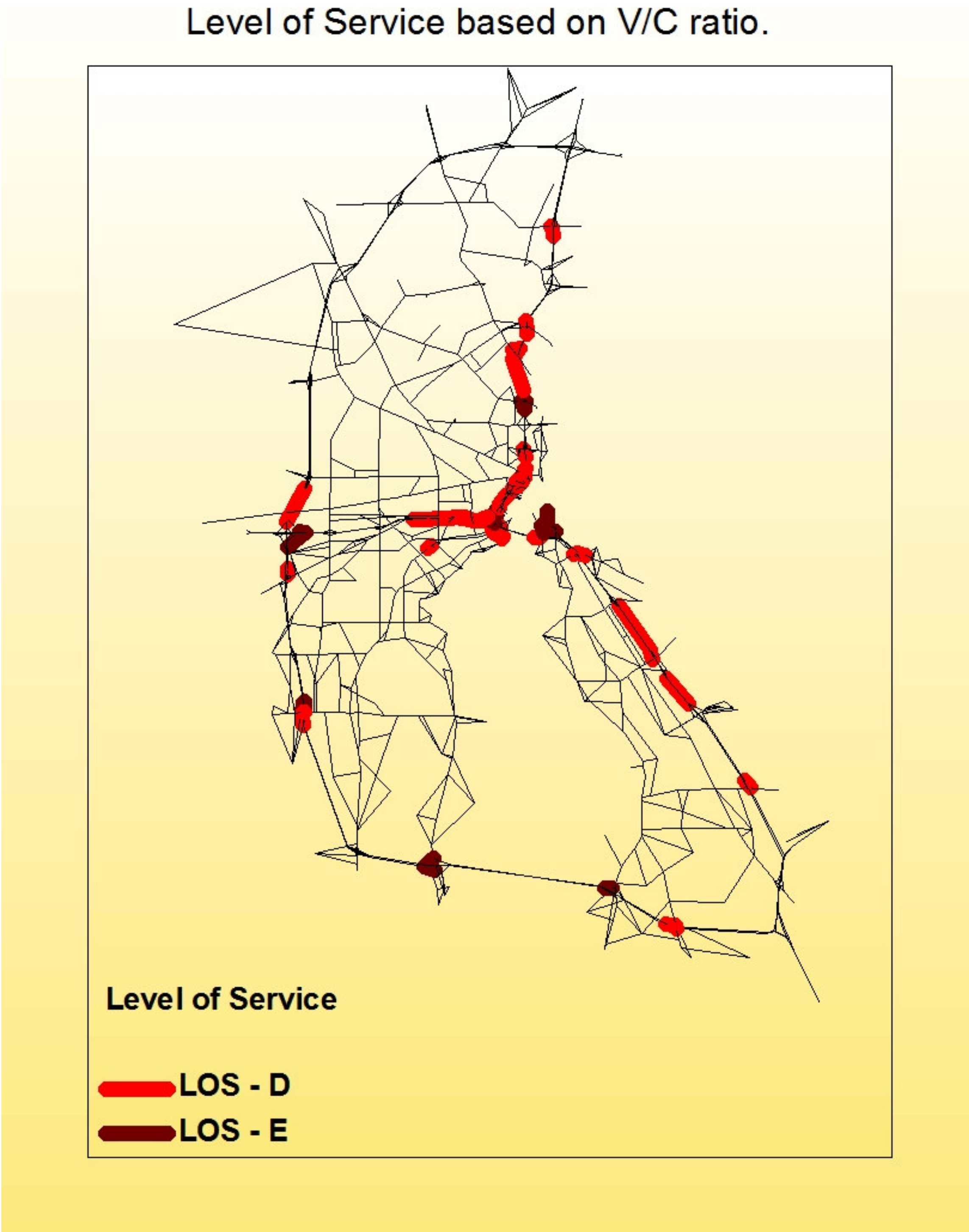


Figure 9-4. Freeway Segments with LOS D and E

Truck Volume: The next criterion used in the screening is the truck volume. In addition to the large volume of truck traffic during peak periods, a lot of trucks choose off-peak periods to move freight and avoid severe congestion. For example, local truck deliveries usually choose the midday off-peak period to avoid travel time delays in urban areas. Therefore, as proposed in the literature[47], this daily truck volume, rather than the peak hour volumes, was used in the screening.

Chu's[44] study of potential TOT lane implementation in Atlanta used 9,000 trucks per day as a threshold of sufficient truck travel demand for candidate TOT lanes. Figure 9-5 shows the average daily truck volumes in the Jacksonville region, based on volume measurements included in the Florida Traffic Information (FTI) CD-ROM.

Truck Percentage: Chu[44] recommended using 15% for selecting corridors for the implementation of TOT lanes. Another report in Florida[45] utilized 11% for this criterion. In consideration of the two studies above, this study uses 10% as the criterion. Figure 9-6 shows the corridor segments that have truck percentages greater than 10% during an analysis period.

