

# **Intermodal Freight Transportation Planning Using Commodity Flow Data**

## **Final Report**

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## **APPENDICES**

Project data, results and some other documents are provided as appendices in separate CDs. The materials are organized into sub-directories on each CD, with a readme file describing the contents of the sub-directory. The following items are included:

NAME AND CODE OF SCTG SYSTEM IN 1997 CFS  
1997 COUNTY LEVEL POPULATION  
1997 COUNTY LEVEL EMPLOYMENT BY COMMODITY  
BASE YEAR O& D  
FORECASTED YEAR O& D  
TRANSCAD NETWORKS FOR MODELING  
RESULTS FOR WOOD & WOOD PRODUCTS MODELONG  
BASE YEAR AND FORECASTED YEARS ASSIGNMENT RESULTS  
AGGREGATED OD FOR SIMULATION DATA INPUT  
SIMULATION MODEL SCRIPTS  
SIMULATION RESULTS  
VITS SIMULATION USER GUIDE

## **ABSTRACT**

This study presents a methodology to conduct statewide freight transportation planning by utilizing public domain data, primarily the Commodity Flow Survey database. The State of Mississippi was used as an example.

Some states such as Mississippi, in spite of its relatively small size and population, have extensive intermodal freight transportation networks that are composed of all major transportation modes. This offers a good opportunity to analyze intermodal transportation characteristics for the state, in anticipation of future congestion on the existing highway system. Studies such as the Latin America Trade and Transportation Study (LATTS) presented a good case for concern, particularly for the states defined in the Southeast Transportation Alliance.

In this study, the 1997 Commodity Flow Survey (CFS) database was identified to be the most cost-effective and flexible database that can be used for conducting statewide freight transportation planning study. The CFS database, together with other related databases such as Vehicle Inventory and Use Survey (VIUS) and Cargo Density Database (CDD), was used in the study to describe freight flows coming into, going out, within and through the state of Mississippi. Geographic Information Systems (GIS) based transportation planning software TransCAD was used to model the transportation system performance. Based on the model from the base year study results, forecasts of future transportation demand for years 2005, 2010, and 2020 were made. The Virtual Intermodal Transportation Simulation (VITS) data were obtained from the commodity flow/truck trips model in TransCAD and other resources, and a prototype simulation model was developed. This model served as a demonstration of the capabilities of simulation as an effective tool to aid in the design, planning, and visualization of a transportation system in aspects not afforded by TransCAD or other traditional/conventional transportation planning tools. Performance measures implemented in the VITS were shown in several scenarios designed to bring into attention how a simulation model can reveal the impact of transportation decisions.

The developed methodology can be further refined and applied to other states. The prototype simulation model can be expanded to demonstrate the potential benefits of integrated intermodal transportation. Continuing research is being planned in those areas.



# 1 INTRODUCTION

Freight transportation planning is an integral component of any state Department of Transportation's (DOT's) long range transportation planning. The importance of developing forecast and description of the intermodal transportation system for states has increased since the enactment of Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the following Transportation Equity Act for the 21<sup>st</sup> Century (TEA-21) of 1998 [1,2]. There are pressing needs to research and develop systematic intermodal freight transportation planning procedures and methodologies to model freight flows on transportation networks, to identify and prioritize transportation improvement needs, to meet the federal requirements, and to enhance the competitiveness of the economy at all levels. The Latin America Trade and Transportation Study (LATTS) provided a strong case for these needs, especially for the states strongly involved in the Latin American trade routes [3].

Prior research on truck travel forecasting at the state level has been limited by the lack of comprehensive data. Obtaining Origin and Destination (O&D) data from surveys of different traffic modes is too time consuming, expensive, and may not be practical in some instances.

Many of the statewide intermodal freight transportation planning methodologies are based on the Reebie Associates' TRANSEARCH database because it is assumed as the best commodity flow data currently available [4,5,6]. Although TRANSEARCH database has the advantage of having the county level data (thus eliminating the trouble of developing breakdown methodology from state level data), the database is very expensive also has limitations. The Commodity Flow Survey (CFS) data, published by Bureau of the Census, on the other hand, can be used to develop a more economical and flexible intermodal transportation planning methodology. Although limitations exist, some of those can be improved with further study (such as the case with incomplete data).

In the market, most of the available simulation software packages are geared towards microscopic traffic simulation. Handling of freight, the related transfers, and intermodal issues are currently unavailable in a comprehensive package. This study included a prototype simulation component that serves to demonstrate the applicability of a simulation model for statewide intermodal transportation planning. Several performance measures were included to indicate system performance under different scenarios.

# 2 PURPOSE AND SCOPE

The objective of this study is to develop a methodology for statewide intermodal transportation planning by using public domain database. The State of Mississippi is used in this study as an example to describe the freight movement characteristics. Since the methods derived are intended to be adaptable for use by other states, the methodology needs to be flexible especially when more detailed or updated data become available over time. Utilization of public domain data instead of commercial data is the key to a flexible and economical planning methodology.

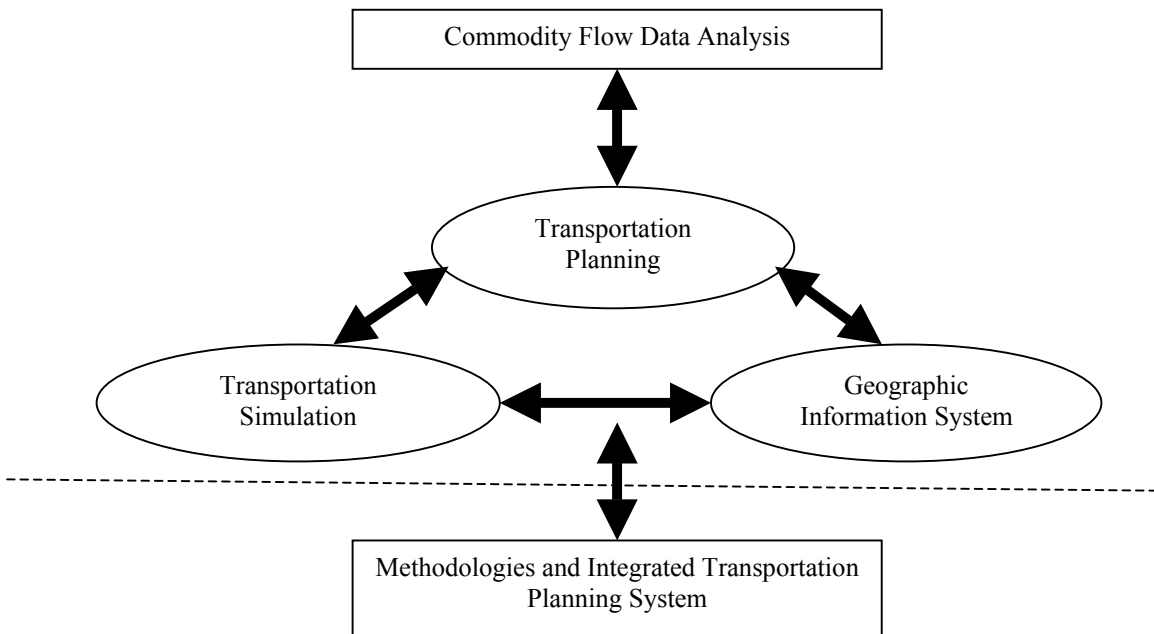
The fact that relatively high percentage of freight trips terminate in the state of Mississippi presents researchers with an excellent opportunity to develop and calibrate demand estimation models with high reliability and accuracy. The availability of comprehensive intermodal networks in the state also enables examination of intermodal freight analysis.

This study also intends to develop a prototype simulation model to provide additional information and visualization of intermodal flows for the State of Mississippi. The simulation provides “what if” scenario analyses that can be used for evaluation of improvement alternatives, and consider future changes in network and flow conditions.

The study includes the following three major components:

- Commodity flow data analysis
- Transportation planning model
- Intermodal transportation simulation model

The three components are integrated to derive the methodologies for statewide intermodal transportation planning. Different components interact with each other, and the relationship is shown in Figure 2-1.



**Figure 2-1 Components and Relationships in the Study**

Commodity flow analysis, transportation planning, and simulation are the three interconnected components of the study. The commodity flow data analysis component of the study is to analyze the CFS data and provide inputs for base year study of transportation modeling. Transportation planning model includes base year study and forecasted year study. The transportation planning procedure is implemented in GIS-based TransCAD package. The results of transportation planning model can also serve as inputs for simulation model and provide calibration and validation data for simulation

model. The simulation model is also based on some mode information and O&D information derived from commodity flow analysis component.

### **3 LITERATURE REVIEW**

In this section, descriptions of literature reviews on federal legislation, statewide and regional intermodal transportation planning practices. European practices, simulation model applications and data sources available are also provided.

#### **3.1 Federal Legislation**

Our nation's highway networks have experienced severe congestion, however other surface modes of transportation are underutilized. Intermodal transportation planning has been given priority since the enactment of ISTEA of 1991 [1]. Addressing the issue of improving the efficiency of moving goods, freight transportation planning should be an integral component of state DOT's long-range transportation planning. Section 2 of ISTEA states:

“It is the policy of the United States of America to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner” [1].

The TEA-21 was signed into law on June 9, 1998 and covers the period October 1, 1997 through September 30, 2003 [2]. It focuses on improving safety, rebuilding America, protecting the environment, creating opportunity and ensuring global competitiveness. To achieve the goal, the following are most important [2]:

- Providing incentive programs to strengthen safety
- Guaranteeing minimum funding levels of about \$198 billion for federal highway, highway safety and transit programs
- Continuing the ISTEA's landmark environmental provisions to protect the environment
- Creating a new program with \$750 million funding for Access to Jobs and Reverse Commute, extending Disadvantaged Business Enterprise program and increasing the tax-exempt transit benefit
- Providing National Highway System (NHS) connectivity with major intermodal transportation facilities and continuing a separate Interstate System maintenance program.

ISTEA and TEA-21 provide the states' DOTs and Metropolitan Planning Organizations' (MPOs) incentives to develop their intermodal transportation systems. Some states are in the process of updating existing models and/or developing new models. This is the motivation behind the study.

## **3.2 Statewide Passenger Transportation Planning vs. Freight Transportation Planning**

Many states have already developed their statewide passenger transportation planning models using the traditional four-step model. Common passenger transportation planning models and procedures have been established since passenger transportation data are easier to obtain than freight data. However, there is no standard freight transportation planning model up to date.

There are two types of transportation planning model for freight transportation. One is commodity-based freight transportation planning, and the other is vehicle-based transportation planning model. The vehicle-based model is based on survey data or trip generation model for freight transportation. However, the expenses of conducting a comprehensive survey to get freight data are usually unaffordable. On the other hand, commodity-based method derives the O&D from the commodity flow data.

## **3.3 Intermodal Transportation Planning in Practices**

### ***3.3.1 Statewide and Regional Practices***

Several major statewide intermodal transportation planning studies completed in other states and metropolitans were reviewed and described in this section. Attention was directed toward databases used in the model, methodologies used for disaggregation & conversion from commodity flow to vehicle trips, and mode change analyses.

#### **3.3.1.1 Wisconsin's model**

The databases used in the model were the 1993 CFS database, TRANSEARCH database, and Input-Output coefficients database. The traditional four-step transportation planning method was adapted in the model. The modal choice step was skipped in this particular analysis because the research was only concerned with commodities transported by trucks. The commodities selected for the analysis were based upon economic sectors that generated most of the freight volumes.

The following outlines what was done in this research:

- Internal-to-internal, internal-to-external, external-to-internal, and external-to-external trip type analysis.
- The 1993 CFS was used to provide the data for the derivation of the production rates.
- Employment data and population data were used to disaggregate commodity flow from the state level to a county level.
- The annual commodity tonnages were divided by 312 (52 weeks times 6 days per week) in order to obtain daily tons.
- Daily tons divided by tons per truck by commodity sector (from Reebie TRANSEARCH database) yielded daily truck trips by all commodities at the Traffic Analysis Zone (TAZ) level.

- An economy-based Input-Output software package, IMPLAN Professional software package, was used to derive the I-O direct matrix and I-O direct coefficients at the state level for developing the trip attraction rates.
- The TRANPLAN software package was used to distribute and assign truck trips generated at the TAZ level for the four trips. Several measures of goodness of fit were used in this process.
- The Link Volumes/Ground Counts ratio, the percent Root Mean Square Error, and the calculated annual vehicle miles traveled were compared with estimates from the Wisconsin Department of Transportation.
- The performance of the model as a forecasting tool was assessed by “back-forecasting” 15 years to the year 1977.
- Zonal productions and attractions from the base year, 1992, were converted to 1977 using county employment variation and producer price indexes, a surrogate for changes in employment productivity.

Overall the model performed well. The results from this application revealed that the methodology could be used by transportation planners as a forecasting and operational tool [7].

#### 3.3.1.2 Indiana’s Model

The Indiana’s model was based on the 1993 CFS database. The model predicted both truck and rail traffic volumes for a network that included a TAZ for each Indiana’s 92 counties, and 53 more TAZs that represented the remaining 47 contiguous states and the District of Columbia. Both the truck and rail networks were developed from U.S. DOT sources. It should be noted that the detailed roadway network for the Indiana freight model extended to about 200 miles beyond the state’s border [8].

The actual workings of the model were very similar to a typical urban model. For each of 21 commodity groups that were considered important to Indiana, trip generation equations were developed based on a regression of data available from the 1993 CFS, nationally.

Forecasts for Indiana county productions and attractions were then based on county-level employment and population projections. For areas outside of Indiana, forecasts were based on national growth factors. Following trip generation, freight shipments were distributed by Gravity Model. The results were calibrated using the national CFS data. Special care was taken to match the average shipping distance per ton for each commodity group. This prevented an inappropriate weighting for many short-distance lightweight deliveries versus a few long distance heavyweight shipments that might be included in the same commodity group.

The mode split step also utilized the 1993 CFS, projecting the 1993 national shares into the future. Mode split for any commodity was a function of distance only. Before assigning traffic to the network, the Indiana model divided the freight tonnages into an equivalent number of vehicles, with tons-per-vehicle rates determined separately for each commodity group. The rates were based on values (by commodity group) from the Rail Waybill Sample, and the assumption that each truckload carries 40% of the load carried

by a railcar. A daily traffic assumption was made for the Indiana model as well, assuming 5 working weekdays and (from the Highway Capacity Manual) 0.44 working days for each weekend day. This resulted in a 5.88-day per week, or 306 days per shipping year.

Finally, the traffic was assigned to the network using an all-or-nothing algorithm. A procedure to adjust the link speeds for non-Interstate highway segments was provided, however, since an unmodified all-or-nothing assignment typically loads too many trips onto Interstate highways, another adjustment was made to the railroad network to account for the tendency of railroads to route cars by mainlines, ignoring many of the shortest paths [9,8,10].

### 3.3.1.3 Virginia's Model

Virginia's statewide freight planning model focused on identifying and prioritizing infrastructure needs to improve the intermodal freight transportation system. The researchers developed the methodology by interpreting the results of extensive reviews of literature on the subject, participant roles such as Freight Advisory Council (FAC), and analytical methodologies to formulate the six steps of the methodology and a case study of Virginia. The researchers used electrical goods to demonstrate the methodology developed for the analysis. Electrical goods were Virginia's third ranked commodities by value of goods shipped and their manufacture was one of the fastest growing industries in the state.

The six steps involved in the statewide intermodal transportation planning process were: (1) develop system inventory; (2) identify problems; (3) establish performance measures; (4) collect data and define conditions for specific problem; (5) develop and evaluate improvement alternatives; and (6) select and implement improvements. Results from this study revealed that a standard but flexible freight planning methodology can aid in the reduction or complete elimination of impediments to an efficient freight transportation system [6].

### 3.3.1.4 New Jersey's Model

In New Jersey's model, a regression model for forecasting truck freight in the continental United States was developed. The model was capable of predicting freight commodity flow information via trucks to assist transportation planners who wished to understand when and where new road facilities were needed. The methods used by the authors can be generalized to transportation modalities. When, as was done in this model by the authors, the regression model was allied with databases of forecasted economic and population data, the model can be used to forecast future truck freight flows.

The dependent or criterion variable was the tonnage of freight between the origin state and the destination state. The independent or predictor variables were populations of the origin and destination states, distance between origin and distribution state, personal incomes of the origin and destination states, wages of the origin and destination states and total employment of the origin and destination states. The prediction model was based upon a gravity flow model. The authors used the regression-based forecasting model that they developed to forecast truck freight flow between New Jersey and the

other 47 contiguous, continental states, between counties within New Jersey, and between New Jersey counties and non-New Jersey counties within 100 miles of the borders of New Jersey [11].

#### 3.3.1.5 Iowa's Model

Iowa's model published the developer's guide, developer's guide frequently asked questions (FAQs), a user's guide, and a discussion of issues affecting freight transportation for the model. The developer's guide described the procedures to reconstruct the statewide multi-modal freight transportation model and its inputs as developed for the Iowa DOT. Specific steps to construct and evaluate the model were addressed in this guide. The developer's guide FAQs contained questions that were most likely encountered by the user. The guide did not provide the answers to the user questions but it gave the user the location where he or she may find the answer to a canned question.

The user guide described the procedures to operate the statewide multi-modal freight transportation model developed for the Iowa DOT. The user may manipulate this model to provide decision-making information for a variety of freight transportation issues. Several classifications of probable freight planning issues, and the necessary model alternatives were described in this guide. The guide discussed several topical areas affecting freight transportation. The topics included, but not limited to, changes in inter-modal operating agreements, changes in technology, subsidies, changes in entry/exit barriers, and changes in taxes/fees/user charges [12].

#### 3.3.1.6 ORNL's Model

The Oak Ridge National Lab (ORNL)'s model described the geography of truck freight shipments in the US and, particularly, measured the degree to which highways served as state and local versus interstate freight systems.

The model estimated ton-miles of commodities shipped by truck within, to, from, and through each state and thereby provided a measure of extent to which each states' economies were linked together. Estimates were determined using the 1993 CFS data, augmented by including farm-based shipments from the 1992 Census of Agriculture and Foreign Trade data to adjust for imports and exports. Through truck shipments as well as all estimates of CFS shipments distances were determined by routing the truck traffic along the minimum impedance paths using the Oak Ridge National Highway Network. Shipments were routed between nodes on the highway networks closest to the centroid of origin and destination zip code. A shortest path mathematical algorithm representing the highway network was used to determine the minimum impedance route between the shipment origin and destination. Truck impedance was calculated as function of travel time designed to simulate to most likely choice of route. In addition, the algorithm determined the state's traverse by each shipment and accumulated the tonnages and distance traveled in each state [13].

### 3.3.1.7 Detroit Area Model

The model combined the techniques presented in the Quick Response Freight Manual published by the U.S. Department of Transportation and a four-step TranPlan travel demand model to develop, assign, and analyze commercial truck trips in a small to medium sized urban area.