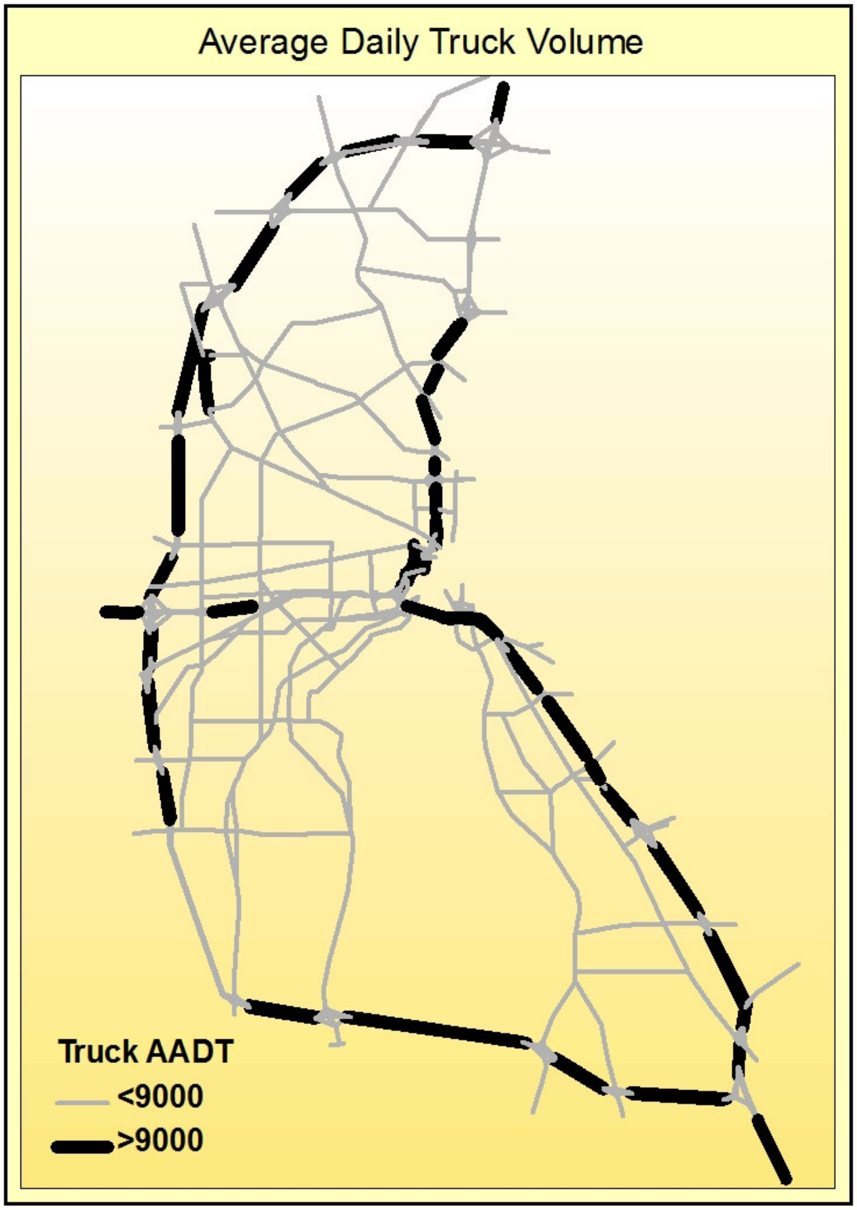


Figure 9-5. Average Daily Traffic Volumes on Jacksonville Freeway Segments

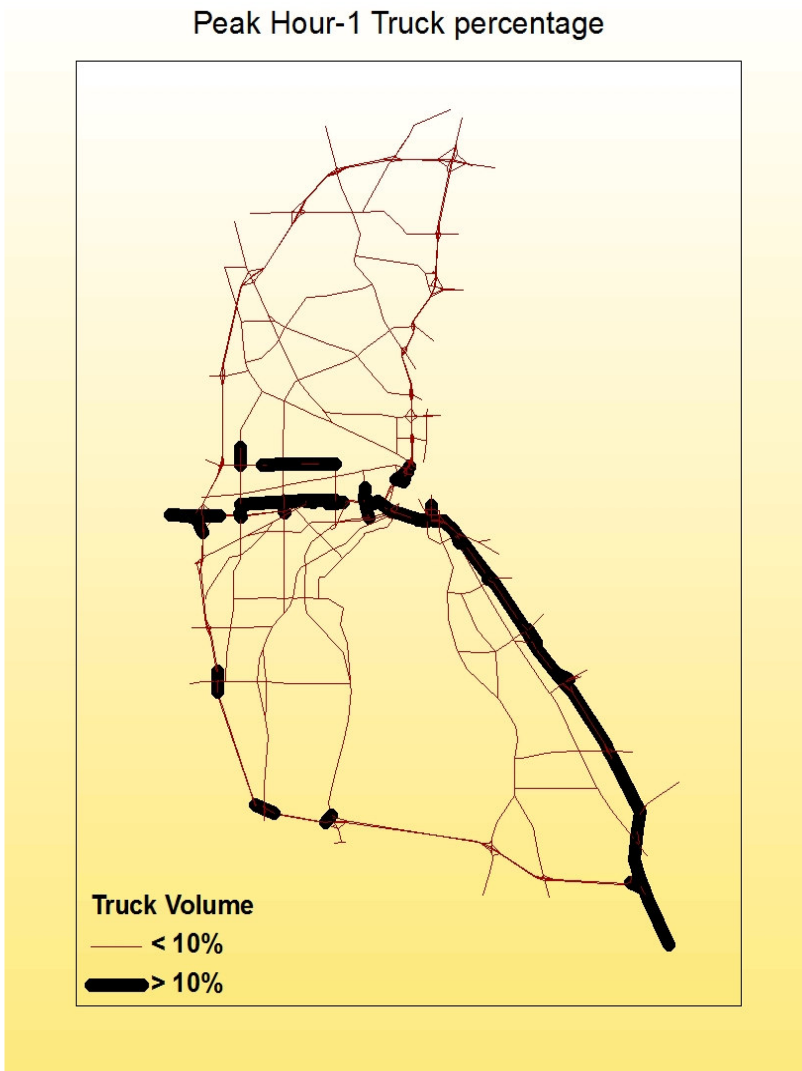
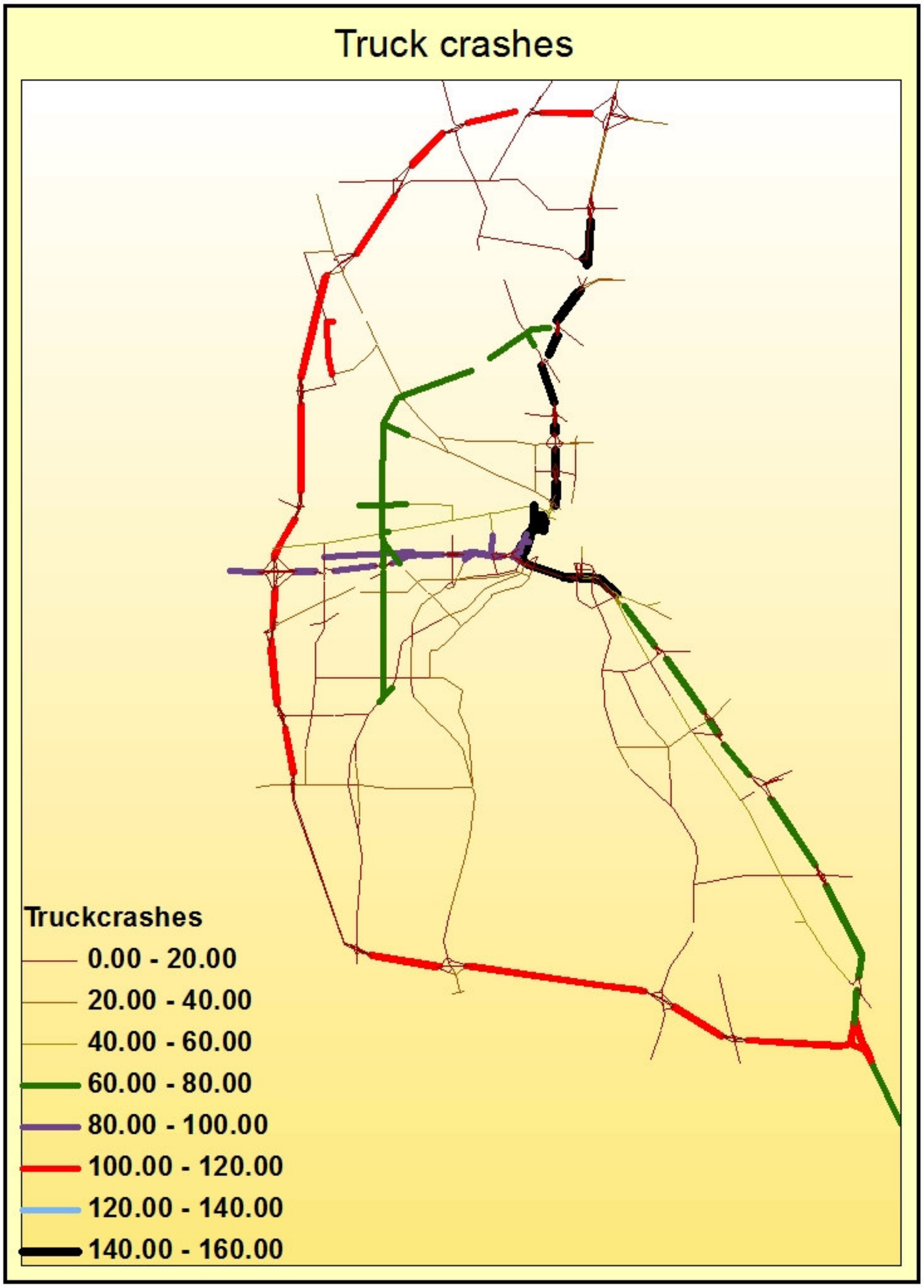


Figure 9-6. Peak One-Hour Truck Percentage on Jacksonville Freeway Segments

Truck-Related Crashes: Data on crashes involving trucks was taken from the FDOT. Three-year crash data from 2005 to 2008 are thus considered. The analysis can be based on crash frequency, rate, or a combination of the two, in addition to crash severity. In this example, only the average number of crashes involving trucks is used.



shows the average number of crashes involving trucks per segment. The corridors which are colored black are the corridors with the highest number of average truck crashes (from 140 to 160 crashes in the three-year analysis period).

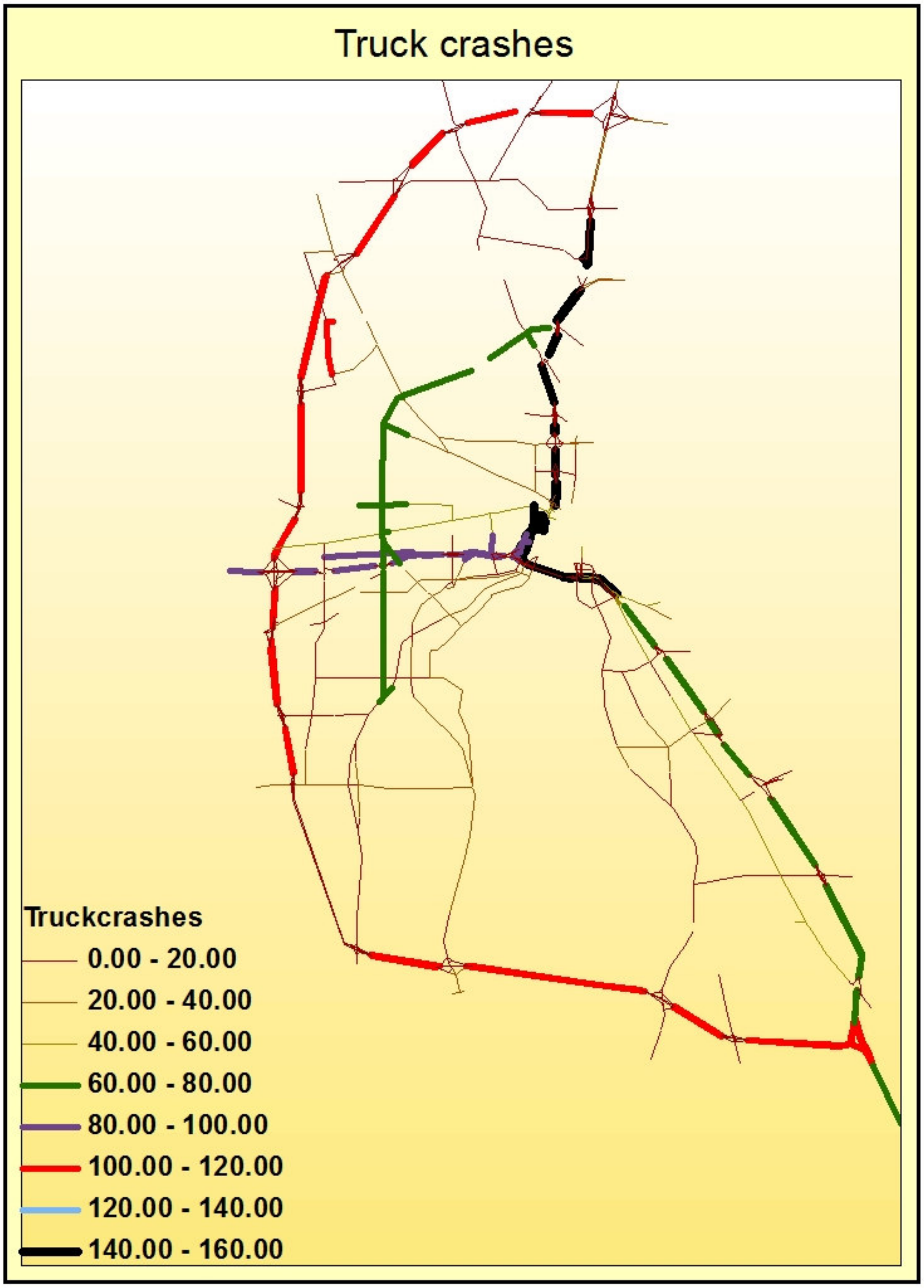


Figure 9-7. Corridor Locations with High Crash Rates

Based on the results of the above assessment, the potential corridor is selected as the I-95 segment shown in Figure 9-8. Based on further examination, two alternative implementations of the TOT lane were selected for testing in this study, as shown in Figure 9-9 and Figure 9-10.

Figure 9-8. Potential Corridor for TOT Lane Implementation

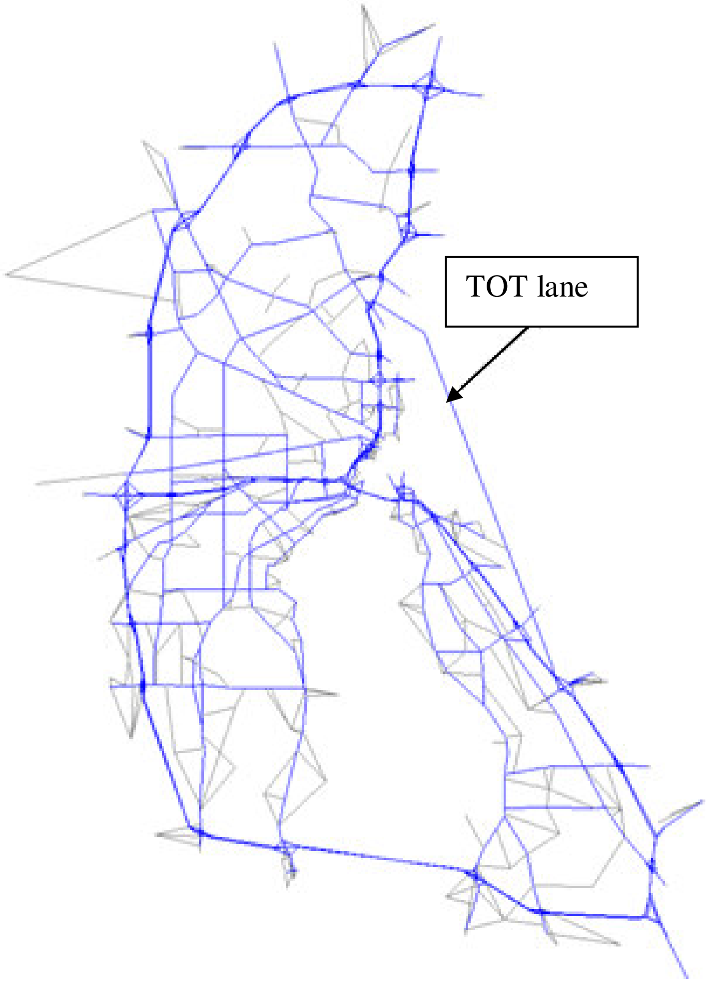


Figure 9-9. Alternative 1 TOT Location

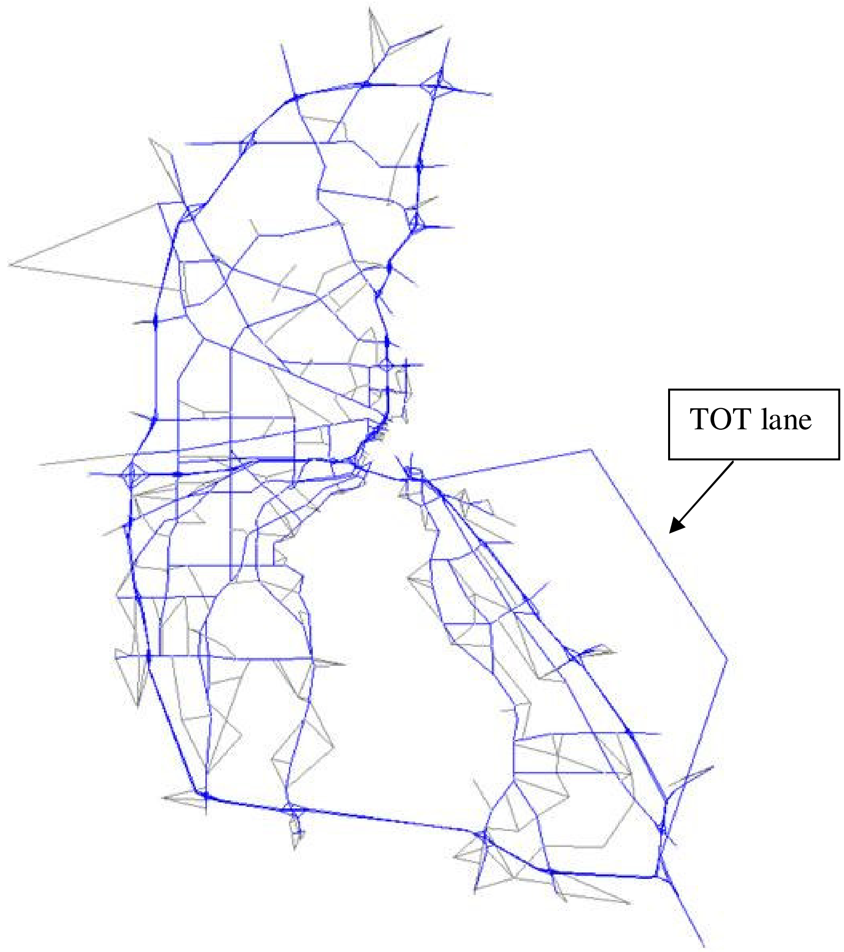


Figure 9-10. Alternative 2 TOT Location

9.3.2. Simulation of the Alternatives

The two TOT alternatives on the I-95 corridor in the Jacksonville area, as identified in the previous section, were modeled in DynusT. The alternatives include converting one general purpose lane into an optional TOT lane. The demands in the network were calculated as described in previous chapters of this document. Since there are no local stated preference survey results that can be used to identify the value of time (VOT) of the trucks, a sensitivity analysis of the variable was conducted in this study. Based on previous surveys; the VOT identified in Georgia, Minnesota, Virginia, and California were $31, $50, $60, and $71, respectively. Thus, the value of time used as input to the simulation model was varied from $40 to 100$ at a $10 interval in the sensitivity analysis of this study.

Table 9-1 shows the simulation results of the Alternative 1 TOT lane. These results show that the utilization rate of the truck lane is expected to be low, even while using $100 per hour as the value of time. This is mainly due to the low congestion level on the I-95 corridor in the model (Level of Service D). Alternative 2 shows higher utilization of the TOT lane. The reason for this is that Alternative 1 connects the southern segment of I-95 to the northern segment of I-95 with no connection to I-10. Alternative 2 connects the southern segment of I-95 with I-10. This connection allows trucks destined to I-10 to use the TOT lane, thereby increasing the utilization of the lane. As shown in Figure 9-11, I-95 northbound truck traffic with destinations around the I-10 corridor is significantly higher than truck traffic destined to the northern segment of I-95.

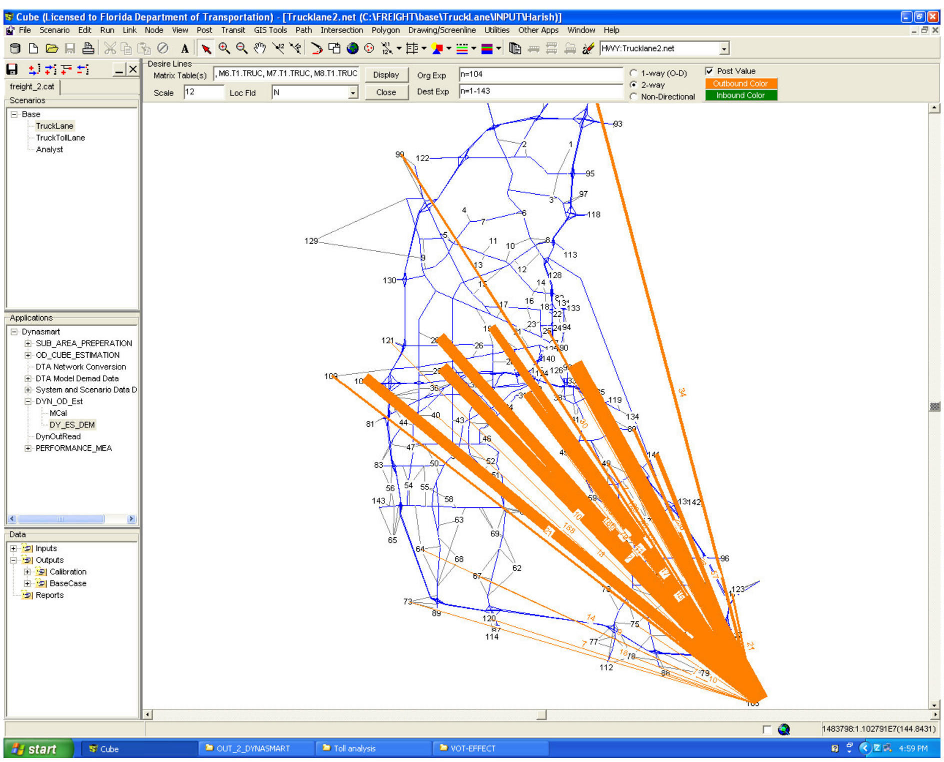


Figure 9-11. Trip Distribution of the Truck Traffic Originated South of I-95

In terms of performance measures, the impact of the TOT lane on both the traffic and truck traffic is minimal according to the simulation results. This is due to the relatively low congestion level on the corridor. However, a mandatory TOT lane will produce a reduction in truck crash rates and generate additional revenues.