The goals of the technique were to allow the planner to: (1) estimate truck trip generation using default rates; (2) prepare a truck network from existing highway network; (3) split truck trips into light, medium, and heavy trucks; (4) distribute the trips purposes with a Gravity Model; (5) assign and analyze truck trips to a truck network; and (6) assign and analyze truck trips, along with passenger car trips, to the entire network. Commercial vehicles under the quick response technique were broken down into three categories or purposes: four-tire vehicles, single unit trucks and combination trucks. Results from this analysis revealed that the quick response process of developing truck trips using the default generation rates and external truck classification can be successfully implemented in TranPlan or any other planning model as a first step in the evaluation of truck trips. The authors indicated that the procedure they used had been done in larger urbanized areas such as Detroit.

In the Detroit application, overall truck vehicle miles travel simulated from the truck model was consistent with vehicle miles travel truck estimates from field surveys. In this study, it was reported that there was a tendency for truck forecasts to be high or low by 20% when stratifying the results by highway functional classification [14].

### 3.3.1.8 Quick Response Freight Manual

The objectives of the Quick Response Freight Manual-Final Report, published by the U.S. Department of Transportation's The Travel Model Improvement Program were as follows [15]:

- To provide background information on the freight transportation system and factors affecting freight demand to planners who may be relatively new to this area;
- To help planners locate available data and freight-related forecasts compiled by others, and to apply this information in developing forecasts by specific facilities;
- To provide simple techniques and transferable parameters that can be used to develop commercial vehicle trip tables which can be merged with passenger vehicle trip tables developed through the conventional four-step planning process;
- To provide techniques and transferable parameters for site planning that can be used by planners in anticipating local commercial vehicle traffic caused by new facilities such as regional warehouses, truck terminals, and inter-modal facilities.

The manual has eight chapters and 13 appendices:

- Chapter 1 contains the introduction, objectives, and organization of the text.
- Chapter 2 identifies the factors that affect freight demand.



- Chapter 3 provides basic methods that can be used to forecast changes in freight demand due to changes in the level of economic activities.
- Chapter 4 deals with the development of commercial vehicle trip tables for use as part of a conventional four-step travel forecasting process.
- Chapter 5 describes and illustrates procedures for predicting the changes in commercial vehicle traffic and level of service characteristics on transportation networks due to specific facilities.
- Chapter 6 identifies primary and secondary collection methodologies and data sources.
- Chapter 7 provides information on the application of methods discussed in the manual on common planning problems.
- Chapter 8 explains the relationships between statewide and regional freight planning. The appendices contain an extensive compilation of data, data source, data collection techniques and other pertinent information on freight analysis.

### ***3.3.2 European Practice***

The research analyzed interregional transport movement in Europe, and forecasted spatial-temporal pattern of new transport economic scenarios. The objectives were to investigate freight flow patterns in Europe from a multi-regional perspective and look into the mode choice of goods from the freight costs and transport time perspectives.

Two models were used in the analysis: a discrete choice (LOGIT) model and a neural network model. These models were used to map out the spatial flow patterns, while allowing comparison of relative performances between two models. The models used a data set, which contained 4,409 observations of the freight flows, and the attributes (time and costs) related to each link between 108 European regions for particular goods (i.e. food). The results of the model applications showed that both models predicted a slightly smaller transport flow than the actual observed flows; however, the predictions made by the LOGIT model were less accurate than that of neural network [16].

### ***3.3.3 Intermodal Transportation Related Simulation Practices***

#### **3.3.3.1 A Simulation Tool for Combined Rail-Road Transport in Inter-Modal Terminals**

In the publication titled “A Simulation Tool for Combined Rail-Road Transport in Inter-Modal Terminals”, by Andrea E. Rizzoli, Nicoletta Fornara, and Luca Maria Gambardella [17], a simulation tool was presented to model the flow of intermodal terminal units (ITUs) among intermodal terminals. The terminal model was composed of road and rail gates and by a set of platforms with intermodal terminals interconnected by rail corridors. Each terminal served user catchments via a road network. The authors stated that the user of the simulation tool could define the structure of the terminal model and the input scenarios. The input scenarios were defined by imposing a train timetable and the patterns of truck arrivals for ITU delivery and pickup.

### 3.3.3.2 Simulation for Policy Evaluation, Planning and Decision Support in an Intermodal Container Terminal

The paper titled “Simulation for Policy Evaluation, Planning and Decision Support in an Intermodal Container Terminal” by Monaldo Mastrolilli, Nicoletta Fornara, Luca Maria Gambardella, Andrea E. Rizzoli, and Marco Zaffalon [18] provided stakeholders with different uses of a simulation tool in an intermodal container terminal. The paper presented part of the authors’ research work aimed at exploiting the representative power of the simulation model of the terminal.

According to the authors, a simulation model of a terminal can provide a valuable tool for the management, especially to evaluate the performance of new policies (policy evaluation), to assess the effect of the implementation of these policies on the terminal state (planning), and to take operational decisions (real time decision support). The authors explored these different uses for the simulation model, particularly with respect to resource allocation and loading and unloading policies.

The first section of the paper was devoted to the description of the structure of the model while the second section introduced the calibration and validation of the model. The third section discussed the integration of the resource allocation module, and the loading and unloading scheduling module with the simulator. The purpose of this integration process was to evaluate the computer-generated policies. The last section of the paper dealt with the use of the simulation model as a mechanism to evaluate medium and long-term planning decisions such as space allocation policies. Also, in this section, the researchers discussed the use of the simulation tool as a decision support tool if real-time data were available.

### 3.3.3.3 Simulation and Planning of an Intermodal Container Terminal

A decision support system for the management of an inter-modal container terminal was presented in the paper titled “Simulation and Planning of an Intermodal Container Terminal”, by Luca Maria Gambardella, Andrea E. Rizzoli, and Marco Zaffalon [19]. The authors revealed that storing containers, allocating resources in the terminal, and scheduling vessel loading and unloading operations were major problems in an inter-modal container terminal. To solve these problems, the researchers defined an architecture composed of these three but strictly connected modules: a simulation model of the terminal, a set of forecasting models to analyze historical data and to predict future events, and a planning system to optimize loading and unloading operations, resource allocation, and container locations on the yard. The focus here was on resource allocation problems where the authors described the modules for the optimization of the allocation process and for the simulation of the terminal. The Contship La Spezia Container Terminal, located in the Mediterranean Sea in Italy was used as a case study.

Results from the use of the case study and the simulation model showed that models developed for the analysis can provide another decision support tool which the authors deemed fundamental to improve terminal management: a job-shop algorithm which could generate the import and export stowage plans for each and train entering and leaving the

terminal which would have to be coupled with a shorter-term reactive job-shop module which could manage the work sequences on each crane in the terminal.

### **3.4 Data Sources**

A variety of data sources have been used in the research of intermodal transportation planning. A list and a succinct description of different databases' availability and applicability for statewide intermodal transportation planning are provided in this section.

#### ***3.4.1 Commodity Flow Data***

Different data sources that can be used for a freight flow study have widely varied degrees of coverage, accuracy, aggregation and completeness [12]. The commodity flow data is directly related to freight flow analysis, which includes data such as the type of commodity, the origin, the destination, the value, the weight, and the ton-miles of the shipments. These data are usually aggregated at the state level, Bureau of Economics Analysis (BEA) Zones, or National Transportation Analysis Regions. To analyze the statewide freight transportation characteristics, a methodology is needed to disaggregate these data to a sub-regional level.

The latest CFS database was conducted in 1997[20]. The commodity data are presented at the state level and grouped by the two-digit Standard Classification of Transported Goods (SCTG) code. It contains commodity flows by tons, value, and ton-miles by commodity on different modes for all states. The CFS data contains data on shipments by domestic establishments in manufacturing, wholesaling, mining, and other industries [20]. The survey coverage excluded establishments classified as farms, forestry, fisheries, oil and gas extraction, government, construction, transportation, households, foreign establishments, and most establishments in retail and services. The database contains the mode information for all the products. The modes discussed include: all modes, single modes, multiple modes, and other unknown modes. In single mode, truck (for hire truck, private truck), rail, water (shallow draft, great lakes, deep draft), air (includes truck and air), and pipeline modes are included. In multiple modes, parcel-US Postal Service or Courier, truck and rail, truck and water, rail and water, and other multiple modes are included in the database.

The CFS data has some inherent advantages when used for freight modeling:

- The CFS data commodity classification is based on the transportation oriented SCTG code.
- The CFS data are public domain data.
- The methodologies developed have flexibility to accommodate future releases of new CFS databases.
- The CFS data specify the different modes clearly, which make intermodal related studies more straightforward. Accurate mode information can be obtained directly without performing mode split procedure.
- Only Internal-Internal (I-I) trip distribution is needed because the origin and destination information is already included in the survey database.

The CFS database also has some limitations:

- Some of the data have not been reported:
  - Data denoted by “-“ represent zero or less than 1 unit of measure
  - Data denoted by “S” represent that the data do not meet publication standards due to high sampling variability or other reasons
  - Data denoted by “D” denote that data were withheld to avoid disclosing data for individual company [20]
- The data are in the state level, therefore, a good disaggregation model is needed to meet the requirements for statewide freight transportation modeling [21]
- Shipments traversing the U.S. from a foreign location to another foreign location (e.g., from Canada to Mexico) are not included, nor are shipments from a foreign location to a U.S. location [20].

As a public domain data source, CFS database has drawn attention in freight transportation planning studies. Many state, such as the State of Virginia [22,23], have used the database to obtain the four components of the commodity flow (Interior-Interior, Exterior-Interior, Interior-Exterior, and Exterior-Exterior)

#### **3.4.2 Reebie Associates TRANSEARCH Database**

Most of the statewide freight forecasting methodologies are based on the Reebie Associates' TRANSEARCH database because it is assumed as the best commodity flow database currently available [24,25]. Because the TRANSEARCH database is at county level, disaggregation of the model is not necessary. Reebie Associates compiles data from a variety of sources, synthesizes the data, and then analyzes the data to get a comprehensive database of commodity movements in the United States.

The TRANSEARCH database contains freight movements by rail, water, air, and truck from manufacturing plants, truck movements of coal, and inland truck movements of imports [12]. The data do not include shipments by pipeline, mail or small package shipments, and secondary truck shipments involving warehouses.

Although TRANSEARCH database has the advantage of having the county level data (thus, development of disaggregation methodology is not necessary), the database still has several limitations.

- Since the database is built from many different databases, different classification on commodities may cause problems [12] (The conversion from one classification to another may lead to some data being put in a wrong category or left unreported).
- The levels of reporting accuracy among different companies may affect the accuracy of the database.
- Models based on the TRANSEARCH database will require regular purchases of data to update the model.

Reebie data however are very expensive. In addition, Reebie database and CFS database are essentially from the same source, so the TRANSEARCH database is not used in this study.

### ***3.4.3 Rail Waybill Data***

The annual Rail Waybill sample contains shipment data from a stratified sample of Rail Waybills submitted by freight railroads to the Surface Transportation Board (STB). The data are based on the Carload Waybill Sample, which are proprietary. All Waybills are submitted by Class I Railroads to the Surface Transportation Board. The Rail Waybill database is from the Surface Transportation Board and the Federal Railroad Administration. The database has national coverage and is collected by the American Association Railroads (AAR) annually. The Rail Waybill contains public-use, non-confidential information [26,12]. The data contains origins and destinations, type of commodity, number of cars, tons, revenue, length of haul, participating railroads, and interchange locations [12]. The disaggregation method is needed if this database is utilized.

The Rail Waybill Data can be used to determine what the most common types of railcars are used to transport different commodities. It is also useful to convert the commodity tonnage to number of railcars. The rail cost data can be used to calculate the rail mode cost and be incorporated to do mode choice in the future research project.

### ***3.4.4 TransCAD Database***

TransCAD [27] is a Geographic Information Systems (GIS) designed, specifically used by transportation professionals to store, display, manage, and analyze transportation data. TransCAD combines GIS and transportation modeling capabilities in a single integrated platform, providing capabilities unmatched by any other packages. TransCAD can be used for all modes of transportation, at any scale or level of detail. TransCAD provides the following features:

- A powerful GIS engine with special extensions for transportation
- Mapping, visualization, and analysis tools designed for transportation applications
- Application modules for routing, travel demand forecasting, public transit, logistics, site location, and territory management

### ***3.4.5 County Population and Employment Data***

The county population data can be obtained from the U.S Bureau of the Census official website on quick facts for all states [28]. It can be used to disaggregate the data from state level to county level when the attraction is concerned. The County employment data for different commodities can be mainly obtained from the County Business Patterns, also distributed by U.S Bureau of the Census [29].

### **3.4.6 Vehicle Inventory Use and Survey (VIUS)**

VIUS, formerly the Truck Inventory Use and Survey (TIUS), is maintained by the Bureau of Statistics [30]. The VIUS was first conducted in 1963 and has been done every five years ever since. Data in VIUS are collected using a mail-out/mail-back survey of selected trucks. A stratified random samples of registered trucks are selected from all 50 states and the District of Columbia. Samples are selected by state and classified mainly by body type. Data collection is staggered as state records become available. Owners report data only for the vehicles selected.

The VIUS contains information for the entire US as well as for all the individual states. This database contains information on the physical characteristics such as date of purchase, empty weight, average and maximum loaded weight, number of axles, overall length, type of engine, and body type. It also contains operational data such as the prominent type of use, lease of characteristics, operator classification, base of operation, gas mileage, annual and lifetime miles driven, weeks operated, and commodities hauled by type.

Most of the DOTs use the data for analysis of cost allocation, safety issues, proposed investments in new roads and technology, and user fees [24]. The Environmental Protection Agency uses the data to determine per mile vehicle emission estimates, vehicle performance and fuel economy, and fuel conservation practices of the trucking industry. The Bureau of Economic Analysis uses the data as a part of the framework for the national investment and personal consumption expenditures component of the Gross Domestic Product (GDP).

### **3.4.7 Ground Counts Data**

Ground Counts Data are usually collected and maintained by State Department of Transportation. Using ground truck counts to validate the freight model is the usual way of doing model validations. However, usage of ground counts data presents some challenges [12]:

- Key commodities are usually identified in many state intermodal transportation planning processes. The traffic assignment results are simply divided by the percentage of the key commodities (% from all commodities). Comparison with ground counts in this way is not accurate. Therefore, all commodities have to be included in the commodity analysis process for a fair comparison.
- Validation using ground truck counts does not fully take advantage of the separate commodity analysis process. If there is truck counts on different commodity database (available from the weigh station), the validation procedure will be more useful.
- Truck counts database does not present the comprehensive information as truck survey does.

### **3.4.8 Comprehensive Truck Survey Database**

Some states have conducted the comprehensive truck surveys. The truck survey includes information on configuration of the vehicle, axle spacing, major commodities carried, and origin and destination of the vehicle [12]. This database can be combined with the VIUS database to derive additional data. The derived data can be utilized either in truck trips conversion process or model validation process. This comprehensive truck survey, however, requires considerably more effort than what most states have already done in getting truck counts. If more usage of this database can be identified, the comprehensive truck survey will be worthwhile.

## **4 METHODOLOGY AND BASE YEAR STUDY**

Base year study is based on 1997 CFS database together with other public domain databases such as VIUS. The model is validated by using Mississippi DOT's ground counts. The detail description of the base year study model and calibration are discussed in this section.

### **4.1 Summary Description of the Study**

CFS data were used to derive the state-level O&D by commodity by mode using a developed Visual Basic-based program, which was developed by the research team. The O&D data was then used for transportation planning and transportation simulation.

The transportation process in the model conforms to the traditional four-step procedure of transportation planning. Basic procedures of the study include:

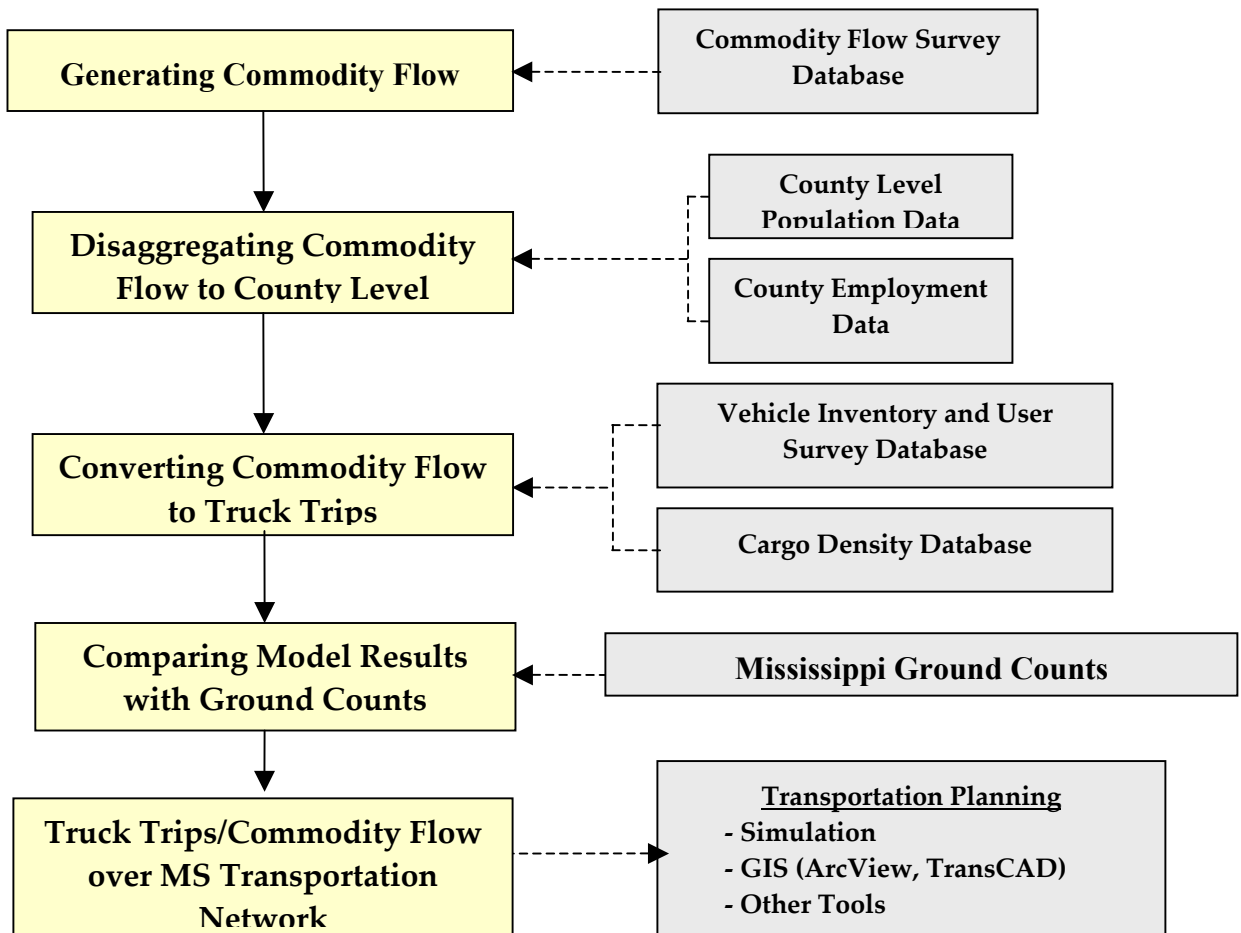
1. The trip generation step was done in the commodity flow data analyses phase.
2. A methodology using population and employment as the production and attraction index was used to break down state level O&D data to county level.
3. The Gravity Model (GM) was used in the trip distribution analysis. Mode information is directly obtained from the commodity data analysis phase.
4. Trip distribution is only needed for "within" commodity since there is O&D information in terms of transported tonnage between different states in CFS.
5. Mode split step was skipped since data on modes are available from the CFS data.
6. Traffic assignments by commodity were performed using shortest path assignment method.
7. Assignment results from different O&D pairs were combined to get the commodity tonnage on the network in the State of Mississippi.
8. A methodology was developed to convert the freight flows to vehicle trips to facilitate model calibration and validation. Yearly truck traffic was converted to daily truck traffic based on the truck usage information for the VIUS.
9. The comparison between the truck volume determined by the model and the ground truck counts on the network was conducted to calibrate and validate the model.
10. Future years' (2005, 2010,2020) transportation characteristics were forecasted based on developed base year model and time series population and employment

data. Traffic assignments for future years were conducted in the base year network.

Research methodology of the base year study is presented in more detail in the next sections. The major issues include the following:

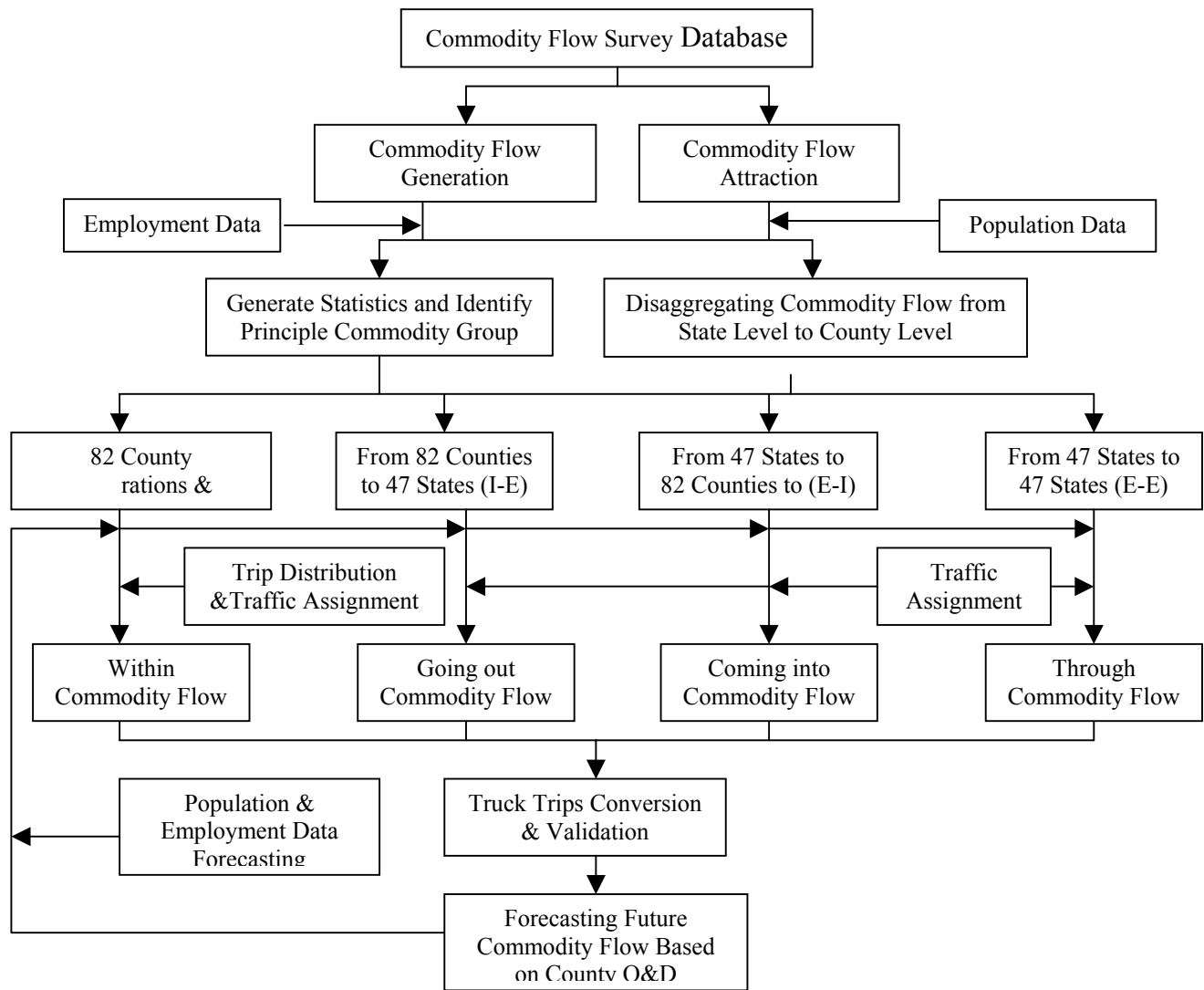
- Usage of the data sources
- Development of networks
- Commodity flow analysis
- Method used for break down analysis
- Commodity flow to truck trips conversion
- Model validation
- Forecasting and planning

Figure 4-1 illustrates the model developed for base year study. The forecasted year studies follow almost exactly procedures shown above using time series population and employment data for different TAZs. Figure 4-2 shows the analysis procedure, with traffic flow components being identified at various stages.



**Figure 4-1 Developed base year study Model in Statewide Intermodal Transportation Planning for Mississippi**



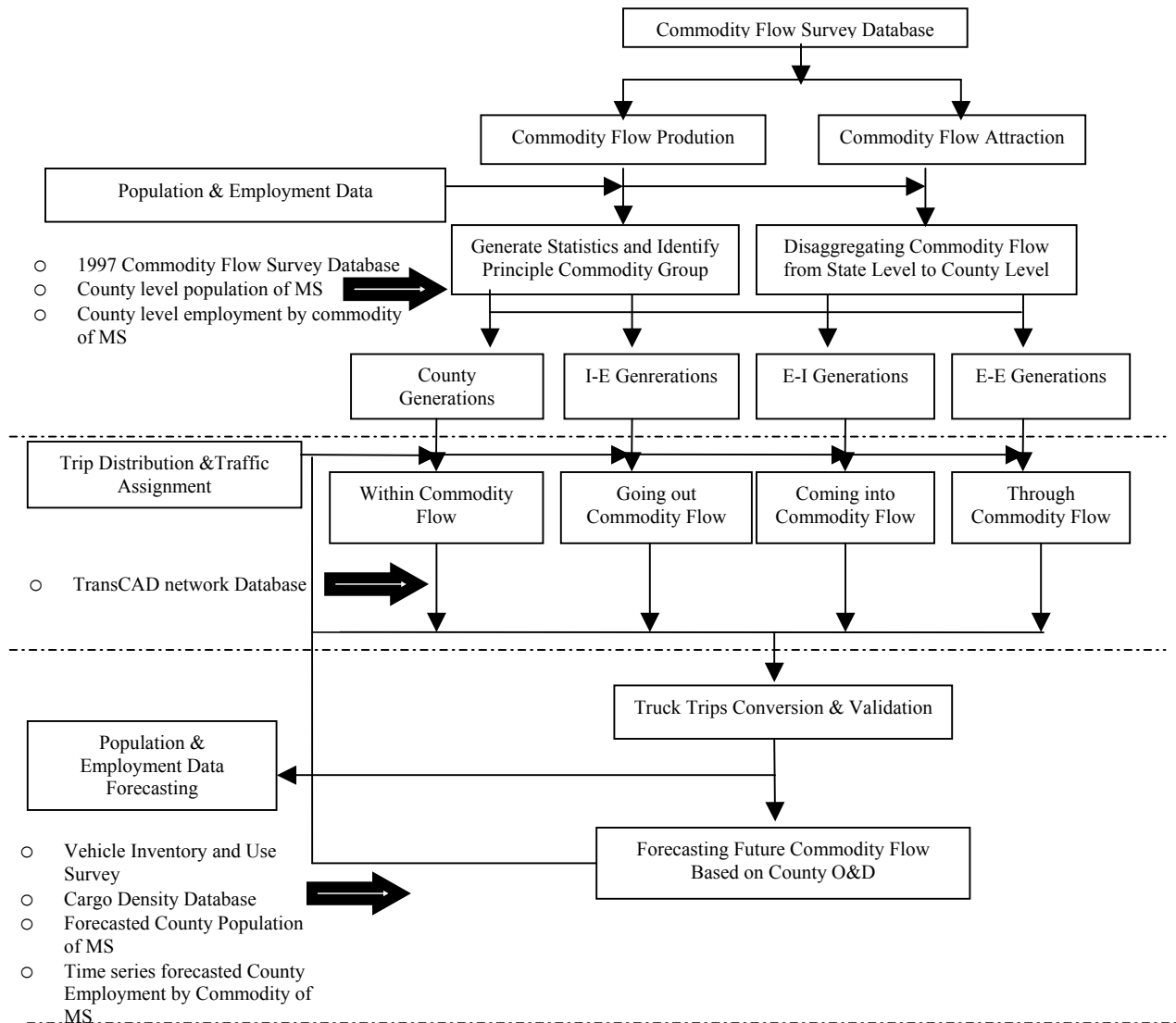


**Figure 4-2 Structured Analysis Procedures for Transportation Analysis**

## 4.2 Data Source Applications

For the statewide freight transportation planning, one of the most important impediments is to get robust, accurate data [31]. It is often difficult to get transportation information based on surveys due to financial and practical considerations. There are, however, a variety of data sources that can be used to estimate the required freight transportation data. These databases may not be uniquely developed for the use by transportation system. As a matter of fact, some of the data can only be used along with cross-referencing to other data sources.

This section focuses on describing how the databases are utilized in the statewide intermodal transportation planning model in the State of Mississippi. Figure 4-3 shows how the databases were used in the study. The details are presented in the following subsections.



**Figure 4-3 Structured Approach and Databases Used in the Planning**

#### 4.2.1 CFS Database Application

The 1997 CFS [20,32] offers good opportunities to determine the following:

- The production and attraction for within the state by commodity and by mode
- The production for going out to different states by commodity and by mode
- The attraction for coming into the state from the other states by commodity and by mode
- Through traffic in a particular state based on OD data of U.S. except for the subject state

The 1997 CFS database provides information on commodity flow out of each state for all the states. The production, attraction, and distribution of different commodities for Mississippi at the state level were determined from the database. Based on the state level

data, a disaggregation method was used to break them down to the county level data. The following four flow components were studied:

- “Within”: Flows originate and terminate in the state of Mississippi;
- “Coming into”: Flows originate in other states and terminate in Mississippi;
- “Going out”: Flows originate in Mississippi and terminate in other states;
- “Through”: Flows originate and terminate in other states that pass through Mississippi.

For the “Within” part, gravity model was used to determine the O&D data between different counties. By aggregating the “Coming into”, “Going out” “Within” and “Through” parts, we can obtain the O&D tables at the county level.

#### ***4.2.2 TransCAD Database Application***

TransCAD database was used to develop the transportation network for the study. Within the borders of the State of Mississippi, the network contains all Interstates, U.S highways, and State Highways. In the surrounding states of Alabama, Louisiana, Tennessee, and Arkansas, all the interstates and U.S highways were included in the network. Other than these 5 states, only Interstate Highways were included in the study. TransCAD software was also used to perform traffic assignment based on the O&D derived from 1997 Commodity Flow Survey database to get the truck flows on the highway systems.

#### ***4.2.3 VIUS Application***

In the Mississippi study, VIUS data was used to determine the vehicle capacity by truck type as well as vehicle distribution by commodity group. This information is helpful when converting commodity flow to truck trips. The 1997 VIUS data was also used to estimate yearly truck usage, which was used to convert the annual truck trips to Average Daily Truck Traffic (ADTT) used in the study. The commodity carried by different types of vehicles is coded using VIUS code. This code system was matched to the SCTG code.

#### ***4.2.4 Cargo Density Database Application***

Cargo densities were obtained from a book distributed by the U.S. Department of Transportation titled “A Shipper’s Guide to Stowage of Cargo in Marine Containers”. The classification of the commodities in the book is based upon the United Nations Standard International Trade Classification Index (SITC) [33].

There are 50 different commodities defined in two-digit level classification. In the four-digit level, each commodity densities are given. In this study, we matched these data with the SCTG coded data on the commodity densities carried in the truck. The matching process is an iterative process based on the matching results of Standard Industrial Classification (SIC) code/SCTG code and SCTG code/VIUS code. During the matching process, dividing or combing commodity groups were necessary to get an approximate optimum solution. The densities of commodity groups were used to get the information on the payload of different truck types for different commodity groups.

#### 4.2.5 Ground Counts Database Application

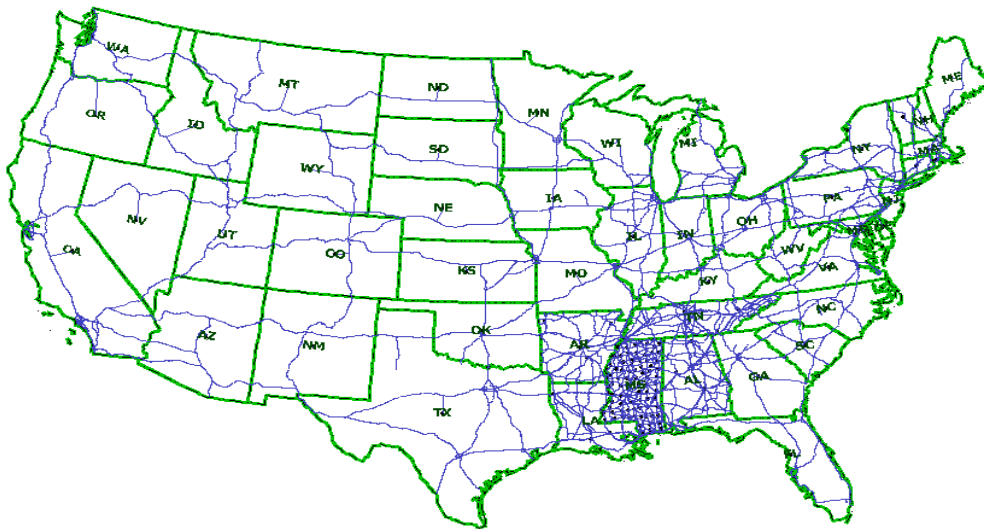
In the Mississippi model, the ground truck counts were used for model validation. The database was obtained from the Mississippi Department of Transportation (MDOT). The ground truck counts data contains classification data, 24 hour counts, and peak hour truck volume for several years. 1997 truck counts data was used to match the results derived from 1997 commodity flow survey database.

### 4.3 Network Development

In this section, highway networks for traffic assignment at the nation level, neighboring states level, county level, and within Mississippi level are presented. Simulation network was independently developed and will be discussed in a separate chapter.

#### 4.3.1 Highway Network for Traffic Assignment

In the highway network used in this study (Figure 4-4), all continental U.S. states are considered. State highways, US highways, and Interstate highways are included in the State of Mississippi. All 82 counties are included in the model as TAZs. In the neighboring states (Alabama, Arkansas, Tennessee, and Louisiana), US Highways and Interstate Highways are included. Selected major cities (total of 18) representing the areas around the cities were used as the centroids of the respective region in the neighboring states. Table 4-1 and Figure 4-5 is the list of cities considered to be the centroids in the neighboring states in the study.



**Figure 4-4 Highway Network in the Nation Level for Truck Flow Analysis**

The interstate highways are the only type of highways included for the representing 43 continental states. Each state except Mississippi and the neighboring states specified above were assumed as a TAZ. The geometric center of each state was used as the centroid. Because we are only concerned about the traffic planning for the State of

Mississippi, the unbalanced characteristics of the network will not affect the results to any significant degree.

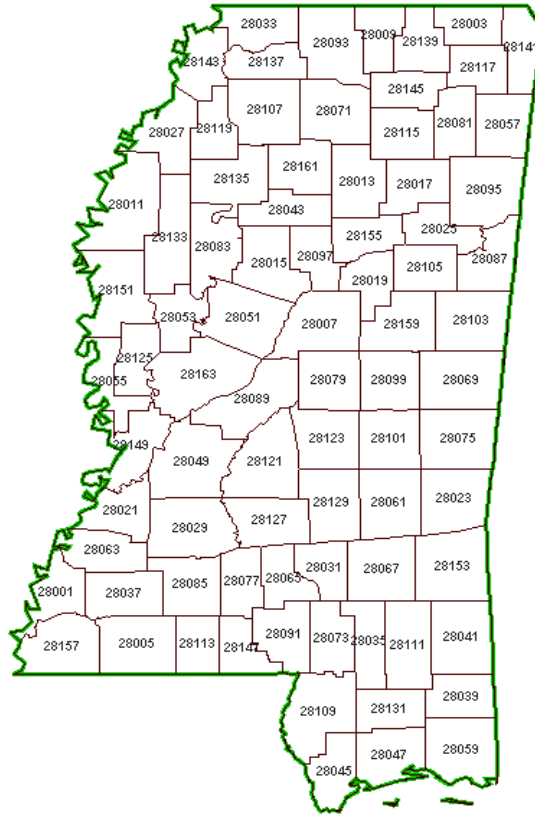
All U.S Highways and State Highways were included for Mississippi, since the commodity flow of going out of Mississippi and coming into Mississippi from neighboring states may not always utilize the interstate highways exclusively. Figure 4-6 shows the TAZs in the States of Mississippi, and Figure 4-7 displays the network in the State of Mississippi.