Table 9-1. Simulation Result of Alternative 1

Alternative	TOT lane			
	VOT	Speed	Travel Time	Utilization Rate
1	40.00	71.00	10.72	5.00
	50.00	72.00	10.70	13.86
	60.00	71.00	10.77	14.00
	70.00	71.00	10.78	17.00
	80.00	71.00	10.78	17.76
	90.00	71.00	10.78	18.09
	100.00	70.00	10.78	19.26
2	40.00	71.00	9.72	45.64
	50.00	72.00	9.70	48.73
	60.00	71.00	9.77	49.81
	70.00	71.00	9.78	47.57
	80.00	71.00	9.78	53.36
	90.00	71.00	9.78	53.51
	100.00	70.00	9.78	53.59

10. User Interface

This section details the user interface developed in this study to allow the user to conduct the various processes, described in previous sections of this report, and the outputs resulting from the modeling environment discussed herein. This implementation was achieved using the script language of the Cube software, Visual Studio, and Fortran.

10.1. Modeling Structure

The modeling processes described in previous sections of this report include subarea network and matrix preparation, network and matrix conversion to DTA model format, O-D matrix estimation using CUBE Analyst, O-D estimation based on dynamic traffic assignment, system and modeling scenario definition, alternative freight strategy definition, data reading and association within the CUBE environment, and performance measures calculation. The Cube modeling structure is shown in Figure 10-1.

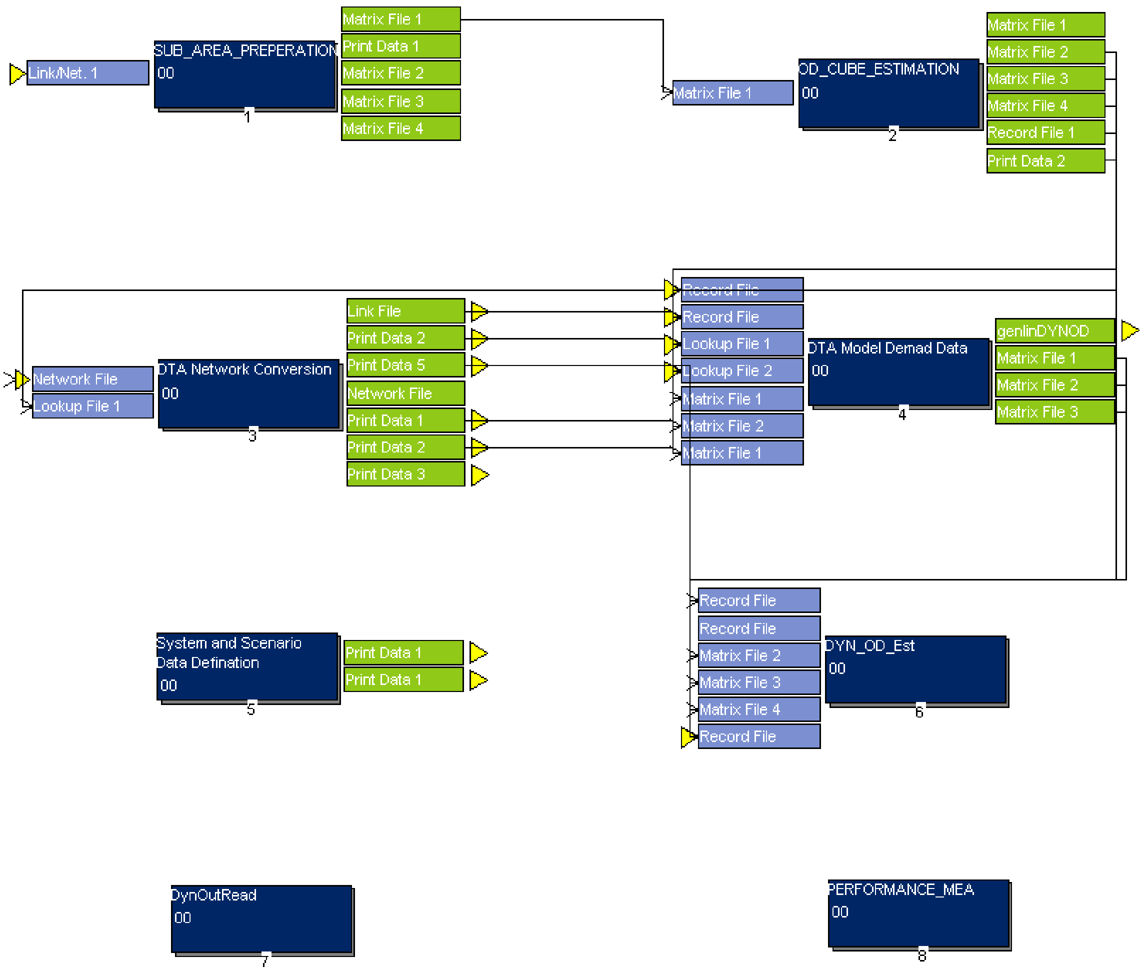


Figure 10-1. Structure of the Modeling Processes

10.2. Input Interface

The input interface for the developed environment was implemented using Cube catalog keys. These keys define items that vary each time an application in a catalog is run. The keys may represent a file, number, character string, or Boolean flag, and are assigned values for each scenario. When a scenario is edited in the developed environment, all of the keys are displayed on a dialog so that each can be given a value for the scenario. How the key appears on the dialog, and the values that it can take, is governed by the definition of the key[48].

The developed user interface is depicted in Figure 10-2 through Figure 10-4. As can be seen in these figures, the inputs are organized into eight subgroups: subarea network, hourly matrix conversion, matrix estimation, advanced scenario information, specification of modules to run, dynamic O-D matrix parameters, traffic flow model parameters, and performance measure estimation. The keys in each of these subgroups are described next.

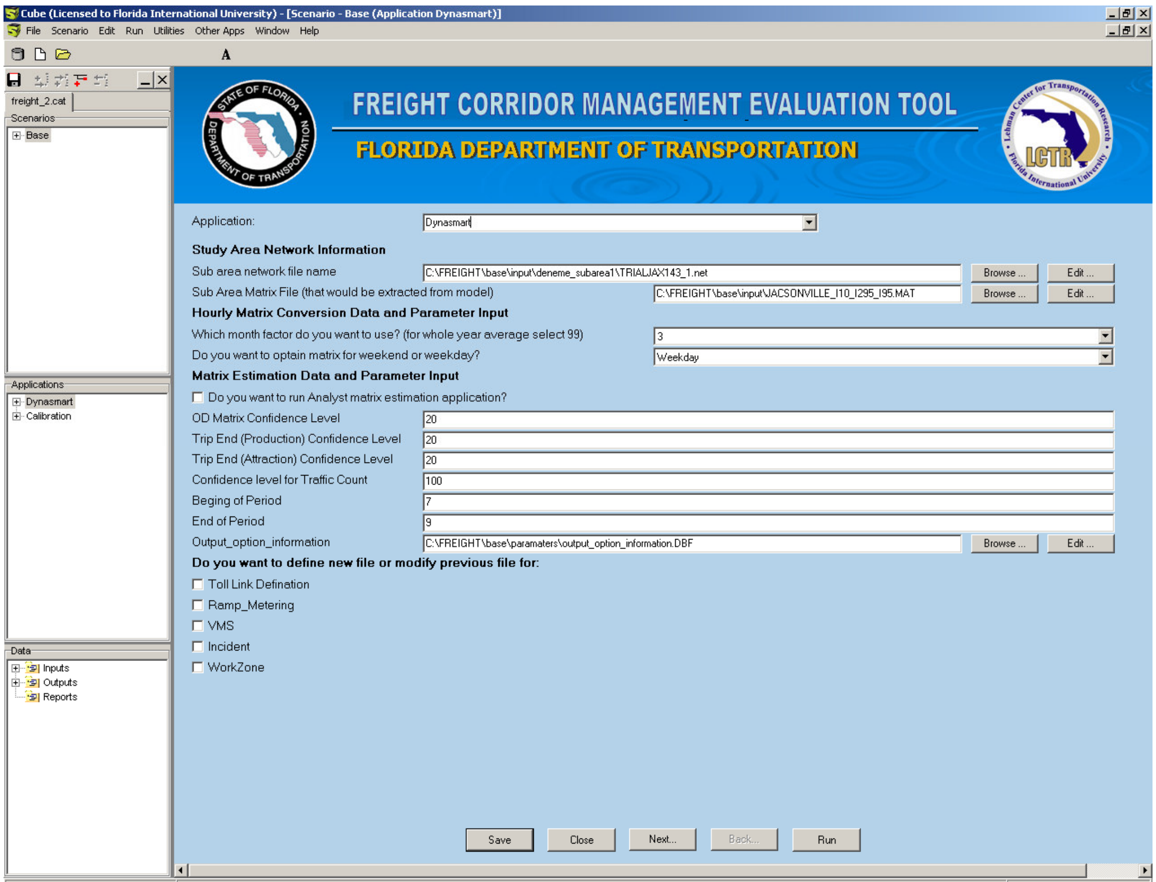


Figure 10-2. User Interface for Data Input (subarea network, hourly matrix conversion, matrix estimation, and additional scenario inputs)