**Table 4-1 The City List in Neighboring States**

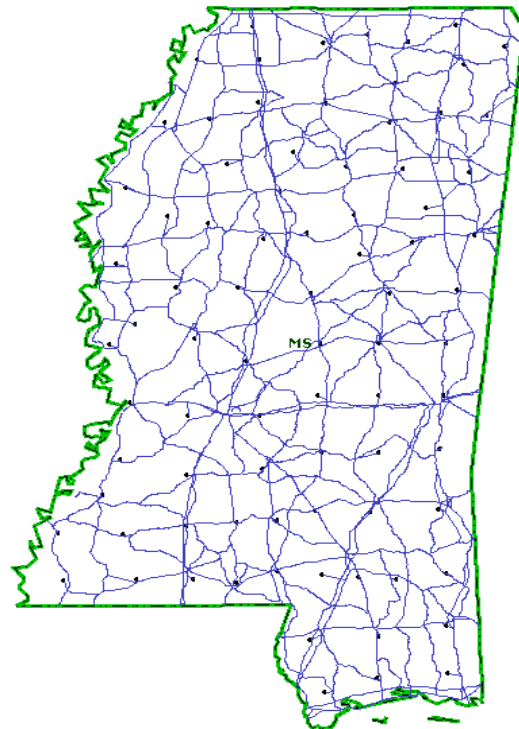
ID in TransCAD	State Code in TransCAD	State Name	City Name	Population
2201	22	Louisiana	BATON ROUGE	227818
2202	22	Louisiana	SHREVEPORT	200145
2203	22	Louisiana	LAFAYETTE	110257
2204	22	Louisiana	NEW ORLEANS	484674
501	5	Arkansas	LITTLE ROCK	183133
502	5	Arkansas	PINE BLUFF	55085
503	5	Arkansas	FORT SMITH	80268
504	5	Arkansas	FAYETTEVILLE	58047
505	5	Arkansas	JONESBORO	55515
101	1	Alabama	MOBILE	198915
102	1	Alabama	MONTGOMERY	201568
103	1	Alabama	BIRMINGHAM	242820
104	1	Alabama	HUNTSVILLE	158216
105	1	Alabama	TUSCALOOSA	77906
4701	47	Tennessee	NASHVILLE-DAVIDSON	545524
4702	47	Tennessee	MEMPHIS	650100
4703	47	Tennessee	CHATTANOOGA	155554
4704	47	Tennessee	KNOXVILLE	173890



**Figure 4-5 Cities in Neighboring States**



**Figure 4-6 Traffic Analysis Zones for Transportation Analysis in Mississippi**



**Figure 4-7 Highway Network for Traffic Assignment in Mississippi**

### 4.3.2 Network for Simulation

The network used in the simulation model includes transportation data analysis network for simulation input and simulation network in the state. Details are described in Chapter 6: *Further Analysis Using Simulations Tools* section of this report.

## 4.4 Commodity Flow Analysis

This section describes the procedure to determine commodity flow components. Commodity flow analysis results are discussed, and several major issues in flow analysis procedure are addressed in the section.

### 4.4.1 Treatment of Missing Data in the CFS Database

Data in CFS denoted by “-“ represents zero or less than 1 unit of measure [20]. They can be considered as 0 without losing any generality in the study. Data denoted by “D” denotes figures that were withheld to avoid disclosing data for individual companies. The problem of having “D”s in the data has been ignored due to the fact that there aren’t too many “D”s in the database. Data denoted by “S” represents that the data does not meet publication standards due to high sampling variability or other reasons. These values are calibrated based on the information on the type of all commodity and individual commodity types. They are determined by calculating the difference between the total quantity of all commodities combined and the sum of the quantity for individual commodity type, and then dividing the result by the quantity of “S”s in the specific category as shown in Equation 4-1.

$$S = \frac{T_j - \sum_{i=1}^n T_i}{N} \quad (4-1)$$

where,

$S$  = estimated value for  $S$ ;

$T_j$  = total quantity of flow in all commodities combined for mode  $j$ ;

$T_i$  = quantity of commodity flow in commodity type  $i$  category;

$i$  = commodity type  $i$ ;

$n$  = number of commodity type;

$N$  = number of  $S$ s in mode  $j$  category.

### 4.4.2 Commodity Flow Generation

Commodity flow generation includes commodity flow production and commodity flow attraction. This section provides description on how to get the going out, coming in, within and through commodity flow components

#### 4.4.2.1 Commodity Flow Production

The tonnage data (in short tons) was given more attention in the study since tonnage is a good indication for evaluating the impact of commodity flow on transportation

infrastructure and can be converted to truck trips. From Mississippi's data are obtained from "Table 15. Shipment Characteristics by Two-Digit Commodity and Mode of Transportation: 1997" of the CFS database (including the destination of Mississippi). The productions for Mississippi were determined as Internal-External (I-E) and Internal-Internal (I-I) flow. This produced the first two components of OD tables at the state level: "Going out" and "Within".

#### 4.4.2.2 Commodity Flow Attraction

From the 47 states data described as "Table 15. Shipment Characteristics by Two-Digit Commodity and Mode of Transportation: 1997" in the CFS database, the attractions for the State of Mississippi were determined as External-Internal (E-I) flow. This component is the third component: "Coming into" at the state level.

#### 4.4.2.3 Through Traffic

O&D data for the 48 states in US were obtained by processing the CFS data using visual basic based codes. External-External (E-E) flow was obtained by excluding the State of Mississippi from the 48\*48 matrix and performing traffic assignment on the transportation network. This process generated the "Through" flow component.

### 4.4.3 *Commodity Flow Analysis Results*

This section presents results from commodity flow composition analysis in the state. Commodity flow mode analysis results and principle commodity identification based on tonnage carried in the transportation network in the state are also described in the section.

#### 4.4.3.1 Commodity Flow Composition

The percentages of tonnage carried by the I-E, E-I, and I-I traffic for different commodities are shown in Table 4-2. (E-E commodity flow data was not included since the E-E data is not commodity specific). All three flow components are mode specific and commodity specific. Combining all commodity types, I-E traffic counts for 24.06% of the total tonnage (I-E, E-I, and I-I combined); E-I traffic counts for 31.11%, and I-I traffic counts for 44.83% respectively.

#### 4.4.3.2 Commodity Flow Mode Analysis

Mode analysis results show that for I-I portion, 86.05% of the commodities carried by single modes are moved by truck and 2.37% commodities carried by single modes are moved by rail. For I-E portion, 57.93% of the commodities carried by single modes are moved by truck and 16.52% commodities carried by single modes are moved by rail. For E-I portion, 55.09% of the commodities carried by single modes are moved by truck and 18.52% commodity carried by single modes is moved by rail. This shows that the modes of truck and rail serve as the major modes of transporting freights in the state. Table 4-3 describes the details.



**Table 4-2 Tonnage Carried of Different Components by Commodity Type**

Commodity Code	Commodity Name	Within (I-I)	Going Out (I-E)	Coming Into (E-I)
01	Live animals and live fish	22.05%	0.00%	77.95%
02	Cereal grains	49.82%	7.69%	42.48%
03	Other agricultural products	43.86%	34.26%	21.89%
04	Animal feed and products of animal origin, n.e.c.	75.89%	3.15%	20.96%
05	Meat, fish, seafood, and their preparations	17.92%	24.55%	57.52%
06	Milled grain products and preparations, and bakery products	22.38%	32.15%	45.47%
07	Other prepared foodstuffs and fats and oils	41.20%	26.26%	32.54%
08	Alcoholic beverages	64.25%	17.16%	18.58%
09	Tobacco products	39.32%	31.75%	28.93%
10	Monumental or building stone	24.32%	33.06%	42.62%
11	Natural sands	50.23%	19.77%	30.00%
12	Gravel and crushed stone	16.44%	34.70%	48.86%
13	Nonmetallic minerals n.e.c.	41.84%	28.29%	29.87%
14	Metallic ores and concentrates	42.12%	31.72%	26.16%
15	Coal	48.70%	24.96%	26.34%
17	Gasoline and aviation turbine fuel	53.76%	15.44%	30.80%
18	Fuel oils	7.62%	65.70%	26.68%
19	Coal and petroleum products n.e.c.	49.43%	25.07%	25.50%
20	Basic chemicals	33.01%	34.16%	32.83%
21	Pharmaceutical products	82.88%	8.81%	8.31%
22	Fertilizers	5.88%	42.19%	51.93%
23	Chemical products and preparations n.e.c.	6.03%	47.21%	46.76%
24	Plastics and rubber	8.45%	50.31%	41.24%
25	Logs and other wood in the rough	11.83%	51.37%	36.80%
26	Wood products	20.57%	38.76%	40.67%
27	Pulp, newsprint, paper, and paperboard	34.59%	33.45%	31.96%
28	Paper or paperboard articles	58.94%	16.92%	24.14%
29	Printed products	48.39%	26.64%	24.96%
30	Textiles, leather, and articles of textiles or leather	18.42%	44.22%	37.35%
31	Nonmetallic minerals products	8.69%	53.92%	37.40%
32	Base metal in primary or semi-finished forms and in finished basic shapes	55.40%	26.05%	18.55%
33	Articles of base metal	1.89%	23.77%	74.34%
34	Machinery	7.42%	56.53%	36.05%
35	Electronic and other electrical equipment and components and office equipment	72.81%	1.78%	25.41%
36	Motorized and other vehicles	46.39%	33.16%	20.45%
37	Transportation equipment, n.e.c.	78.38%	0.00%	21.62%
38	Precision instruments and apparatus	9.15%	44.57%	46.27%
39	Furniture, mattresses and mattress supports, lamps, light fittings, and illuminated signs	11.13%	55.91%	32.96%
40	Miscellaneous manufactured products	70.98%	16.57%	12.45%
41	Waste and scrap	48.37%	8.54%	43.09%
43	Mixed freight	69.20%	21.51%	9.29%
44	Commodity unknown	0.00%	0.00%	100.00%
<b>Total</b>		44.83%	24.06%	31.11%

**Table 4-3 The Percentage of Commodity Carried by Truck or Rail (Single Mode)**

Commodity Code	I-I		I-E		E-I	
	Truck	Rail	Truck	Rail	Truck	Rail
All Commodities	86.05%	2.37%	57.93%	16.52%	55.09%	18.52%
01	98.63%	0.00%	78.81%	0.00%	83.37%	0.00%
02	98.63%	4.06%	53.80%	0.00%	71.82%	0.00%
03	98.63%	4.06%	51.74%	16.15%	92.63%	3.19%
04	68.82%	3.92%	43.27%	10.53%	78.05%	0.00%
05	99.81%	0.00%	70.46%	0.00%	69.33%	2.98%
06	98.63%	0.00%	58.80%	29.40%	68.45%	0.00%
07	78.40%	21.56%	61.23%	17.37%	90.41%	0.00%
08	100.00%	0.00%	88.31%	0.00%	78.29%	0.00%
09	100.00%	0.00%	31.49%	0.00%	69.20%	0.00%
10	0.00%	0.00%	0.00%	0.00%	103.55%	0.00%
11	98.63%	0.00%	0.00%	0.00%	49.22%	0.00%
12	99.68%	0.93%	47.22%	0.00%	70.38%	5.31%
13	98.63%	4.06%	53.87%	22.05%	69.72%	20.61%
14	98.63%	0.00%	59.49%	0.00%	35.20%	15.37%
15	98.63%	0.00%	0.00%	0.00%	2.82%	96.68%
17	49.70%	0.62%	51.79%	0.00%	72.15%	0.00%
18	61.32%	0.00%	32.47%	0.00%	10.64%	0.32%
19	100.00%	0.00%	45.23%	23.82%	78.70%	10.44%
20	75.17%	24.83%	38.97%	46.32%	22.44%	21.01%
21	100.00%	0.00%	46.03%	0.00%	59.27%	4.68%
22	47.07%	5.38%	52.85%	24.46%	58.72%	18.34%
23	85.47%	6.23%	53.09%	10.45%	69.32%	0.66%
24	81.59%	29.50%	72.00%	40.76%	75.93%	23.10%
25	97.31%	1.21%	121.45%	19.29%	75.77%	0.00%
26	99.05%	1.37%	65.36%	29.67%	87.33%	5.90%
27	64.65%	35.67%	30.02%	58.08%	52.61%	19.53%
28	100.00%	0.00%	45.13%	0.00%	74.91%	28.83%
29	100.00%	0.00%	39.57%	0.83%	57.98%	0.00%
30	100.00%	0.00%	83.22%	5.56%	69.09%	0.00%
31	98.63%	4.06%	68.31%	33.04%	68.85%	10.03%
32	100.00%	0.00%	82.26%	18.87%	92.71%	10.11%
33	100.00%	0.00%	82.74%	0.00%	92.95%	0.00%
34	98.75%	0.00%	87.38%	15.59%	100.59%	0.00%
35	100.00%	0.00%	95.20%	0.00%	58.72%	0.00%
36	98.63%	4.06%	66.72%	0.00%	82.92%	1.30%
37	98.63%	0.00%	45.82%	0.00%	102.71%	0.00%
38	98.63%	0.00%	45.15%	0.00%	69.14%	0.00%
39	98.63%	0.00%	97.42%	6.37%	78.16%	0.00%
40	100.00%	57.79%	95.11%	41.15%	94.16%	0.00%
41	100.00%	0.00%	35.58%	0.00%	83.85%	0.00%
43	100.00%	0.00%	99.90%	0.00%	75.26%	0.00%
44	98.63%	0.00%	44.01%	0.91%	78.50%	1.99%

Note: Please refer to the commodity names in Table 4-2.

#### 4.4.3.3 Major Commodities Identification

Major commodities are identified after the commodity flow analysis. Commodity tonnage is used as the selection criteria to measure the importance of the commodity for the highway flows. Top commodities for different movement types (I-I, I-E, E-I) were identified. The union set of these three has been considered as the final analysis commodity set. Table 4-4 shows the identified commodities.

**Table 4-4 List of Principle Commodities**

I-E			E-I			I-I		
Commodity Type	Tonnage	Rank	Commodity Type	Tonnage	Rank	Commodity Type	Tonnage	Rank
04	4100	9	04	3075	12	04	1806	7
07	3358	10	07	4336	10	07	2238	6
12	7732	5	12	14418	4	12	7643	2
17	15736	2	15	9347	6	17	11286	1
18	5430	6	17	17902	3	18	4107	5
19	4445	8	18	11719	5	22	1067	8
20	2532	11	19	5150	8	25	6132	3
25	13181	4	20	4658	9	26	5297	4
26	13848	3	25	19094	2	32	632	10
27	4680	7	26	8748	7	43	1053	9
31	22475	1	31	21441	1			
			32	3316	11			

Note: The unit is thousand tons;  
 The results derived from the data before “S” calibration;  
 The union of these three parts is the final commodity analysis set which includes: Commodity types 4, 7, 12, 15, 17, 18, 19, 20, 22, 25, 26, 27, 31, 32, 43;  
 Please refer to the commodity name in Table 4-2 or appendix I.

#### 4.4.3.4 Special Analysis of Wood and Wood Products

Since wood and wood products are among the most important commodities in the state. The SCTG code commodity 25: logs and other wood products in the rough and commodity 26: wood products were given high priority in the study. The mode analysis for these two commodities is presented in the Table 4-5 and Figure 4-8. This also gives insights on performing case study for these commodities in the simulation component.

**Table 4-5 Mode Share Analysis for Commodity 25 & 26**

	Commodity Category					
	C25	C26	C25 Mode Share	C26 Mode Share	(C25+C26)	(C25+C26) Mode Share
<b>All modes</b>	14184	17041			31225	
<b>Single modes</b>	13836	16667	97.55%	97.81%	30503	97.69%
Truck	9919	11911	69.93%	69.90%	21830	69.91%
Rail	3764	1710	26.54%	10.03%	5474	17.53%
Water	0	2830	0.00%	16.61%	2830	9.06%
Shallow draft	0	2830	0.00%	16.61%	2830	9.06%
Deep draft	0	0	0.00%	0.00%	0	0.00%
Air (includes truck and air)	0	0	0.00%	0.00%	0	0.00%
Pipeline	0	0	0.00%	0.00%	0	0.00%
<b>Multiple modes</b>	348	46	2.45%	0.27%	394	1.26%
Parcel, US Postal Service or courier	0	3	0.00%	0.02%	3	0.01%
Truck and rail	348	43	2.45%	0.25%	391	1.25%
Truck and water	0	0	0.00%	0.00%	0	0.00%
Rail and water	0	0	0.00%	0.00%	0	0.00%
Other multiple modes	0	0	0.00%	0.00%	0	0.00%
<b>Other and unknown modes</b>	0	328	0.00%	1.92%	328	1.05%
<b>All modes</b>	14184	17041			31225	
<b>Single modes</b>	13836	16667	97.55%	97.81%	30503	97.69%
<b>Multiple modes</b>	348	46	2.45%	0.27%	394	1.26%
<b>Other and unknown modes</b>	0	328	0.00%	1.92%	328	1.05%

Note: the unit for is in thousands of tons



**Figure 4-8 Mode Share Analysis for Commodity 25 and 26**

From the mode share analysis results for commodity 25 (Logs and other wood in the rough) & 26 (Wood products), we can also reach the conclusion that the utilization of intermodal transportation in the State of Mississippi has great potential for improvements.

Similarly, the mode share for every other commodity can be derived from the methodology and database developed for the State.

## 4.5 Commodity Flow Disaggregation

Traffic analysis has to be done at a county or regional level when conducting statewide transportation planning. “Proportioning” can be used in the disaggregation phase. The E-I, I-E, E-E and I-I freight data were disaggregated to the county level. Based on the productions and attractions of each TAZ, the gravity model (GM) was used to get the trip distribution data for within Mississippi. The methodology used is very similar to the research done by the Virginia Transportation Research Council [22].

### 4.5.1 Population Data

The county population data was used to disaggregate the attraction data from the state level to the county level (when the attraction is concerned). The area population of the cities selected from surrounding states was also used to disaggregate the data. The data is obtained from the Bureau of Census Bureau official website on quick facts of Mississippi [34]. (Appendix II)

### 4.5.2 Employment Data

Employment data was used to determine productions at the county level. The main source for the employment data is the County Business Patterns distributed by U.S Census Bureau [35]. The 2 digits SCTG code classification is matched to 4 digits SIC code classification (Table 5-5), using the website of Occupational Safety & Health Administration of U.S. Department of Labor as reference [36]. (Appendix II)

The limitations of this data and estimations are as follows: The employment data figure obtained from the County Business Patterns is the number of employees for one week including March 12 1997, which represents a snapshot of the employment at a given time, not the average employment for the year. The problem with this figure is that the data may not be representative of the annual employment, especially when the employment is expected to be seasonal, like in the case of Agriculture, which is expected to have a higher employment during Summer time.

### 4.5.3 Disaggregation

The relationship used to distribute freight among counties can be stated in Equations 4-2 and 4-3:

$$TO_{ki} = \left( \frac{IP_{ki}}{IP_{kr}} \right) * TO_{kr} \quad (4-2)$$

$$TD_{ki} = \left( \frac{IA_{ki}}{IA_{kr}} \right) * TD_{kr} \quad (4-3)$$

where,

$TO_{ki}$  = tons of commodity  $k$  originating from county  $i$ ;

$TD_{ki}$  = tons of commodity  $k$  destined in county  $i$ ;

$IP_{ki}$  = indicator of production for commodity  $k$  in county  $i$ ;

$IP_{kr}$  = indicator of production for commodity  $k$  in entire state;

$IA_{ki}$  = indicator of attraction for commodity  $k$  in entire county  $i$ ;

$IA_{kr}$  = indicator of attraction for commodity  $k$  in entire state;

$TO_{kr}$  = total tons of commodity  $k$  originating in the state;

$TD_{kr}$  = total tons of commodity  $k$  destined for the state.