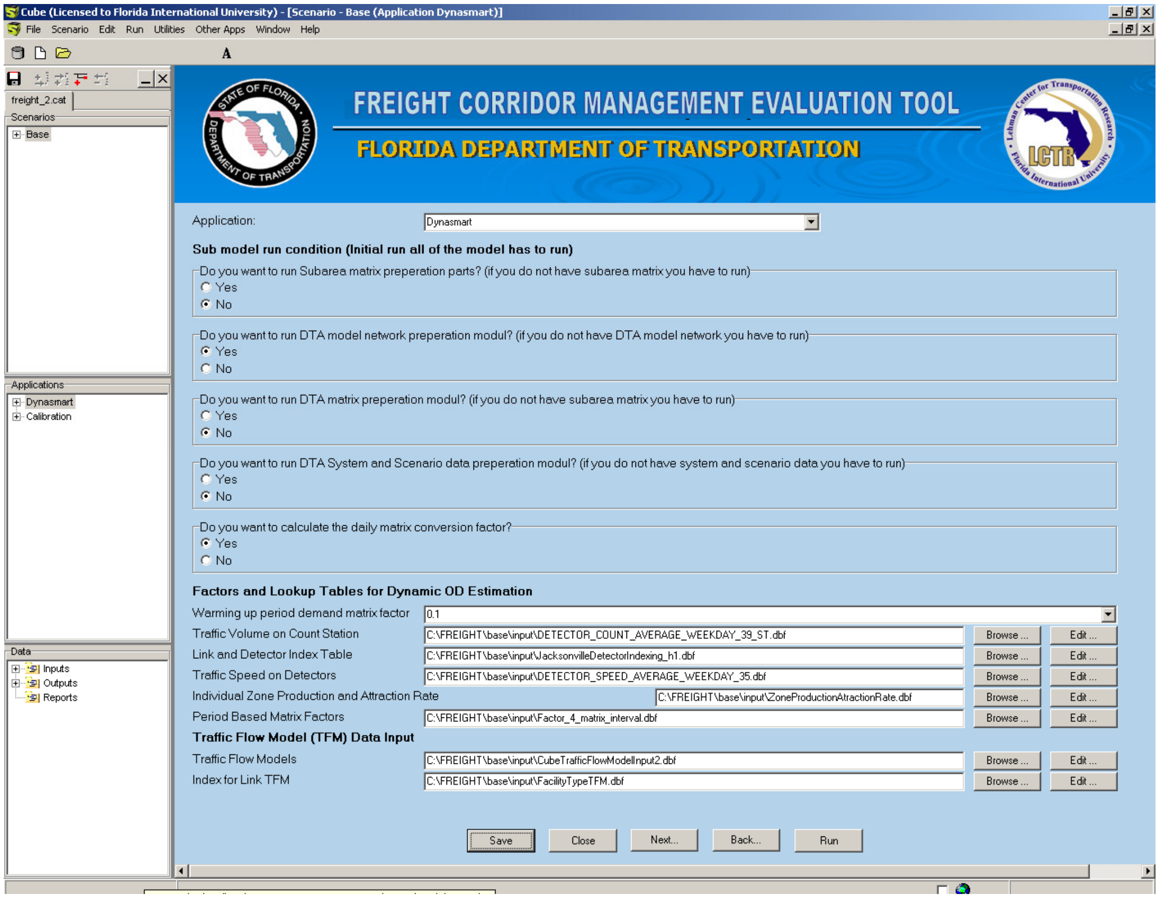


Figure 10-3. User Interface for Data Input (specification of modules to run, OD matrix estimation, and traffic flow model specification)

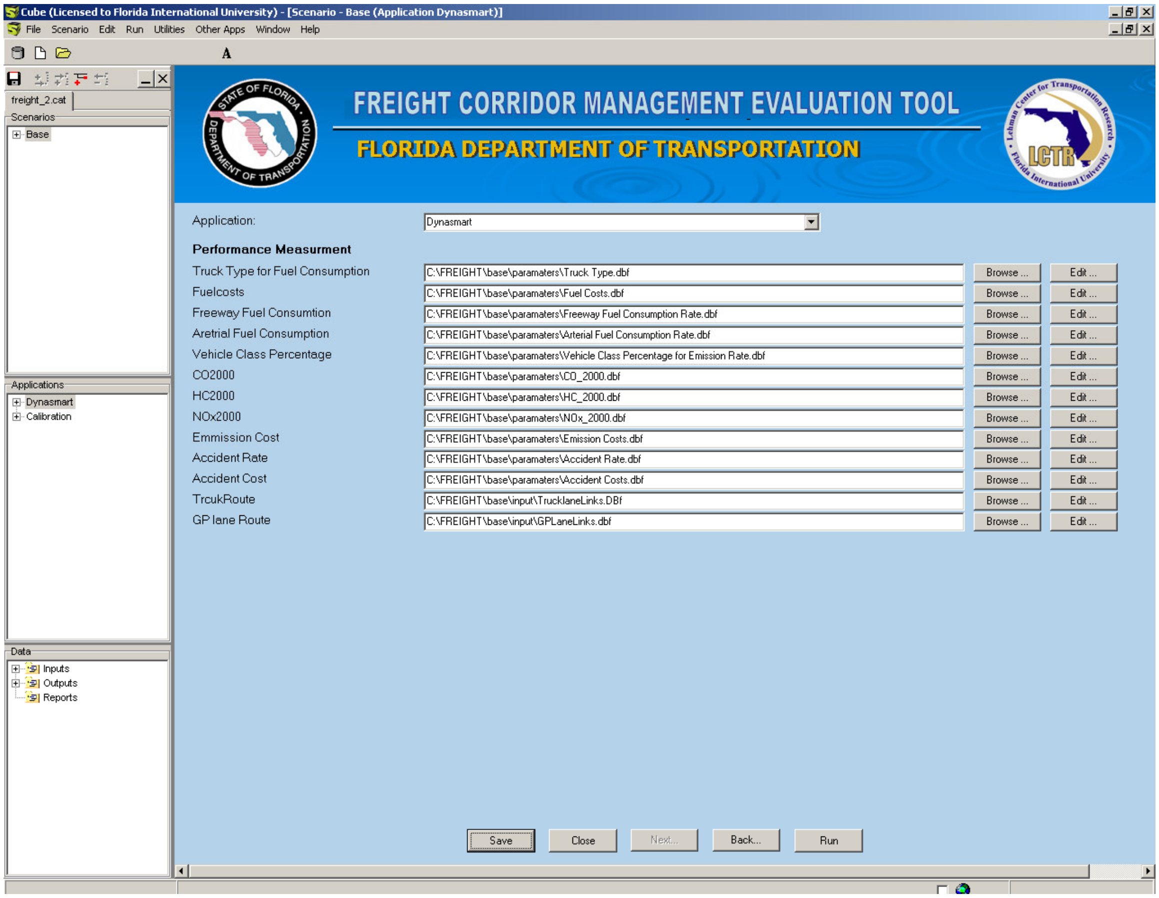


Figure 10-4. User Interface for Data Input (performance measurement group)

Subarea Network

This subgroup includes the specifications of two required input file names: subarea network file name and subarea matrix file.

Hourly Matrix Conversion

The following information is included for this subgroup:

- The month for which the O-D matrix estimation will be done (by using the counts for that month in the estimation). The user can specify "1" to "12" to indicate the month of the year, or "99" to indicate the average for the whole year.
- The user can specify if the estimation is for weekday or weekend demands.

Matrix Estimation

The following information is included for this subgroup:

- The user can specify that the initial matrices used in the dynamic O-D matrix estimation are those resulting from running Cube Analyst with the factorized hourly matrices as inputs to Cube Analyst. Otherwise, the factorized matrices are used as inputs to the dynamic O-D estimation without running Cube Analyst as an intermediate step.
- The user can specify the confidence levels in the O-D matrix estimation process associated with the following:
  - Initial O-D matrix (default is 20%)
  - Zone production (default is 20%)
  - Zone attraction (default is 20%)
  - Traffic counts (default is 100%)
- The user can specify the beginning of the model period and the end of the model period.

Advanced Scenario Information

In this subgroup, the user can click on boxes to define the following additional scenario information:

- Toll link definition
- Ramp Metering
- Variable message signs (VMS)
- Incident information
- Work zone information

Specification of Modules to Run

The user is given the option to either run or not run a number of modules at any given execution of the environment. In the initial run, all modules must be run. However, in subsequent runs, some of the modules may not be needed. The modules are as follows:

- The subarea matrix preparation module: If a subarea matrix has not been extracted, then this module has to be run.
- The DTA network preparation module to convert the Cube network to DTA format: If the user already has a converted network for the DTA model, then he/she does not have to run this module.
- DTA Model matrix preparation module: If a DTA model matrix is not available, then this step is needed to convert the Cube matrix to the DTA tool format. If the user already has a converted matrix, then this step is not required.
- DTA Scenario and System data preparation module: This is required to establish scenario and system input files for the Dynasmat/DynusT DTA tool.

Dynamic O-D Estimation Parameters

This subgroup includes the following parameters that can be used in the estimation of O-D matrices:

- Warming-Up Period Demand Matrix Factor: In this study, two warm-up intervals (30 minutes) are used in the DTA model runs. This factor is a multiplication factor that the user can input to calculate the O-D matrices during the warm-up period by multiplying by first interval O-D matrix by this factor.
- Traffic Volume: This is the text file that includes 15-minute interval traffic counts at the detector stations, as discussed in Chapter 3 of this document.
- Traffic Speed on Detectors: This is a text file that includes 15-minute average speed at the detector stations, as discussed in Chapter 3 of this document.
- Link and Detector Index Table: This is a lookup table that associates detection stations and the modeled links in the FSUTMS model.

- Period-based Matrix Factor: This is a factor that the user can use to increase or decrease individual interval matrices before running the dynamic O-D estimation process. As explained earlier in this study, the use of this factor was found to be helpful in achieving better sets of initial O-D matrices for the dynamic O-D estimation process.
- Individual Zone Production and Attraction Rate Factor: This is a factor that the user can use to increase or decrease individual zone attraction or production rates prior to running the dynamic O-D estimation process.

Traffic Flow Model (TFM) Parameters

This subgroup includes the following:

- Traffic flow models: This is a file that defines the traffic flow model to be utilized in DTA model.
- Index for Link TFM: This is a file that associates each link with a TFM.

Performance Measurement

This group includes parameters that can be used to calculate performance measures in the post-processing of DTA model outputs, as follows:

- Truck Type for Fuel Consumption: This file includes the proportion of truck (gasoline or diesel).
- Fuel Cost: Gasoline and diesel cost per gallon.
- Freeway Fuel Consumption: This file includes fuel consumption rates for different speeds and vehicle types on freeways.
- Arterial Fuel Consumption: This file includes fuel consumption rates for different speeds and vehicle types on arterials.
- Vehicle Class Percentages

- CO2000: The name of file that includes CO emission rates for different vehicle classes.
- HC2000: The name of file that includes HC emission rates for different vehicle classes.
- NOx2000: The name of the file that NOx emission rates for different vehicle classes.
- Emission Costs: These are the unit costs for CO, HC, and NOx.
- Crash Rates: These are the crash rates for PDO, Injury, and Fatality crashes for different facility types.
- Crash Costs: These are the costs of PDO, Injury, and Fatality.
- Truck Lane Route: This is a file which shows the links on the truck lane route.
- GP Lane Route: This is a file which shows the links on the GP lane route.

Table 10-1 presents the keys needed in the two main stages of the use of the analysis environment in this study. These two stages are the "Development and Calibration" and the "Strategy Evaluation" stages.

Table 10-1. Purpose of Keys in CUBE

CUBE Key	**Calibration**	**Strategy**
Subarea Network Information		
Subarea network file name	√	
Subarea matrix file	√	
Hourly Matrix Conversion Data and Parameter Input		
Which month factor do you want to use? (for whole year average, select 99)	√	
Do you want to obtain a matrix for weekend or weekday?	√	
Matrix Estimation Data and Parameter Input		
Do you want to run the Analyst matrix estimation application?	√	
O-D Matrix Confidence Level	√	
Trip End (Production) Confidence Level	√	
Trip End (Attraction) Confidence Level	√	
Confidence Level for Traffic Count	√	
Beginning of Period	√	
End of Period	√	
Do you want to define a new file or modify existing file for:		
Toll link definition	√	√
Ramp Metering	√	√
VMS	√	√
Incident	√	√
Work Zone	√	√
Submodel Run Condition (note: for initial run, all of the model must be run)		
Do you want to run subarea matrix preparation module?	√	
Do you want to run DTA Model network preparation module?	√	√
Do you want to run DTA Model matrix preparation module?	√	
Do you want to run DTA Scenario and System data preparation module?	√	√
Factors and Lookup Tables for Dynamic O-D Estimation		
Warming-up period demand matrix factor	√	
Traffic Volume on Count Station	√	
Traffic Speed on Detectors	√	
Link and Detector Index Table	√	
Period-based Matrix Factor	√	
Individual Zone Production and Attraction Rate	√	

Table 10-1. Purpose of Keys in CUBE (Continued)

Traffic Flow Model (TFM) Data Input		
Traffic flow models	√	√
Index for Link TFM	√	√
Performance Measurement		
Truck Type for Fuel Consumption		√
Fuel Cost		√
Freeway Fuel Consumption		√
Arterial Fuel Consumption		√
Vehicle Class Percentage		√
CO2000		√
HC2000		√
Nox200		√
Emission Cost		√
Accident Rate		√
Accident Cost		√
Truck Lane Route		√
GP Lane Route		√

11. Post-Processing of Modeling Results

The results from modeling tools such as dynamic traffic assignment can be further processed to supply additional performance measures not provided by the tools, or provided by the tools but with different estimation parameters.

In this study, the post-processing of the outputs is illustrated by the introduction of three modules for post processing of the data. These modules are introduced as examples, and other modules can be introduced as needed to the modeling environment. The three modules used in this study are those used as part of the Florida ITS Evaluation (FITSEVAL) tool to estimate safety, fuel consumption, and emission. FITSEVAL is a sketch-planning tool developed for FDOT to evaluate ITS developments.[49]

11.1. Safety

A module that was incorporated in the developed environment to post process the DTA model output is the Safety Module. This module estimates only property damage (PDO), injury, and fatality crash rates based on volume/capacity (V/C) ratio. These rates provide the default crash rates in terms of crashes per Million Vehicle Miles Traveled (MVMT) for different crash, facility, and vehicle types.

11.2. Emission

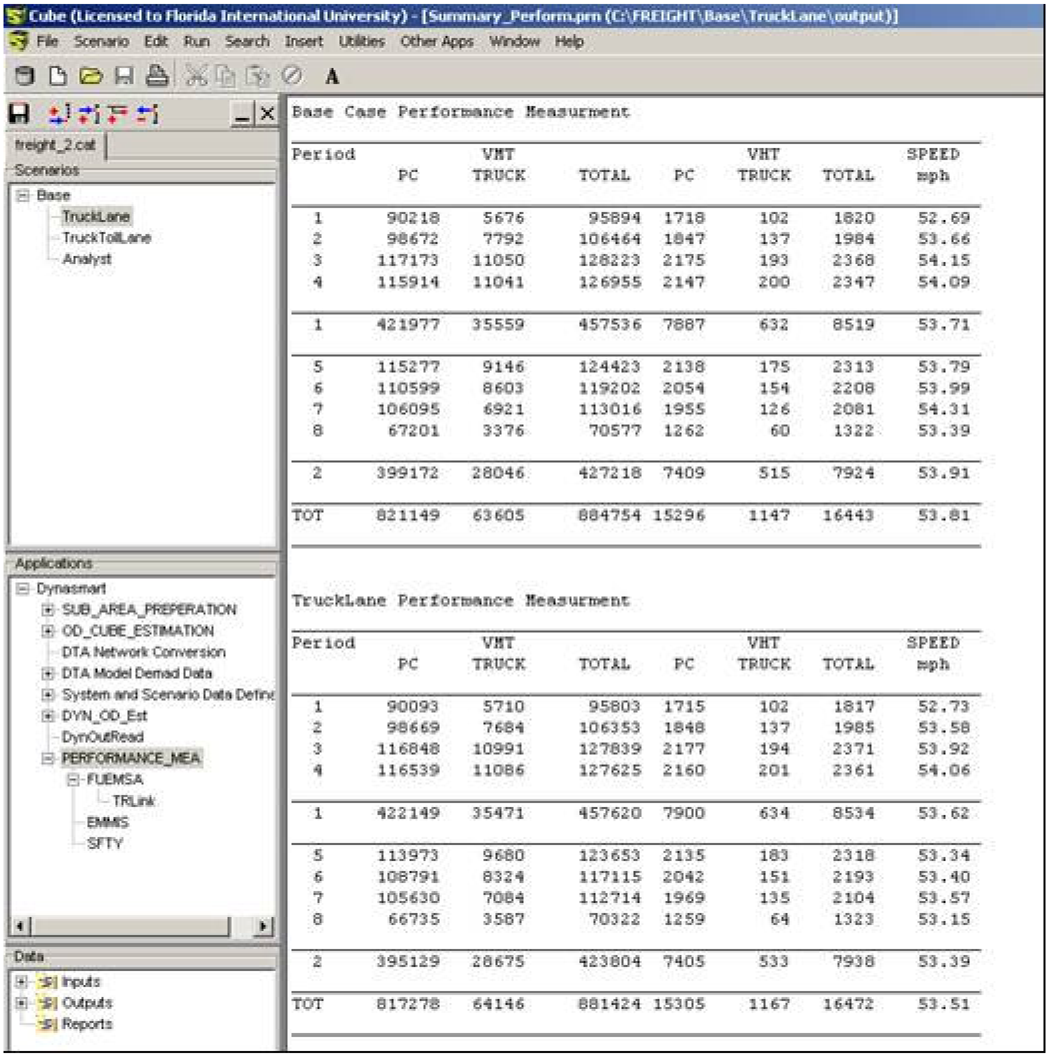
The emission module in FITSEVAL provides estimates of nitrogen oxides (NOx) and carbon monoxide (CO) from different vehicle types. FITSEVAL includes lookup tables (by year) that incorporate emission rates. The emission rates are functions of traffic speed, and are for vehicle speeds ranging from 2.5 to 65.0 mph (4.0 to 104.6 kph) at 5.0 mph (8.0 kph) intervals. These rates were provided by the FDOT and have been derived based on Mobile 6 model runs. Different models could be used instead of the FITSEVAL module. The FDOT has initiated an effort to integrate emission model estimation based on the recently released MOVE environmental model with FSUTMS analysis. As such, this model could be used instead of the FITSEVAL model to estimate emission.

11.3. Fuel Consumption

FITSEVAL estimates fuel consumption using a module that is based on that which is used by the ITS Deployment Evaluation Tool (IDAS).[50] As with emission rates, the fuel consumption rates are a function of traffic speed. The module rates utilized are categorized by facility type (freeways and arterials), speed range (0 to 70 mph, depending on facility), and vehicle type (autos and trucks). The same rates used in FITSEVAL were incorporated in the environment developed in this study.

11.4. Example Output

Figure 11-1 presents the output of network-wide performance measures for base and truck lane cases. As can be seen in the figures, the post-processing component of the modeling environment of this study produces various measures of performance that can be used in assessing and comparing various strategies. Figure 11-2 through Figure 11-4 present safety, fuel consumption, and emission measures of base and truck lane cases.