One of the most basic measures of production is industry employment [31]. The information is obtained by the methodology that converts the employment based on SIC code to SCTG code by commodity, as shown in Table 4-6. The most basic and commonly used measure of attraction is population. This measure is used because it often relates to consumption.

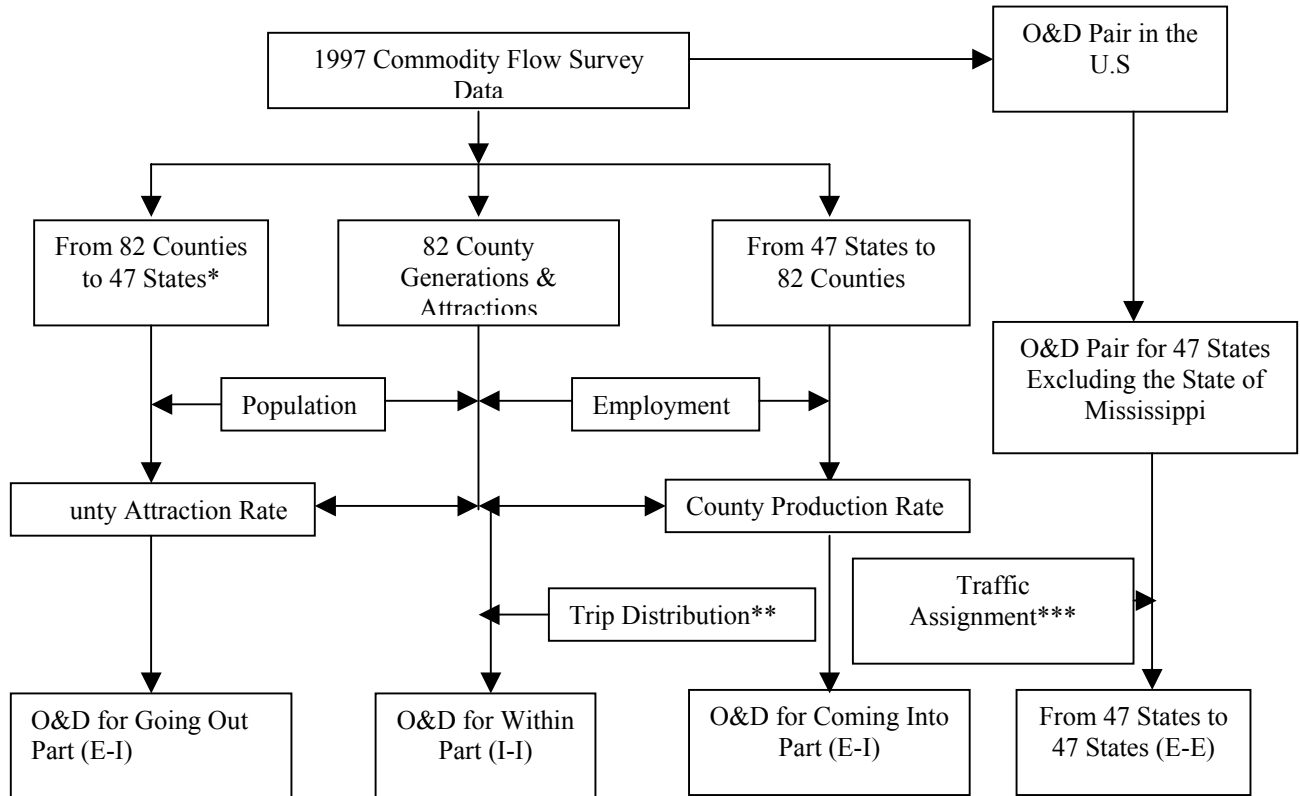
**Table 4-6 Two-digit SCTG & Four-digit SIC Code Matching Results**

SCTG Code	SCTG Name	SIC Code	SIC Name
04	Animal Feed and Prod of Animal Origin, n.e.c.	2040	Grain Mill Products
07	Other Prepared Foodstuffs and Fats and Oils	2000	Food and Kindred Products
12	Gravel and Crushed stone	1440	Sand and Gravel
15	Coal	1400*	Non-Metallic Minerals, except Fuels
17	Gasoline and Aviation Turbine Fuel	1300	Oils and Gas Extraction
18	Fuel Oils	1310	Crude Petroleum and Natural Gas
19	Coal and Petroleum Products n.e.c.	5170	Petroleum and Petroleum Products
20	Basic Chemicals	2800*	Chemicals and Allied Products
22	Fertilizers	2800*	Chemicals and Allied Products
25	Logs and Other Wood Products in the Rough	2410	Logging
26	Wood Products	2400	Lumber and Wood Products
27	Pulp, Newsprint, Paper and Paperboard	2600	Paper and Allied Products
31	Non-Metallic Mineral Products	1400*	Non-Metallic Minerals, except Fuels
32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	3400	Fabricated Metal Products
43	Mixed Freight	4700	Transportation Services

Note: The product can be divided to several parts to match the code  
 SCTG—Standard Commodity Transportation Group used in 1997 Commodity Flow Survey  
 SIC—Standard Industrial Classification

As might be expected, these measures have limitations. Employment levels and population are not the only variables that can be used as indicators of production and attraction. There may be more descriptive and accurate indicators, depending on the commodity type. For example, the Iowa study used farm acreage as an indicator of

attraction for farm machinery [31]. Farm acreage can be a more logical choice as an indicator than population of popular shipping destinations for farm machinery, since the product is typically sold to farmers, not the general public, and there are few farms located in areas of dense population. This issue also extends to wood where the production is usually around areas of low population. These issues can be taken into consideration in future research projects when disaggregating state level data. Figure 4-9 describes the methodology used to disaggregate state level commodity flow to county level.



Note: \* Neighboring states are represented by 18 TAZs. The other 43 states except the neighboring states and Mississippi are represented by 1 TAZ each;  
 \*\*Gravity Model (GM) is used to do trip distribution;  
 O&D pairs in the U.S are derived from 1997 CFS data by Visual Basic program developed by the authors;  
 \*\*\*All-or-Nothing method is used during the traffic assignment process.

**Figure 4-9 The Methodology to Disaggregate State Level Data to County Level**

#### 4.6 Commodity Flow Distribution

Commodity flow distribution is only needed for I-I in the model. The other three components do not need commodity flow distribution since the CFS database contains destination and origin information. Based on the production and attraction for each TAZ, the gravity model, shown in Equation 4-4, is used to get the trip distribution data for I-I component.



$$T_{kij} = \frac{TO_{ki}TD_{kj}F_{kj}}{\sum_{j=1}^n TD_{kj}F_{ij}} \quad (4-4)$$

where,

$T_{kij}$  = freight flow of commodity k between TAZ i and j;

$TO_{ki}$  = tons of commodity k originated from TAZ i;

$TO_{kj}$  = tons of commodity k destined to TAZ j;

$F_{ij}$  = impedance factor from i to j.

The distance between county centroids is used as the distance between O&D pairs. The Inverse Power function is used as the impedance factor from origin i to destination j.

$$F(d_{ij}) = d_{ij}^{-b} \quad (4-5)$$

According to the Travel Estimation techniques for Urban Planning (NCHRP365, 1998) [37], b=2 is used in the inverse power function.

## 4.7 Commodity Flow Assignment

Commodity flow assignments were performed for each component using shortest path assignment algorithm. Also, assignment results analyses are presented in this section.

### 4.7.1 Commodity Flow Assignment

Four categories of traffic assignments (I-I, I-E, E-E, and E-I) were performed for each commodity group. Combining the four assignment results, the truck trips on all links were determined. The all-or-nothing (free) assignment method was chosen for the study. Constrained assignment methodologies were also performed to do sensitive analysis on the assignment methodologies. The results showed that travel time was not sensitive to specific commodity type. With an all-or-nothing assignment procedure, whether the assignment is performed before truck trips conversion process or after the process makes no difference. Shortest travel time method was used in the assignment. The speed used was determined based on speed limits of different kind of facilities (Table 4-7).

**Table 4-7 Speed Limit Used in Shortest Travel Time Traffic Assignment**

Type of Highway	Number of Lanes (two directions)	Speed Used (mph)
Interstate	2,3	50
	4,5	70
	6,7	65
	8,9	60
US Highway	2	55
	4	65
State Highway	2	50
	4	55
Connector	2	35

### 4.7.2 Assignment Results Analysis

The link volume for each segments in the network described in the network section of this chapter can be obtained from the results. Since there is a large amount of data involved in the assignment results, this section just generalizes the functions of different highway system and conducts the special analysis for wood and wood products.

#### 4.7.2.1 Freight Flows on Different Infrastructure Facilities

The assignment results indicate that the interstate highways serve as the predominant infrastructure to carry freight in the state. The analysis results, Table 4-8, are consistent with the research done by ORNL [13].

**Table 4-8 Distribution of Tons of Freight by Type of Highways in Mississippi**

<b>Component</b>	<b>Interstate Highway</b>	<b>US Highway</b>	<b>State Highway</b>
I-E	80.5%	15.16%	4.34%
E-I	57.83%	27.77%	14.39%
I-I	74.75%	19.11%	6.13%
E-E	92.35%	7.04%	0.73%

Note: Based on Tonnage

#### 4.7.2.2 Commodity Flows in the State of Mississippi

Total commodity flow characteristics are shown in Figure 4-10. The commodity flow characteristics on wood and wood products were also evaluated as an example to show the model's capability to analyze major products identified in the state. Figures 4-11, 4-12, and 4-13 show information on the results of wood and wood product analysis.

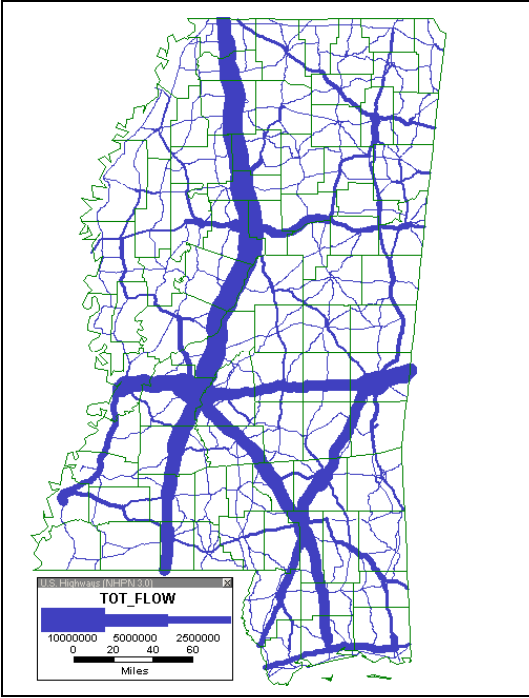


Figure 4-10 Total Commodity Flow in the State of Mississippi (based on tons)

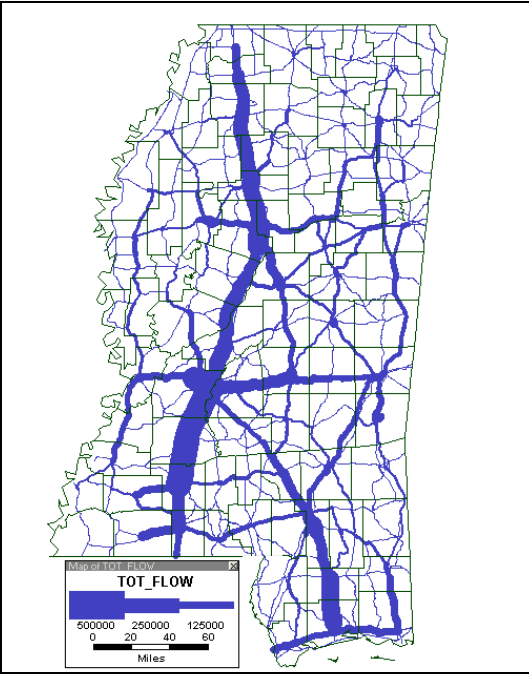
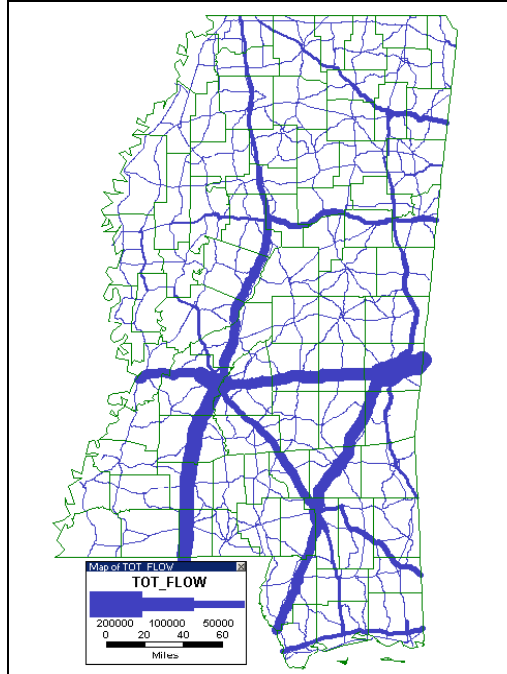
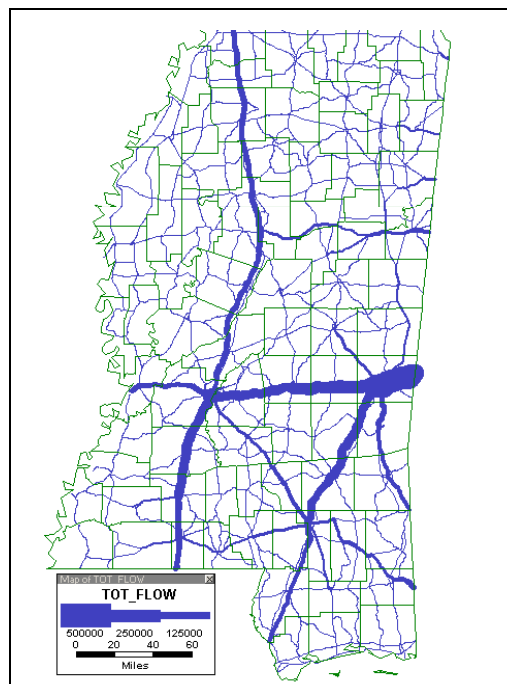


Figure 4-11 Wood and Wood Products in the State of Mississippi (I-I) (based on tons)



**Figure 4-12 Wood and Wood Products in the State of Mississippi (E-I) (based on tons)**



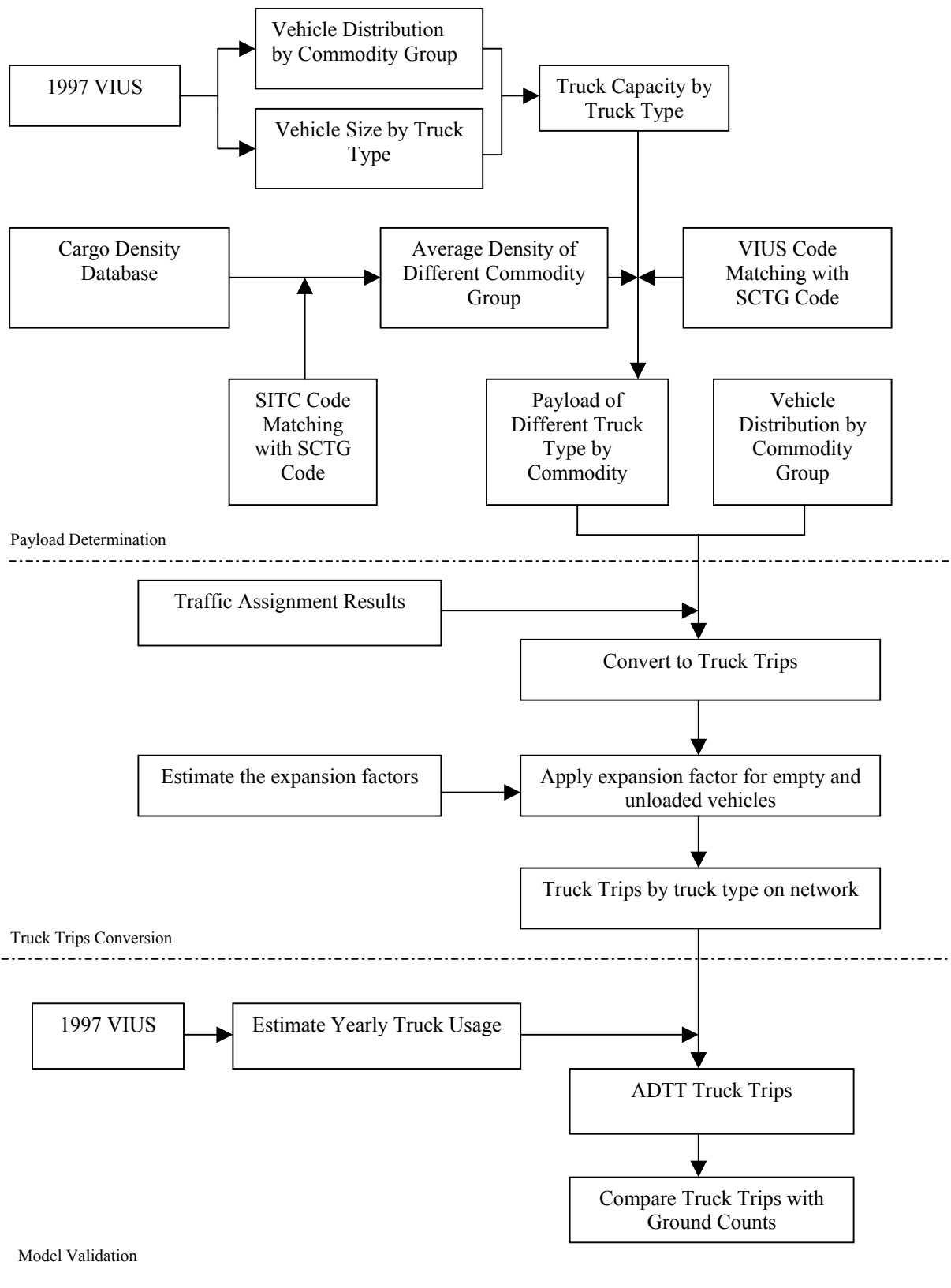
**Figure 4-13 Wood and Wood Products in the State of Mississippi (I-E) (based on tons)**

The commodity flow characteristics for other commodity types can also be generated from the model. From the figures shown above, we can see that interstate highways in the state serve as the major transportation means for transportation commodities for the state. These results are consistent with the actual commodity flows in the state. Also, since we use shortest path assignment algorithm, links with higher speed have better “attraction” ability when comparing to other links. Thus interstate highways tend to carry much more tonnage of commodities than other highway types.

#### **4.8 Conversion from Commodity Flows to Truck Trips**

The conversion of commodity flows to truck trips is complicated due to the presence of empty and partially loaded vehicles. Vehicle loads for different commodities are also different [12]. The Indiana model converts flows to vehicle units using load factors obtained from the Rail Waybill data. The researchers assumed that trucks would carry 40% of the load carried by railcars [38]. The conversion factors are specific to each commodity group but do not address different types of vehicles. The South Carolina model developed commodity-specific estimation of the portion of tonnage carried in each truck weight class and the average truck payload for each weight class [39]. The estimates were developed using data from the federal Truck Inventory and User Survey data and some truck origin/destination survey data. The method used in the State of Iowa is commodity and vehicle specific [12]. The model converts commodity weight into a number of annual trucks by using average density of freight and average load per truck. Empty loads were added to the network in a separate step. The Wisconsin model used the TRANSEARCH database data on tons per truck carried based on different commodity.

The method used in this model is a combination of the Iowa and South Carolina methodologies. In the Iowa model, the Iowa Truck Survey is used to determine the two most common trailer types for each commodity group, as well as the average total weight of the vehicle and load carried by truck [12]. Because specific survey data is unavailable in the State of Mississippi, the VIUS database is used to estimate the composition of different truck types carrying different commodity groups. The truck capacity was obtained mainly from the VIUS database and a book titled “Intermodal Freight Transportation” by Gerhardt Muller [40]. The density of the cargo carried by trucks is estimated from the book titled “A Shipper’s Guide to Stowage of Cargo in Marine Containers” [33]. The methodology is shown in Figure 4-14.



**Figure 4-14 Methodology for Converting Commodity Flow to Truck Trips**

The process is divided into three basic phases: payload determination, truck trips conversion, and model validation. The procedures are as follows:

1. Determine the composition of vehicle types used to transport different commodities based on the VIUS database.
2. Determine the vehicle size distributions of different truck types and the capacity of different truck types.
3. Estimate the density of different commodity group transported by the vehicles.
4. Estimate average load of selected commodities in trucks.
5. Convert assigned freight flow to truck units based on data generated in step 4.
6. Estimate the expansion factor by commodity to take consideration of the empty and unloaded vehicles using VIUS database.
7. Estimate yearly truck usage using VIUS database.
8. Convert annual truck trips to ADTT and compare them with ground counts to validate the model.

Steps 1 through 4 are classified as payload determination component, steps 5 and 6 are classified as truck trip conversion component, and steps 7 to 8 are classified as model validation component. The detail descriptions of each component are discussed in the following sections.

#### **4.8.1 Payload Determination**

##### 4.8.1.1 Truck Capacity Determination

The number of trucks by truck type, classified by the vehicle size in VIUS is used to determine truck capacity. There are some “V”s and “S”s in the database. The “V”s represent less than 50 vehicles. They are assumed as “0”. The “S”s are calibrated by the method in which the difference between the total number of trucks and sum of the number of different truck type is divided by the number of “V”s in the specific category.

$$V = \frac{T_j - \sum_{i=1}^n T_{ij}}{N} \quad (4-6)$$

where,

$V$  = the V's value;

$T_j$  = total number of trucks in  $j$  vehicle size category;

$T_{ij}$  = number of trucks for different truck type in  $j$  vehicle size category for truck type  $i$ ;

$i$  = type  $i$  truck;

$n$  = the number of truck types in  $j$  vehicle size category;

$N$  = number of Vs in  $j$  vehicle size category.

The vehicle size in the VIUS database is classified into several ranges of lengths as shown in Table 4-9. Average length in each category was used in the analysis. The product of truck width and truck height is considered to be a constant, assuming to be 60

square feet as in some other studies [40]. The capacity analysis results are also found in Table 4-9.

**Table 4-9 Truck Capacity by Type**

Length (Feet)	Truck Type					
	Single-Unit Trucks	Combination				
		Single-Unit Truck with Trailer	Single-Unit Truck With Utility Trailer	Truck-tractor with Single Trailer	Truck-Tractor with Double Trailers	Truck-Tractor with Triple Trailers
Less than 20	96.46%	0%	0.79%	0	0	0
20.0 to 27.9	2.66%	1.79%	19.33%	0	0.15%	3.19%
28.0 to 35.9	0.77%	10.19%	67.37%	1.06%	0.049%	1.06%
36.0 to 40.9	0.091%	10.90%	6.99%	2.77%	0	0
41.0 to 44.9	0.016%	15.91%	3.56%	2.67%	0	0
45.0 or more	0.007%	61.22%	1.96%	93.50%	99.8%	95.74%
Weighted Average Length	18	45.5	31.5	49.3	65	77.7
Average Available Trailer Length	15	40	25	40	55	68
Average Capacity (cubic feet)	1050	2800	1750	2800	3850	4760

Note: The number in the upper part of the table represents percentage of different size of trucks in that category;

According to Intermodal Freight Transportation 4<sup>th</sup> edition by Gerhardt Muller, (the width)\* (the height) of the truck can be assumed as 70 square feet;

Average Capacity (Cubic Feet) = (average available trailer length)\*(the width)\* (the height);

Pickups, panels, vans, minivans, and sport utilities are not included.

#### 4.8.1.2 SCTG Code and VIUS Code Matching

The classifications of commodities in CFS and that of VIUS are different and therefore, matching between the SCTG code and VIUS code is necessary. The matching process is basically a listing and comparison process. Most of the SCTG codes studied can be matched exactly with the VIUS code. The matching results are shown below in Table 4-10. This matching procedure facilitates the related analysis procedures performed on the VIUS database.



**Table 4-10 SCTG code and VIUS code Matching Results**

SCTG Code	SCTG Product Name	VIUS Code	VIUS Product Name
04	Animal Feed and Prod of Animal Origin	30	Animal Feed
07	Prepared Foodstuffs and Fats and Oils	03	Processed Foods
12	Gravel and Crushed Stone	05	Building Materials
15	Coal	04*	Mining Products
17	Gasoline and Aviation Turbine Fuel	10*	Petroleum
18	Fuel Oils	10*	Petroleum
19	Coal and Petroleum Products, n.e.c	10*	Petroleum
20	Basic Chemicals	09*	Chemicals
22	Fertilizer	09*	Chemicals
24	Logs and Other Wood in the Rough	06	Logs and Other Forest Products
26	Wood Products	07	Lumber and Fabricated Wood Products
27	Pulp, Newsprint, Paper, and Paperboard	08	Paper Products
31	Nonmetallic Mineral Products	05	Building Materials
		26	Glass Products
32	Base Metal in Primary or Semi-finished Forms and in Finished Basic	12	Primary Metal Products
		13	Fabricated Metal Products
43	Mixed Freight	20	Mixed Cargos

Note: The product can be divided into several parts to match the SCTG code.

#### 4.8.1.3 Commodity Density Estimation

“A Shipper’s Guide to Stowage of Cargo in Marine Containers” distributed by U.S Department of Transportation is used to determine the average density for each commodity group [33]. The commodity density information in the book is classified based on Standard International Trade Classification Index Division (SITC). To obtain the density on SCTG code, the SITC code was matched with SCTG code. The matching results and the commodity density estimation results are found in Table 4-11. The results can be used to determine payload matrix of commodity by truck type.

#### 4.8.1.4 Determination of Average Load Weight of Each Truck Type

Based on the information derived from Tables 4-9, 4-10, and 4-11, the average payload is determined for all commodities by truck type and the results are shown in Table 4-12 (before payload limit consideration) and Table 4-13 (after payload limit consideration). During this process, the weight limit regulations enacted by Federal Highway Administration and Mississippi Department of Transportation were referenced. Any total vehicle weight (including payload) from our derivations that exceeds this amount was adjusted to the weight limit.

**Table 4-11 Commodity Density Carried by Truck**

SCTG Code	Product Name	SITC Code	Product Name	Density (LB/Cu.Ft)	Average Density (LB/Cu. Ft)
4	Animal Feed and Prod of Animal	8	Feeding-Stuff for Animals	20	20
7	Prepared Foodstuffs and Fats and Oils	9	Miscellaneous Food Preparations	38	38
12	Gravel and Crushed Stone	66-1*	Concrete Brick / Block	80	80
		66-2*	Glazed Brick / Block	80	
15	Coal	32	Coal, Coke & Briquettes	53	53
17	Gasoline and Aviation Turbine Fuel	34	Gas, Natural & Manufactured	26	26
18	Fuel Oils	22	Oil-Seeds, Oil-Nuts and Oil Kernels	30	29
		55	Essential Oils & Perfume Products	28	
19	Coal and Petroleum Products, n.e.c	33	Petroleum & Petroleum Products	50	51
		52	Mineral Tar & Crude Petroleum Chemicals	51	
20	Basic Chemicals	51	Chemical Elements & Compounds	64	50
		59	Chemical Materials & Products	36	
22	Fertilizer	27	Crude Fertilizers & Crude Materials	64	64
25	Logs and Other Wood in the Rough	24	Wood, Lumber and Cork	25	25
26	Wood Products	82	Furniture	7	13
		63	Wood & Cork Manufactures	18	
27	Pulp, Newsprint, Paper, and Paperboard	25	Pulp & Waste Paper	34	27
		64	Paper, Paperboard & Manufactured Thereof	20	
31	Nonmetallic Mineral Products	66	Non-Metallic Mineral Manufactures	60	60
32	Base Metal in Primary or Semi-finished Forms and in Finished Basic	69	Manufactures of Metal	39	89
		67	Iron & Steel	139	
43	Mixed Freight	89	Miscellaneous Manufactures Articles NEC	21	21

Note: \* Represents that one sub-group of 66-Non-Metallic Mineral Manufactures;  
SITC stands for Standard International Trade Classification Code.

**Table 4-12 Payload by Truck Type for Different Commodities (Before Payload Limit Consideration)**

<i>Product Information</i>			<i>Average Payload by Truck Type</i>					
<i>SCTG Code</i>	<i>Product Name</i>	<i>Average Density</i>	<i>Single-unit Trucks</i>	<i>Single-unit Truck with Trailer</i>	<i>Single-unit Truck with Utility Trailer</i>	<i>Truck-tractor with Single Trailer</i>	<i>Truck-tractor with Double Trailers</i>	<i>Truck-tractor with Triple Trailers</i>
04	Animal Feed and Prod of Animal	20	21000	56000	35000	56000	77000	95200
07	Prepared Foodstuffs and Fats and Oils	38	39900	106400	66500	106400	146300	180880
12	Gravel and Crushed Stone	80	84000	224000	140000	224000	308000	380800
15	Coal	53	55650	148400	92750	148400	204050	252280
17	Gasoline and Aviation Turbine Fuel	26	27300	72800	45500	72800	100100	123760
18	Fuel Oils	29	30450	81200	50750	81200	111650	138040
19	Coal and Petroleum Products, n.e.c	51	53550	142800	89250	142800	196350	242760
20	Basic Chemicals	50	52500	140000	87500	140000	192500	238000
22	Fertilizer	64	67200	179200	112000	179200	246400	304640
25	Logs and Other Wood in the Rough	25	26250	70000	43750	70000	96250	119000
26	Wood Products	13	13650	36400	22750	36400	50050	61880
27	Pulp, Newsprint, Paper, and Paperboard	27	28350	75600	47250	75600	103950	128520
31	Nonmetallic Mineral Products	60	63000	168000	105000	168000	231000	285600
32	Base Metal in Primary or Semi-finished Forms and in Finished Basic	89	93450	249200	155750	249200	342650	423640
43	Mixed Freight	21	22050	58800	36750	58800	80850	99960
Payload Limit			32860	45000	45000	50560	75000	78500

**Table 4-13 Payload by Truck Type by Commodities (After Payload Limit Consideration)**

<i>Product Information</i>			<i>Average Payload by Truck Type</i>						<i>Average</i>
<i>SCTG Code</i>	<i>Product Name</i>	<i>Average Density</i>	<i>Single-unit Trucks</i>	<i>Single-unit Truck with Trailer</i>	<i>Single-unit Truck with Utility Trailer</i>	<i>Truck-tractor with Single Trailer</i>	<i>Truck-tractor with Double Trailers</i>	<i>Truck-tractor with Triple Trailers</i>	<i>Payload by Commodity</i>
04	Animal Feed and Prod of Animal	20	21000	45000	35000	50560	75000	78500	23095
07	Prepared Foodstuffs and Fats and Oils	38	32860	45000	45000	50560	75000	78500	38201
12	Gravel and Crushed Stone	80	32860	45000	45000	50560	75000	78500	35204
15	Coal	53	32860	45000	45000	50560	75000	78500	39134
17	Gasoline and Aviation Turbine Fuel	26	27300	45000	45000	50560	75000	78500	31994
18	Fuel Oils	29	30450	45000	45000	50560	75000	78500	34501
19	Coal and Petroleum Products, n.e.c	51	32860	45000	45000	50560	75000	78500	36420
20	Basic Chemicals	50	32860	45000	45000	50560	75000	78500	34869
22	Fertilizer	64	32860	45000	45000	50560	75000	78500	34869
25	Logs and Other Wood in the Rough	25	26250	45000	43750	50560	75000	78500	33414
26	Wood Products	13	13650	36400	22750	36400	50050	61880	16162
27	Pulp, Newsprint, Paper, and Paperboard	27	28350	45000	45000	50560	75000	78500	32778
31	Nonmetallic Mineral Products	60	32860	45000	45000	50560	75000	78500	35196
32	Base Metal in Primary or Semi-finished Forms and in Finished Basic	89	32860	45000	45000	50560	75000	78500	36155
43	Mixed Freight	21	22050	45000	36750	50560	75000	78500	30793
Weighted Average			18875.13	775.51	958.41	11387	1450.3	64.4269	35000

Note: The unit of the average density is (lb/cu. Ft);  
 Commodities included are top 15 in the State of Mississippi;  
 Truck classification is based on the VIUS classification system.  
 Pickups, panels, vans, minivans, and sport utilities are not included.

From Tables 4-12 and 4-13, weighted average of payload in the State of Mississippi is determined to be 35000 lb, or 17.5 tons per truck.

#### 4.8.1.5 Truck Distribution Estimation by Commodity Group

The data describing the number of trucks by truck type on primary commodities carried was used. The “V”s and “S”s were calibrated by the similar methodology described in the former sections. The information was converted to SCTG code-based grouping by referring the matching results of VIUS code and SCTG code. The results of the procedure are shown in Table 4-14.

**Table 4-14 Truck Type Distribution by Commodity**

VIUS Code	Product Name	Truck Type					
		Single-unit Trucks*	Single-unit Truck with Trailer*	Single-unit Truck with Utility Trailer*	Truck-tractor with Single Trailer*	Truck-tractor with Double Trailers*	Truck-tractor with Triple Trailers*
30	Animal Feed	91.82%	0.42%	2.46%	4.93%	0.35%	0.01%
3	Processed Foods	70.99%	0.44%	0.51%	27.00%	1.06%	0.00%
5	Building Materials	85.98%	1.84%	3.26%	8.32%	0.60%	0.00%
4	Mining Products	66.02%	2.76%	1.14%	28.13%	1.95%	0.00%
10	Petroleum	79.60%	2.24%	1.10%	16.51%	0.55%	0.00%
9	Chemicals	88.61%	0.30%	1.15%	9.64%	0.30%	0.00%
6	Logs and Other Forest Products	68.58%	2.43%	6.50%	22.04%	0.42%	0.02%
7	Lumber and Fabricated Wood Products	87.53%	0.97%	2.58%	8.76%	0.17%	0.00%
8	Paper Products	81.17%	0.24%	0.00%	17.57%	0.97%	0.06%
5	Building Materials	86.02%	1.84%	3.25%	8.30%	0.59%	0.00%
26	Glass Products	88.57%	0.00%	0.00%	9.47%	0.00%	1.95%
12	Primary Metal Products	75.81%	1.30%	0.81%	21.59%	0.49%	0.00%
13	Fabricated Metal Products	86.20%	0.61%	3.51%	9.30%	0.38%	0.00%
20	Mixed Cargos	73.60%	0.33%	0.00%	21.08%	4.55%	0.44%

Note: Source—Vehicle Inventory and Use Survey table for the U.S trucks by truck type on primary products carried.

\*Pickups, panels, vans, minivans, and sport utilities are not included.

Results from this analysis show that single unit trucks are the dominant types of trucks hauling commodities in Mississippi. This percentage distribution in the state can be used for other analyses such as estimating distribution of trucks on different types of highways.

#### 4.8.2 Truck Trips Conversion

Truck trips conversion procedure is based on information on the estimated empty factors, average payload, and truck distribution by commodity. Details are discussed in the

following sections. The expansion factors estimation procedure can be improved with more information on the transportation and economic condition of surrounding states.

#### 4.8.2.1 Estimation of Expansion Factors

Some trucks on the network carry partial or empty payloads. However, ground counts include full, partially loaded, and empty trucks. The empty truck issue was not addressed in the assignment method and in the conversion process. According to Iowa State’s model, the expansion factors were estimated using commodity characteristics [12]. The factor captures the likelihood that a particular commodity is backhauled. According to the Iowa State’s Model, a factor of 2.0 indicates that no backhaul is present – all vehicles must return empty. A factor of 1.0 indicates the presence of backhaul - the returning vehicle can be used to haul another commodity. A factor of 1.5 was used to account for vehicles that may have an opportunity for a backhaul in some instances, but not in all the situations. The sensitivity of the model output to these assumptions is analyzed during the model validation process. Detailed information of the expansion factors in this study is presented in Table 4-15.

**Table 4-15 Expansion Factors**

<b>Product</b>		<b>Expansion Factors by Truck Type</b>
<b>SCTG Code</b>	<b>Product Name</b>	
04	Animal Feed and Prod of Animal	2
07	Prepared Foodstuffs and Fats and Oils	1.5
12	Gravel and Crushed Stone	2
15	Coal	2
17	Gasoline and Aviation Turbine Fuel	2
18	Fuel Oils	2
19	Coal and Petroleum Products, n.e.c	2
20	Basic Chemicals	2
22	Fertilizer	2
25	Logs and Other Wood in the Rough	1.5
26	Wood Products	1.5
27	Pulp, Newsprint, Paper, and Paperboard	1.5
31	Non-metallic Mineral Products	2
32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic	2
43	Mixed Freight	2

#### 4.8.2.2 Truck Trips Conversion

The conversion from tonnage to trips was done after traffic assignment instead of before. By using an all-or-nothing assignment, it makes no difference between the two methodologies. The conversion to number of vehicles by truck type was accomplished by using the following tables developed in the former sections and adjusted by traffic assignment results [12].

- Table 4-13 Average load weight of each vehicle type;
- Table 4-14 Truck distribution by commodity;
- Table 4-15 The expansion factor for the treatment of empties.