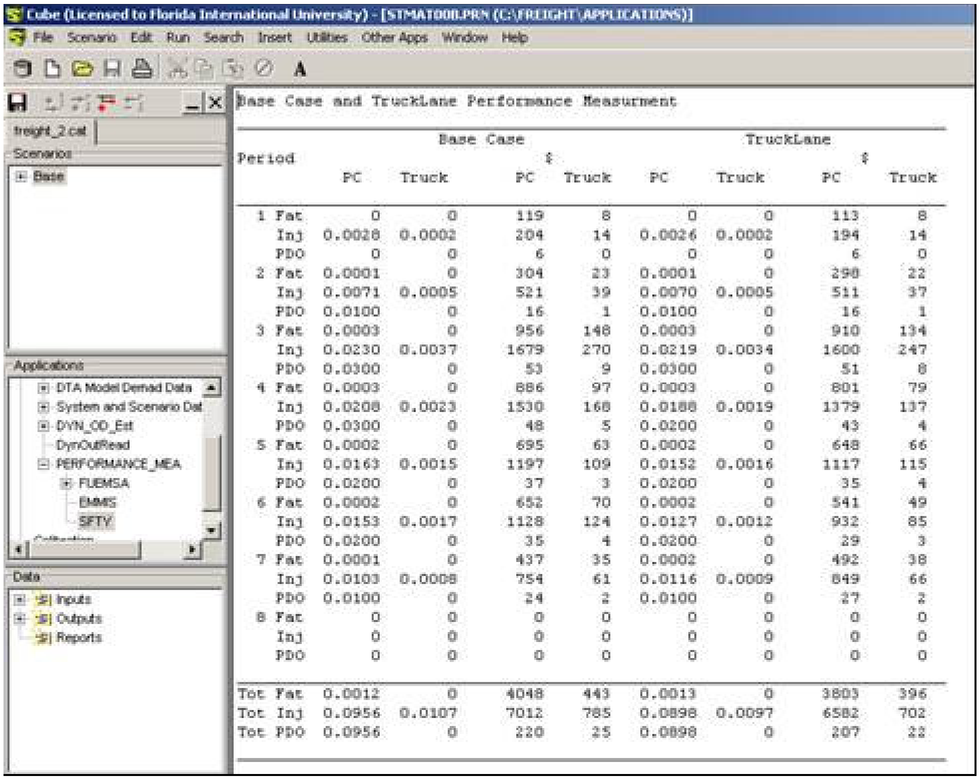
Base Case Performance Measurment

Period	PC (VMT)	TRUCK (VMT)	TOTAL (VMT)	PC (VHT)	TRUCK (VHT)	TOTAL (VHT)	SPEED mph
1	90218	5676	95894	1718	102	1820	52.69
2	98672	7792	106464	1847	137	1984	53.66
3	117173	11050	128223	2175	193	2368	54.15
4	115914	11041	126955	2147	200	2347	54.09
1	421977	35559	457536	7887	632	8519	53.71
5	115277	9146	124423	2138	175	2313	53.79
6	110599	8603	119202	2054	154	2208	53.99
7	106095	6921	113016	1955	126	2081	54.31
8	67201	3376	70577	1262	60	1322	53.39
2	399172	28046	427218	7409	515	7924	53.91
TOT	821149	63605	884754	15296	1147	16443	53.81

TruckLane Performance Measurment

Period	PC (VMT)	TRUCK (VMT)	TOTAL (VMT)	PC (VHT)	TRUCK (VHT)	TOTAL (VHT)	SPEED mph
1	90093	5710	95803	1715	102	1817	52.73
2	98669	7684	106353	1848	137	1985	53.58
3	116848	10991	127839	2177	194	2371	53.92
4	116539	11086	127625	2160	201	2361	54.06
1	422149	35471	457620	7900	634	8534	53.62
5	113973	9680	123653	2135	183	2318	53.34
6	108791	8324	117115	2042	151	2193	53.40
7	105630	7084	112714	1969	135	2104	53.57
8	66735	3587	70322	1259	64	1323	53.15
2	395129	28675	423804	7405	533	7938	53.39
TOT	817278	64146	881424	15305	1167	16472	53.51

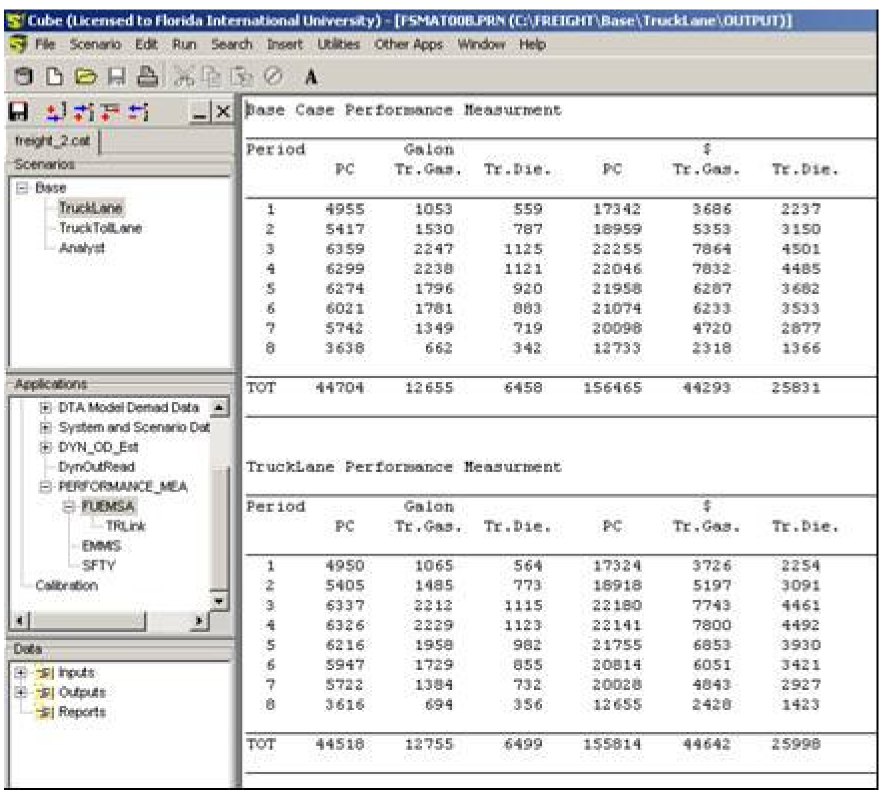
Figure 11-1. Network Wide Performance Measures



Base Case and TruckLane Performance Measurment

Period		Base Case PC	Base Case Truck	Base Case $ PC	Base Case $ Truck	TruckLane PC	TruckLane Truck	TruckLane $ PC	TruckLane $ Truck
1	Fat	0	0	119	8	0	0	113	8
	Inj	0.0028	0.0002	204	14	0.0026	0.0002	194	14
	PDO	0	0	6	0	0	0	6	0
2	Fat	0.0001	0	304	23	0.0001	0	298	22
	Inj	0.0071	0.0005	521	39	0.0070	0.0005	511	37
	PDO	0.0100	0	16	1	0.0100	0	16	1
3	Fat	0.0003	0	956	148	0.0003	0	910	134
	Inj	0.0230	0.0037	1679	270	0.0219	0.0034	1600	247
	PDO	0.0300	0	53	9	0.0300	0	51	8
4	Fat	0.0003	0	886	97	0.0003	0	801	79
	Inj	0.0208	0.0023	1530	168	0.0188	0.0019	1379	137
	PDO	0.0300	0	48	5	0.0200	0	43	4
5	Fat	0.0002	0	695	63	0.0002	0	648	66
	Inj	0.0163	0.0015	1197	109	0.0152	0.0016	1117	115
	PDO	0.0200	0	37	3	0.0200	0	35	4
6	Fat	0.0002	0	652	70	0.0002	0	541	49
	Inj	0.0153	0.0017	1128	124	0.0127	0.0012	932	85
	PDO	0.0200	0	35	4	0.0200	0	29	3
7	Fat	0.0001	0	437	35	0.0002	0	492	38
	Inj	0.0103	0.0008	754	61	0.0116	0.0009	849	66
	PDO	0.0100	0	24	2	0.0100	0	27	2
8	Fat	0	0	0	0	0	0	0	0
	Inj	0	0	0	0	0	0	0	0
	PDO	0	0	0	0	0	0	0	0
Tot	Fat	0.0012	0	4048	443	0.0013	0	3803	396
Tot	Inj	0.0956	0.0107	7012	785	0.0898	0.0097	6582	702
Tot	PDO	0.0956	0	220	25	0.0898	0	207	22