The procedures of the conversions are:

1. The number of trucks for transporting a specific commodity is determined by dividing assigned commodity tonnage by average load for the specific commodity.
2. Based on the truck distribution, the number of trucks by truck type is determined for each commodity group.
3. Total number of truck flows is determined by expanding the commodities to accommodate the excluded commodities during the analysis.

The formulas used in the process are:

$$N_j = \frac{W_j}{(\sum_i^n W_{ij}) / n} \quad (4-7)$$

where,

$N_j$  = the annual total number of all vehicles for transporting commodity  $j$ ;

$W_j$  = the annual weight of commodity  $j$  assigned to link (tons);

$W_{ij}$  = the average weight by truck type  $i$  for transporting commodity  $j$ ;

$n$  = the number of truck types studied.

$$N_{ij} = N_j * P_{ij} * X_i \quad (4-8)$$

where,

$N_{ij}$  = The number of trucks for transporting commodity  $j$  using truck type  $i$ ;

$N_j$  = the annual total number of all vehicles for transporting commodity  $j$ ;

$P_{ij}$  = the percentage of truck type  $I$  for transporting commodity  $j$ ;

$X_i$  = the vehicle expansion factor for empty truck type  $i$ .

### 4.8.3 Model Validation

#### 4.8.3.1 Yearly Truck Usage Estimation

To convert the annual truck trips to average daily truck traffic counts (ADTT), many researches recommend that the annual number of vehicles be divided by 260 days [41]. Many other researches suggest that weekdays are assumed as a whole day, while weekends are considered as 0.44 work days [42]. As such, the number of working days is considered to be 306 per year [43,38]. In our study, the working days per year for the trucks are obtained from VIUS database. A table in VIUS describes the weeks operated by trucks of different type. The “V”s and “S”s are estimated using the similar method described before. From the analysis, the average number of days for a specific truck type is obtained. The analysis results are presented in Table 4-16. The analysis results are truck type specific, and the average days operated of these trucks are 288 days, which is consistent with many research results [38,41,42,43]. The method used here can be justified using the process of calibrating and validating traffic assignment results, which will be discussed in 4.9 of this chapter.

**Table 4-16 Estimate Yearly Truck Usage by Truck Type**

Weeks Operated	Weeks Operated Used for Calculation	Truck Type					
		Single-unit Trucks	Combination				
		Single-unit Truck with Trailer	Single-unit Truck with Utility Trailer	Truck-tractor with Single Trailer	Truck-tractor with Double Trailers	Truck-tractor with Triple Trailers	
Less than 1 week	1	2.14%	2.41%	1.03%	1.62%	1.36%	0.00%
1 to 4	3	2.77%	5.09%	4.25%	1.72%	1.15%	0.00%
5 to 8	7	2.61%	5.27%	6.94%	2.40%	1.88%	1.22%
9 to 12	11	2.75%	3.42%	8.23%	2.59%	1.56%	0.00%
13 to 16	15	2.17%	2.96%	3.72%	1.97%	1.36%	4.88%
17 to 20	18	1.87%	2.22%	4.51%	1.95%	0.94%	1.22%
21 to 24	23	2.52%	6.75%	3.58%	2.73%	1.77%	1.22%
25 to 28	27	3.99%	5.74%	5.08%	3.60%	2.71%	7.32%
29 to 32	31	3.19%	5.18%	3.67%	2.62%	1.25%	1.22%
33 to 36	35	3.42%	6.57%	4.39%	3.07%	1.77%	1.22%
37 to 40	39	3.23%	11.47%	5.43%	4.71%	3.96%	3.66%
41 to 44	43	3.89%	7.49%	4.38%	6.51%	3.44%	3.66%
45 to 49	47	7.08%	7.49%	10.86%	15.18%	5.11%	1.22%
49 to 52	51	58.37%	27.94%	33.94%	49.34%	71.74%	73.17%
Average Weeks Operated		41.12	34.24	34.18	41.58	44.89	44.99
Average Days Operated		288	240	239	291	314	315

Note: Pickups, panels, vans, minivans, and sport utilities are not included



#### **4.8.4 Discussion on Truck Trips Conversion**

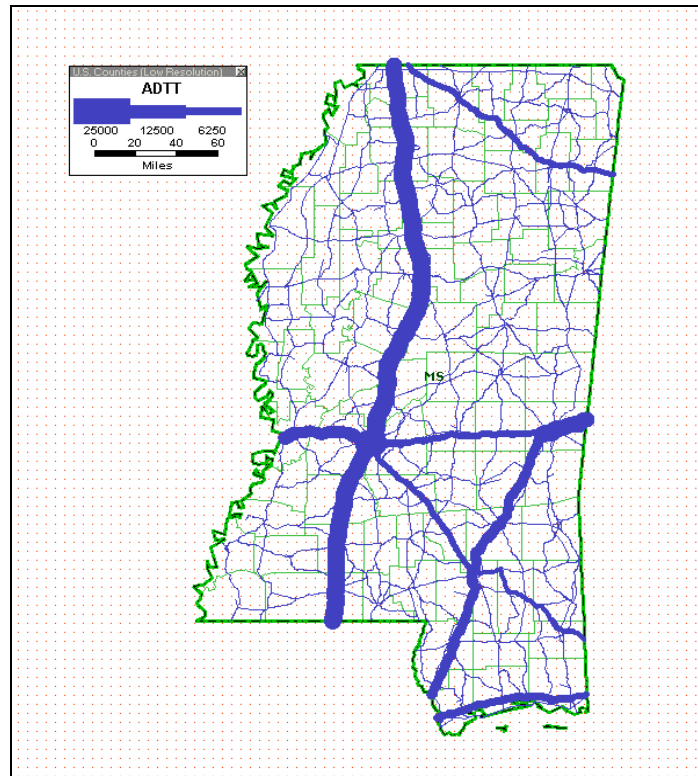
This study demonstrates a feasible methodology for using VIUS database to convert assigned commodity flows on each link in the network to numbers of trucks by truck type. The average loads for trucks are compared to other sources, such as the data reported in the Iowa model, with very positive results.

The aforementioned methodology was a basis for studying freight movement in Mississippi. For future projects, the following areas need to be looked into:

1. All the truck information is based solely on data for entire U.S. If different states' data are available and used to determine the number of trucks by different truck type, the information on truck will be much more accurate;
2. The vehicle capacity analysis process can be strengthened with more robust data sources and better matching process between different classification scheme (i.e. the matching process of SCTG-VIUS and SCTG-SITC can be refined to get better results).

#### **4.9 Model Validation and Calibration**

The traffic assignment results of I-I, E-I, I-E, and E-E O&D pairs were combined to get the truck volume on each segment of State Highways, US Highways, and Interstate Highways in Mississippi (Figure 4-15 shows the ADTT in the state). The 1997 truck counts provided by the Mississippi Department of Transportation were used to validate the aforementioned methodologies.



**Figure 4-15 Average Daily Truck Traffic (ADTT) in the State of Mississippi**

The validation procedure is as follows:

1. The truck flows for those commodity types that were not analyzed individually were determined using an expansion factor;
2. Some of the model volumes are grouped together to match the available truck counts data;
3. Trucks are broken down into different configurations of types;
4. Volumes from the model analysis were compared to the ground truck counts.

The comparison between model results and ground truck counts are presented in Table 4-17. Figure 4-16 shows the comparison results at selected locations of the state network. The index information of those locations along major highways is presented in a separate figure, Figure 4-17, to facilitate references.

The results show good agreement between ground truck counts and model volumes on the identified links of interstate highways, U.S. Highways and State Highways (with a weighted error margin of less than 30%). Although ground counts database may have estimate error, the overall comparison error is within the acceptable limit of model error, and is consistent with other studies in other states [6,7].

Like other studies conducted in other states, discrepancies of certain level were observed. Almost all the model volumes are somewhat lower than the ground truck counts except on the Interstate 55. Some explanations and discussions are provided as follows:

- The city selection methodology may have affected the final analysis results on the interstate highway 55. Memphis is selected as one of the representative cities in the State of Tennessee. Memphis has one of the biggest international freight airports and is located just north of the State of Mississippi. Baton Rouge, New Orleans, and Lafayette are selected as the representative cities in the State of Louisiana. Those cities are close to each other and all of them are located just to the south of the State of Mississippi. The goods transported between Memphis and the three cities in Louisiana accounts for a large percentage of the south-north freight movement, and were assigned to I-55 due to its capacity & speeds. This is probably the reason that the model overestimated the flow on Interstate 55.
- The industry coverage of the CFS data has an effect on the model volume results as well. According to CFS report, the 1997 CFS survey coverage excludes establishments classified as farms, forestry, fisheries, most establishments in retail, and some other establishments [1]. This may affect the results to certain degree as the State of Mississippi is primarily an agriculture state. In addition, the 1997 CFS survey does not include the shipments that are traversing the U.S from a foreign location to another foreign location and the shipments from a foreign location to U.S location. With Port of New Orleans located just south of the state border, flows from international trade may be underestimated. Those may have been some of the reasons that volumes from the model are lower on routes other than I-55.

**Table 4-17 Comparison Results (Model Results vs. Ground Counts)**

COUNTY	LOCATION	ID	LENGTH	NAME	TYPE	ADTT	GROUND COUNTS	COMPARISON INDEX	DIFF. (GROUND COUNTS-ADTT)	PERCENTAGE OF DIFF. (DIFF./GROUND COUNTS)
HANCOCK	I-10 3.5 MI W OF MS 607	4416654	2	I10	Interstate	7264	7661	1	397	5.18%
HARRISON	I-10 1.0 MI W OF I-110	4445810	3	I10	Interstate	7421	6979	2	-442	-6.33%
JACKSON	I-10 1.3 MI E OF MS 63	4456328	6	I10	Interstate	6904	6666	3	-238	-3.57%
WARREN	I-20 0.2 MI W OF WISCONSIN AVE	4369613	0	I20	Interstate	11900	7949	4	-3951	-49.70%
HINDS	I-20 0.2 MI W OF NATCHEZ TRACE	4380332	1	I20	Interstate	11780	8578	5	-3202	-37.33%
HINDS	I-20 1.0 MI E OF I-220	4382095	1	I20	Interstate	12231	13299	6	1068	8.03%
LINCOLN	I-55 1.0 MI N OF BROOKWAY BLVD	4325250	13	I55	Interstate	16245	4925	7	-11320	-229.85%
MADISON	I-55 2.0 MI N OF US 51	4492223	9	I55	Interstate	17099	6508	8	-10591	-162.73%
DESOTO	I-55 1.2 MI N OF TATE COUNTY LINE	6863928	7	I55	Interstate	15590	5453	9	-10137	-185.90%
PERAL RIVER	I-59 0.3 MI S OF MS 43W	4423366	2	I59	Interstate	9030	4222	10	-4808	-113.89%
PEARL RIVER	I-59 2.0 MI N OF MS 43	4423998	1	I59	Interstate	9029	3700	11	-5329	-144.03%

FORREST	I-59 0.2 MI E OF LAMAR COUNTY LINE	4439414	4	I59	Interstate	9676	7444	12	-2232	-29.98%
LAMAR	I-59 1.5 MI N OF US 98	4440542	1	I59	Interstate	9545	7140	13	-2405	-33.68%
JASPER	I-59 4.0 MI S OF CLARKE COUNTY LINE	4512672	19	I59	Interstate	9450	3735	14	-5715	-153.00%
CLARKE	I-59 3.0 MI N OF MS 18	4518439	8	I59	Interstate	9398	4272	15	-5126	-119.98%
HINDS	MS 18 0.5 MI W OF TIMBERLAWN ROAD	12362874	21	S18	State Route	9	877	16	868	98.97%
HINDS	MS 25 0.5 MI E OF RIDGEWOOD	12362791	1	S25	State Route	27	1845	17	1818	98.54%
LEAKE	MS 25 2.0 MI SW OF ATTALA COUNTY LINE	12363132	18	S25	State Route	97	586	18	489	83.45%
WINSTON	MS 25 3.1 MI N OF MS 395	12363221	6	S25	State Route	119	514	19	395	76.85%
WINSTON	MS 25 3.1 MI N OF MS 395	12363223	10	S25	State Route	119	523	20	404	77.25%
LAUDERDU	MS 25 0.2 MI N OF PINE LN	12363241	7	S25	State Route	92	91	21	-1	-1.10%
WALTHALL	MS 27 2.0 MI N OF SALEM	12362741	9	S27	State Route	10	139	22	129	92.81%
COPIAH	MS 27 4.0 MI NW OF MS 28	12362867	14	S27	State Route	30	549	23	519	94.54%
LAUDERDU	MS 19 2.1 MI E OF NEWTON COUNTY LINE	12363175	12	S29	State Route	205	785	24	580	73.89%

DESOTO	MS 302 1.8 MI W OF MARSHALL COUNTY LINE	12363308	6	S302	State Route	27	228	25	201	88.16%
ATTALA	MS 35 0.5 MI S OF NATCHEZ TRACE PKWY	12362818	16	S35	State Route	359	1150	26	791	68.78%
MARION	MS 35 1.0 MI N OF LOUISIANA STATE LINE	12363067	3	S35	State Route	124	436	27	312	71.56%
LAUDERDALE	MS 39 1.2 MI S OF KEMPER COUNTY LINE	12363088	10	S39	State Route	90	178	28	88	49.44%
LEE	OLD US 45 0.5 MI S OF NORTH GREEN STREET	12363347	3	S145	State Route	0	938	29	938	100.00%
YAZOO	US 49 2.5 MI S OF MS 16	4393830	16	U49W	US Route	451	914	30	463	50.66%
SUNFLOWER	US 49W 3.2 MI N OF MS 8	6745066	13	U49W	US Route	65	582	31	517	88.83%
KEMPER	US 45 2.0 MI S OF SCOوبا	4537444	18	US45	US Route	567	957	32	390	40.75%
LEE	US 45 2.0 MI E OF SHANNON	6921397	3	US45	US Route	317	1536	33	1219	79.36%
FORREST	US 49 0.1 MI NE OF AIRPORT ROAD	4441053	4	US49	US Route	0	1638	34	1638	100.00%
FORREST	US 49 1.5 MI N OF I-59	12362764	5	US49	US Route	0	4405	35	4405	100.00%
MADISON	US 51 7.0 MI N OF MS 16	4494203	16	US51	US Route	0	105	36	105	100.00%
WARREN	US 61 3.0 MI N OF I-20	4371767	5	US61	US Route	435	1553	37	1118	71.99%

WARREN	US 61 3.2 MI N OF MS 3	4387679	7	US61	US Route	388	740	38	352	47.57%
SHARKEY	US 61 1.4 MI S OF MS 434	4388585	6	US61	US Route	385	558	39	173	31.00%
BOLIVAR	US 61 2.0 MI S OF MS 444	6741375	15	US61	US Route	297	596	40	299	50.17%
DESOTO	US 61 1.5 MI S OF TENNESSEE STATE LINE	6862619	3	US61	US Route	38	1465	41	1427	97.41%
DESOTO	US 78 4.5 MI SE OF MS 302	6869805	7	US78	US Route	5184	6495	42	1311	20.18%
LEE	US 78 0.5 MI W OF US 45	6898902	4	US78	US Route	5374	5753	43	379	6.59%
SUNFLOWER	US 82 1.0 MI E OF WASHINGTON COUNTY LINE	4392666	6	US82	US Route	264	1770	44	1506	85.08%
WAYNE	US 84 1.0 MI W OF PINE STREET	4513384	15	US84	US Route	124	1275	45	1151	90.27%
LINCOLN	US 84 2.0 MI W OF LAWRENCE COUNTY LINE			US84	US Route	183	1105	46	922	83.44%
JACKSON	US 90 0.5 MI E OF MS 611	4443376	0	US90	US Route	0	932	47	932	100.00%
PIKE	US 98 2.0 MI W OF WALTHALL COUNTY LINE	4326392	11	US98	US Route	331	1198	48	867	72.37%
PERRY	US 98 2.0 MI E OF FORREST COUNTY LINE	4451253	7	US98	US Route	4834	2132	49	-2702	-126.74%
HIGHWAY SYSTEM							143079		-40027	-27.98%