Figure 11-2. Safety Measurements for Base and Strategy Cases



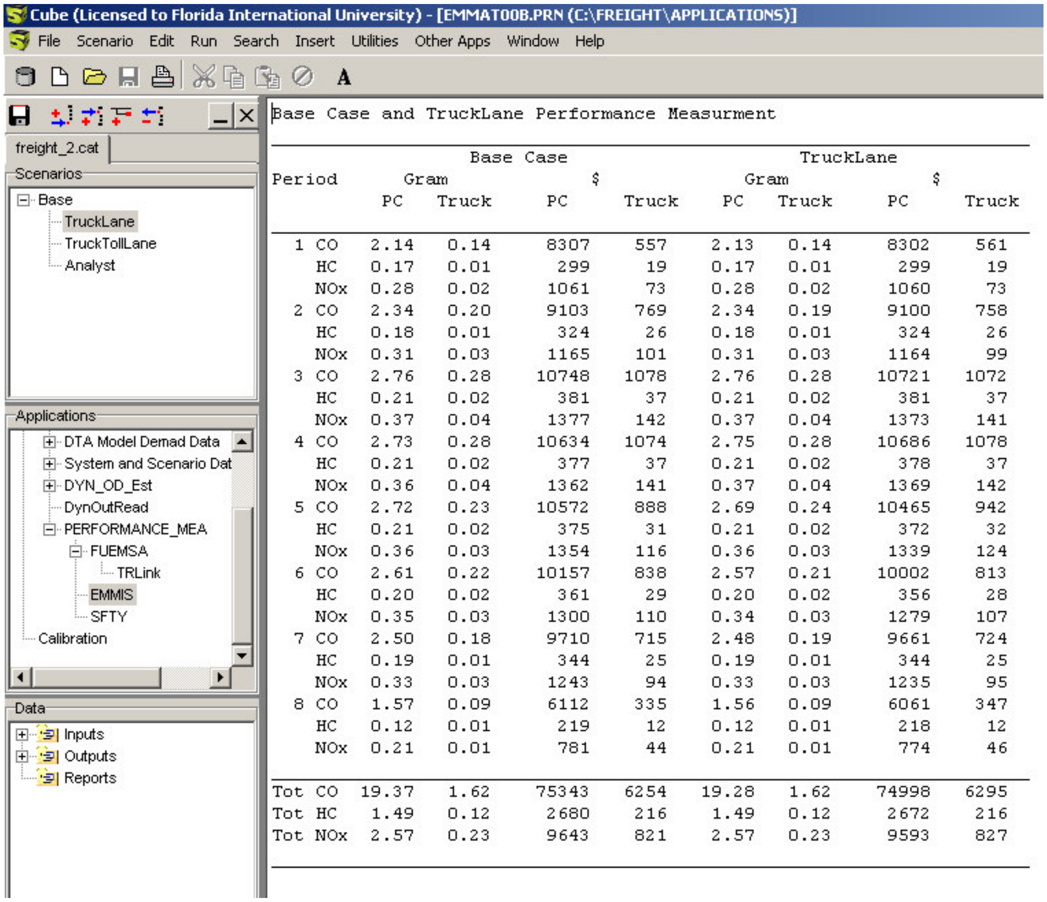
Base Case Performance Measurment

Period	Galon PC	Galon Tr.Gas.	Galon Tr.Die.	$ PC	$ Tr.Gas.	$ Tr.Die.
1	4955	1053	559	17342	3686	2237
2	5417	1530	787	18959	5353	3150
3	6359	2247	1125	22255	7864	4501
4	6299	2238	1121	22046	7832	4485
5	6274	1796	920	21958	6287	3682
6	6021	1781	883	21074	6233	3533
7	5742	1349	719	20098	4720	2877
8	3638	662	342	12733	2318	1366
TOT	44704	12655	6458	156465	44293	25831

TruckLane Performance Measurment

Period	Galon PC	Galon Tr.Gas.	Galon Tr.Die.	$ PC	$ Tr.Gas.	$ Tr.Die.
1	4950	1065	564	17324	3726	2254
2	5405	1485	773	18918	5197	3091
3	6337	2212	1115	22180	7743	4461
4	6326	2229	1123	22141	7800	4492
5	6216	1958	982	21755	6853	3930
6	5947	1729	855	20814	6051	3421
7	5722	1384	732	20028	4843	2927
8	3616	694	356	12655	2428	1423
TOT	44518	12755	6499	155814	44642	25998

Figure 11-3. Fuel Consumption for Base and Strategy Cases



Base Case and TruckLane Performance Measurment

Period		Base Case Gram PC	Base Case Gram Truck	Base Case $ PC	Base Case $ Truck	TruckLane Gram PC	TruckLane Gram Truck	TruckLane $ PC	TruckLane $ Truck
1	CO	2.14	0.14	8307	557	2.13	0.14	8302	561
	HC	0.17	0.01	299	19	0.17	0.01	299	19
	NOx	0.28	0.02	1061	73	0.28	0.02	1060	73
2	CO	2.34	0.20	9103	769	2.34	0.19	9100	758
	HC	0.18	0.01	324	26	0.18	0.01	324	26
	NOx	0.31	0.03	1165	101	0.31	0.03	1164	99
3	CO	2.76	0.28	10748	1078	2.76	0.28	10721	1072
	HC	0.21	0.02	381	37	0.21	0.02	381	37
	NOx	0.37	0.04	1377	142	0.37	0.04	1373	141
4	CO	2.73	0.28	10634	1074	2.75	0.28	10686	1078
	HC	0.21	0.02	377	37	0.21	0.02	378	37
	NOx	0.36	0.04	1362	141	0.37	0.04	1369	142
5	CO	2.72	0.23	10572	888	2.69	0.24	10465	942
	HC	0.21	0.02	375	31	0.21	0.02	372	32
	NOx	0.36	0.03	1354	116	0.36	0.03	1339	124
6	CO	2.61	0.22	10157	838	2.57	0.21	10002	813
	HC	0.20	0.02	361	29	0.20	0.02	356	28
	NOx	0.35	0.03	1300	110	0.34	0.03	1279	107
7	CO	2.50	0.18	9710	715	2.48	0.19	9661	724
	HC	0.19	0.01	344	25	0.19	0.01	344	25
	NOx	0.33	0.03	1243	94	0.33	0.03	1235	95
8	CO	1.57	0.09	6112	335	1.56	0.09	6061	347
	HC	0.12	0.01	219	12	0.12	0.01	218	12
	NOx	0.21	0.01	781	44	0.21	0.01	774	46
Tot	CO	19.37	1.62	75343	6254	19.28	1.62	74998	6295
Tot	HC	1.49	0.12	2680	216	1.49	0.12	2672	216
Tot	NOx	2.57	0.23	9643	821	2.57	0.23	9593	827

Figure 11-4. Emission Measurements for Base and Strategy Cases

11.5. DTA Output Displays in Cube

The outputs from the DTA tool, including volume, speed, and travel time estimates for each interval and each link, were imported into the Cube Voyager Network to allow the use of Cube graphical presentation features (such as link bandwidth, boundary presentation, path analysis, etc.). For example, it was possible to use the band animation feature of Cube to animate the consecutive interval network measures. The user can also import the DTA output to the GIS format for further analysis. Figure 11-5 shows different interval volumes in a "Band animation" format for a one-hour period.

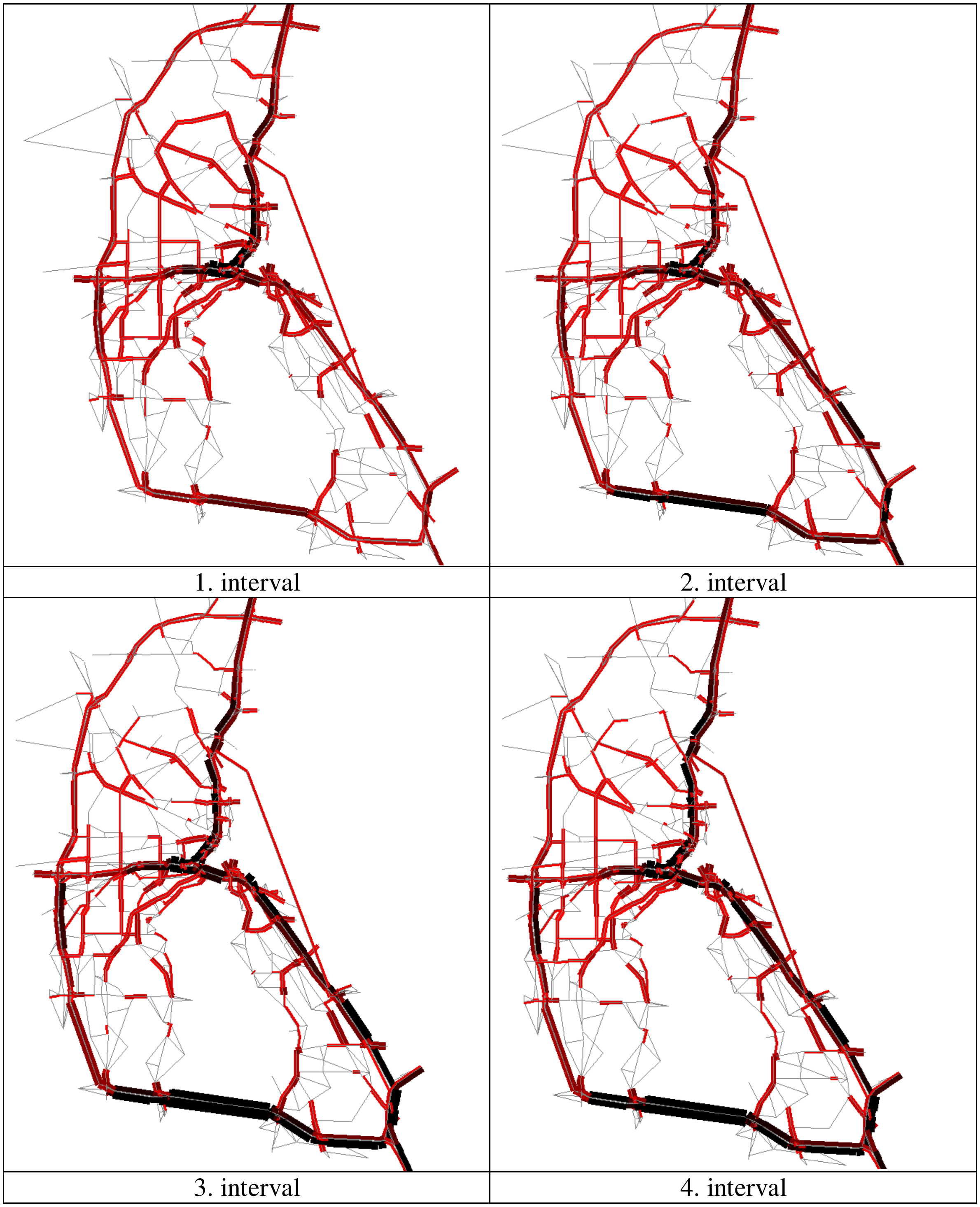


Figure 11-5. Band Animation for a One-Hour Period Based on DTA Tool Output in Cube

END NOTES

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