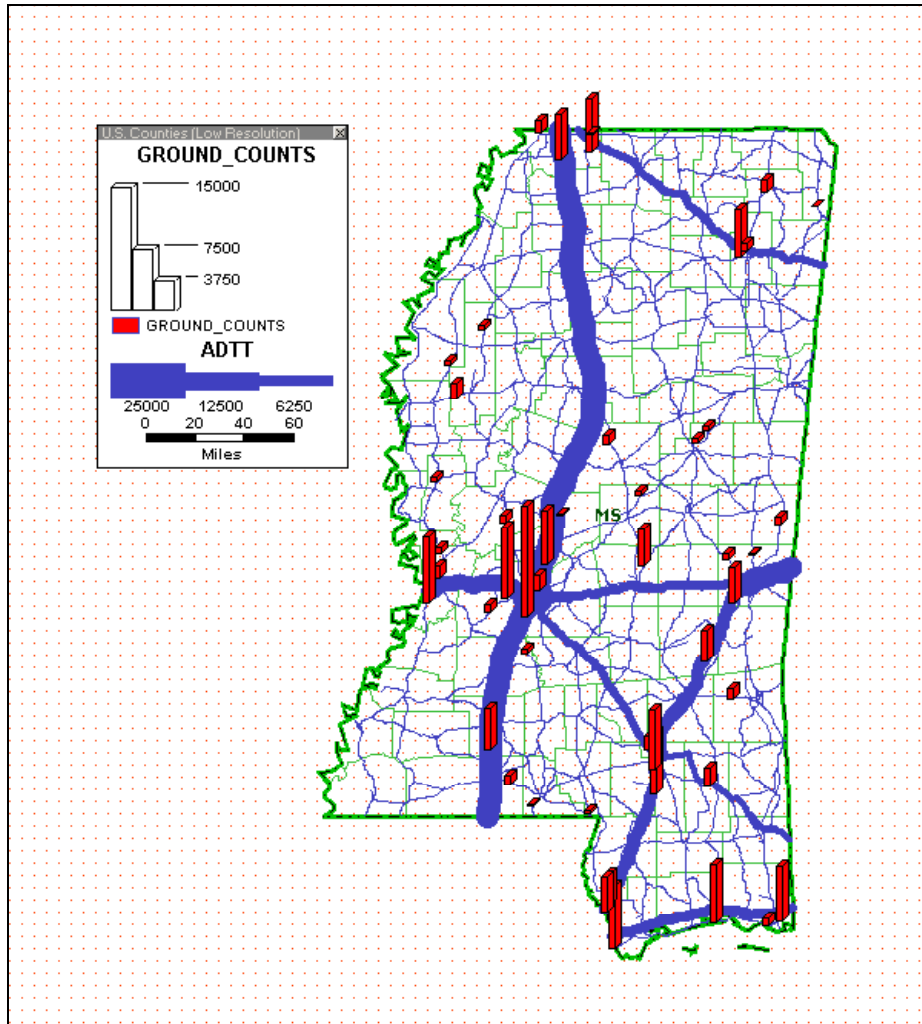


Figure 4-16 Comparison between ground counts and model results



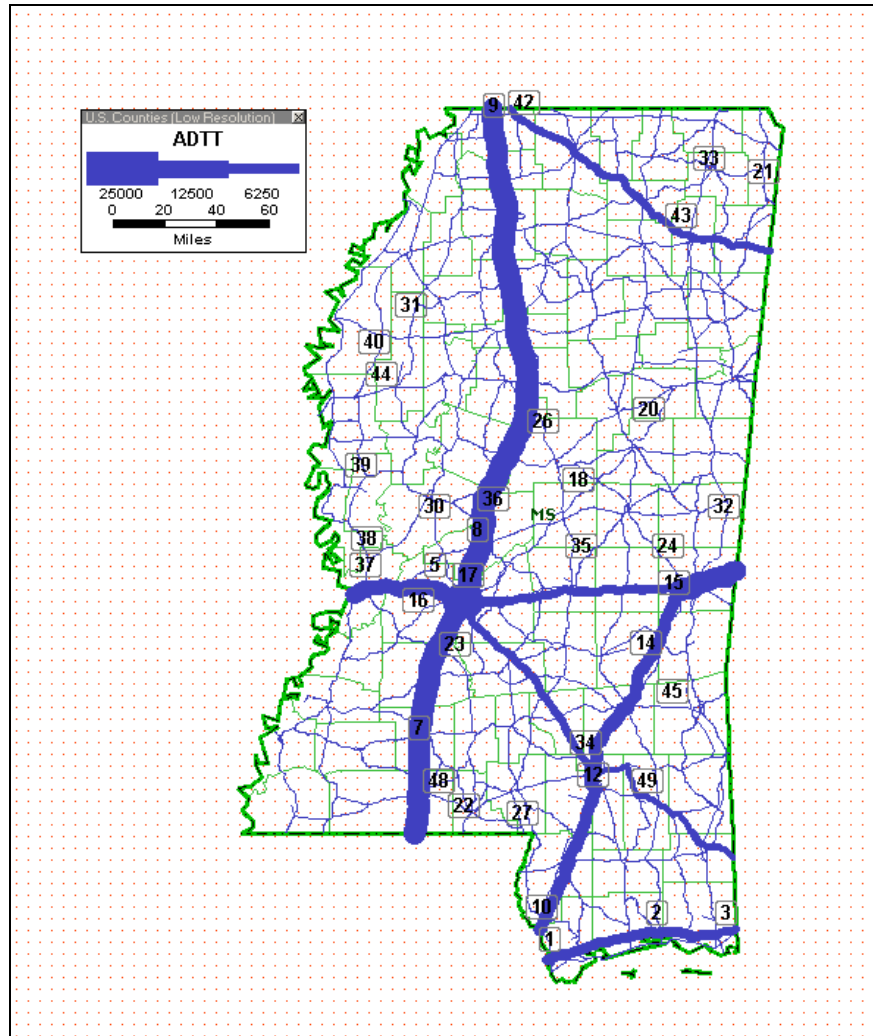


Figure 4-17 Major locations index used in comparison

## **5 FREIGHT FLOW FORECASTING**

Using methodologies and procedures developed for the based year, freight forecasting can be performed based on future economic data. The same indicators of transportation attractions and productions are used in the forecasting: population data are used to forecast the attractions, while employment data are used to estimate productions.

### **5.1 Economic Data**

Population data and employment data are obtained from Complete Economic and Demographic Data Source (CEDDS). The CEDDS data contains time series data for future years.

#### ***5.1.1 Population Data***

Population data used for transportation forecasting in this study was obtained from Complete Economic and Demographic Data Source (CEDDS) data set distributed by 2001 Woods & Pool Economics, Inc [44]. CEDDS contains data and projections for all counties, states, and regions in the U.S. through the year 2025.

#### ***5.1.2 Employment Data***

Employment data used for transportation forecasting in this study was also obtained form CEDDS data set. Since the commodity classification in CEDDS data set is more general than what was used in base year study. All the commodities studied in base year analyses (four digit SIC category) were classified into commodity categories in CEDDS data set (two digit SIC category). The commodity category matching results are presented in Table 5-1.

### **5.2 Methodology for Forecasting**

The same indicators of production and attraction as in the disaggregation process of based year study were used to forecast the commodity flow in the future years. The base year (1997) county production and attractions, along with the projected economic data for future years, were used to forecast the future commodity flow in the State of Mississippi, including the going out, within, coming into and through movements. The future years considered in the study include 2005, 2010, and 2020. The projection method used is similar to the one by the Virginia Transportation Research Council, as described in Equation 5-1 [22,23].

Similar formulas are used to project freight destinations, using the forecasted indicator of attraction. In the study, the indicator of production increase percentage is still based on employment increase. Similarly, the indicator of attraction increase percentage is based on population increase for the specific future year in study.

$$TO_{kif} = TO_{kib} * \frac{IP_{kif}}{IP_{Kib}} \quad (5-1)$$

where,

$TO_{kif}$  = tons of commodity k originating in i in the future year;

$TO_{kib}$  = tons of commodity k originating in i in the base year;

$IP_{kif}$  = indicator of production for commodity k in TAZ i in the future year;

$IP_{kib}$  = indicator of production for commodity k in TAZ i in the base year;

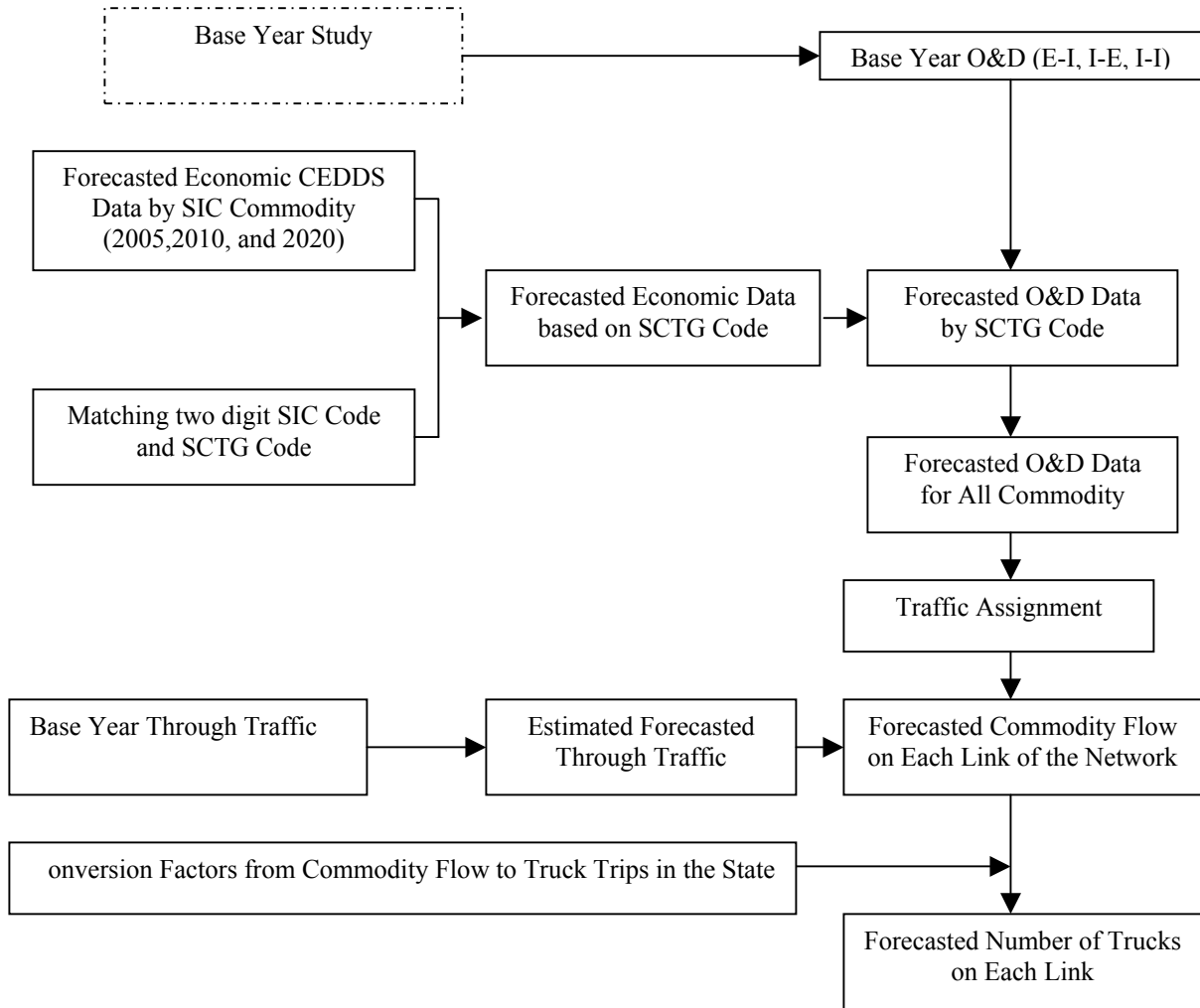
i = traffic analysis zone i.

**Table 5-1 Matching between SCTG Code and Two Digit SIC Code**

SCTG Code	SCTG Name	SIC Code	SIC Name	SIC Category
04	Animal Feed and Prods. of Animal Origin, n.e.c.	2040	Grain Mill Products	Manufacturing (20--)
07	Other Prepared Foodstuffs and Fats and Oils	2000	Food and Kindred Products	Manufacturing (20--)
20	Basic Chemicals	2800*	Chemicals and Allied Products	Manufacturing (20--)
22	Fertilizers	2800*	Chemicals and Allied Products	Manufacturing (20--)
25	Logs and Other Wood Products in the Rough	2410	Logging	Manufacturing (20--)
26	Wood Products	2400	Lumber and Wood Products	Manufacturing (20--)
27	Pulp, Newsprint, Paper and Paperboard	2600	Paper and Allied Products	Manufacturing (20--)
32	Base Metal in Primary or Semi-finished Forms and in Finished Basic Shapes	3400	Fabricated Metal Products	Manufacturing (20--)
12	Gravel and Crushed Stone	1440	Sand and Gravel	Mining (10--)
15	Coal	1400*	Non-metallic Minerals, except Fuels	Mining (10--)
17	Gasoline and Aviation Turbine Fuel	1300	Oils and Gas Extraction	Mining (10--)
18	Fuel Oils	1310	Crude Petroleum and Natural Gas	Mining (10--)
31	Non-metallic Mineral Products	1400*	Non-metallic Minerals, except Fuels	Mining (10--)
19	Coal and Petroleum Products n.e.c.	5170	Petroleum and Petroleum Products	Wholesale Trade (50--)
43	Mixed Freight	4700	Transportation Services	Transportation and Public Utilities (40--)

After production and attractions were estimated, the same procedures of base year studies were performed for the future forecasted years respectively (2005,2010, and 2020). In this study, the traffic assignment procedure was only performed on the total commodity

flow in the state (I-E, E-I, I-I) instead of by specific commodity type due to the limited time available for the research.



**Figure 5-1 Forecasting Procedures**

Through traffic in the state is based on the traffic assignment results excluding the State of Mississippi in U.S. OD table. Theoretically the through traffic can be estimated by forecasted U.S. OD table, however to get forecasted U.S. OD table, procedures of transportation planning in the united states have to be performed. This is out of the scope of this study. Through traffic in the state is based on the traffic assignment results excluding the State of Mississippi in U.S. OD table. Theoretically the through traffic can be estimated by forecasted U.S. OD table, however to get forecasted U.S. OD table, procedures of transportation planning in the united states have to be performed. This is out of the scope of this study. The through truck traffic was estimated to increase 50% percent in future years. So the effect of this increase was also incorporated. If time permitted, other analyses can be performed such as the increase of different commodities on a specific link in the network, the total traffic change on a specific link in the network, the efficiency evaluation of the network, and even the potential projects prioritization analysis. Please refer to Figure 5-1 for detail freight flow forecasting procedures.

### 5.3 Limitation of the Methodology

The forecasted flow may not be an accurate estimation of the freight flow produced and attracted by the counties in the State of Mississippi due to the percentage of traffic increase may not have exactly linear relationship with the increase of the economic condition. Based on the analysis of the relationship between the traffic increase and the economic condition, a more detailed model may be developed to obtain a more reasonable forecasting of the freight flow in the future in the state.

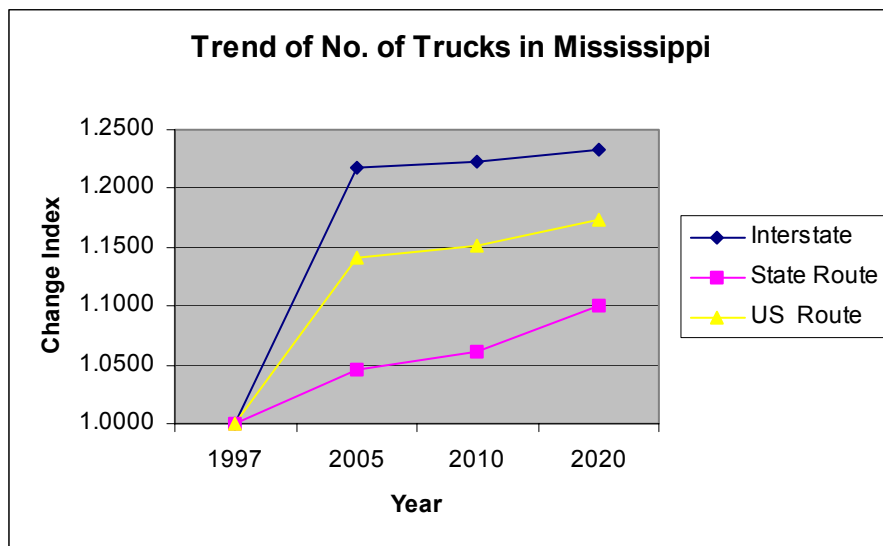
Since the public domain data from the County Business Patterns distributed by U.S Census Bureau doesn't have multiple year data readily available, and due to the time constraints, we used privately owned data from CEDDS, even though the cost to obtain CEDDS data is very minimal. This limitation can, however, be eliminated by analyzing and forecasting future time series economic data.

### 5.4 Forecasting Results Analyses

Combining Within, Going out and Coming into assignment results, together consideration of through truck traffic, we obtained the relative increase trends on the highways. Table 5-2 and Figure 5-2 show the forecasting results.

**Table 5-2 Base Year and Forecasted Years Transportation Comparison**

	1997	2005	2010	2020
<b>Interstate</b>	1.0000	1.2177	1.2223	1.2323
<b>State Route</b>	1.0000	1.0451	1.0615	1.1004
<b>US Route</b>	1.0000	1.1415	1.1513	1.1736



**Figure 5-2 Trend of Number of Trucks in Mississippi**

This forecasted levels of increase is in line with some US DOT estimation, but significant lower comparing to other research results [3]. Possible reasons of the low estimation are:

- CFS data doesn't include shipments traversing the U.S. from a foreign location to another foreign location (e.g., from Canada to Mexico) [20].
- CFS data doesn't include shipments from a foreign location to a U.S. location [20].
- The commodity forecasting doesn't account for the transportation increase caused by the impact of Latin American Trade.

Overall, the methodology is a valid and efficient way for forecasting the transportation flow in the State of Mississippi. Around 20% increase of transportation activities in the state has been estimated; the corresponding infrastructures planning and design should consider this increase.

## 6 FURTHER ANALYSIS USING SIMULATION TOOLS

The simulation component of this research is a discrete-event macroscopic simulation. Currently, there is a lack of macroscopic transportation simulation software that is suitable for a statewide intermodal planning process. A prototype intermodal transportation planning simulation model - Virtual Intermodal Transportation Simulation (VITS) - was developed to demonstrate the feasibility of using simulation to aid in the planning and design process. It simulates the movements of trucks, trains, barges, and ships on the transportation network as well as the transference of freight between the different modes. Figure 6-1 shows a screenshot of the VITS's animation.

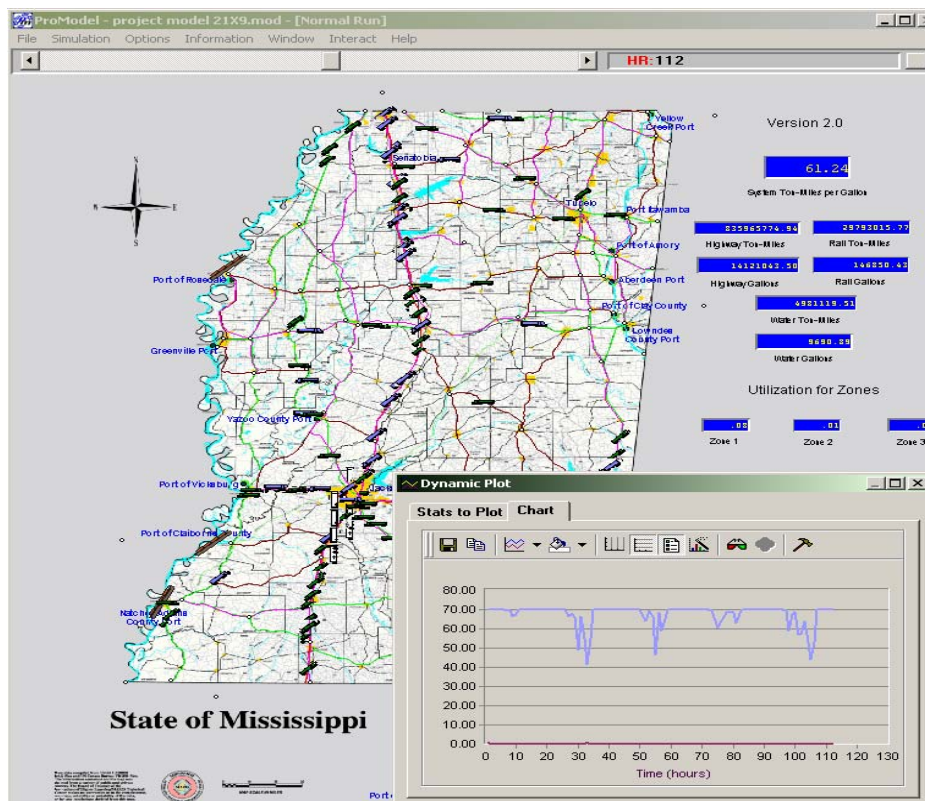


Figure 6-1: Screenshot of the VITS Animation

The data that drives the simulation is based on the O&D data derived from earlier phases of the research process. In this prototype, performance measures such as link congestion and average traveling speed, utilization of traffic analysis zones, and the fuel efficiency have been implemented. Other performance measures and/or changes can be implemented in the future version of VITS. A simulation software package called ProModel was used in the development of the simulation component.

## 6.1 Simulation O&D Data Preparation

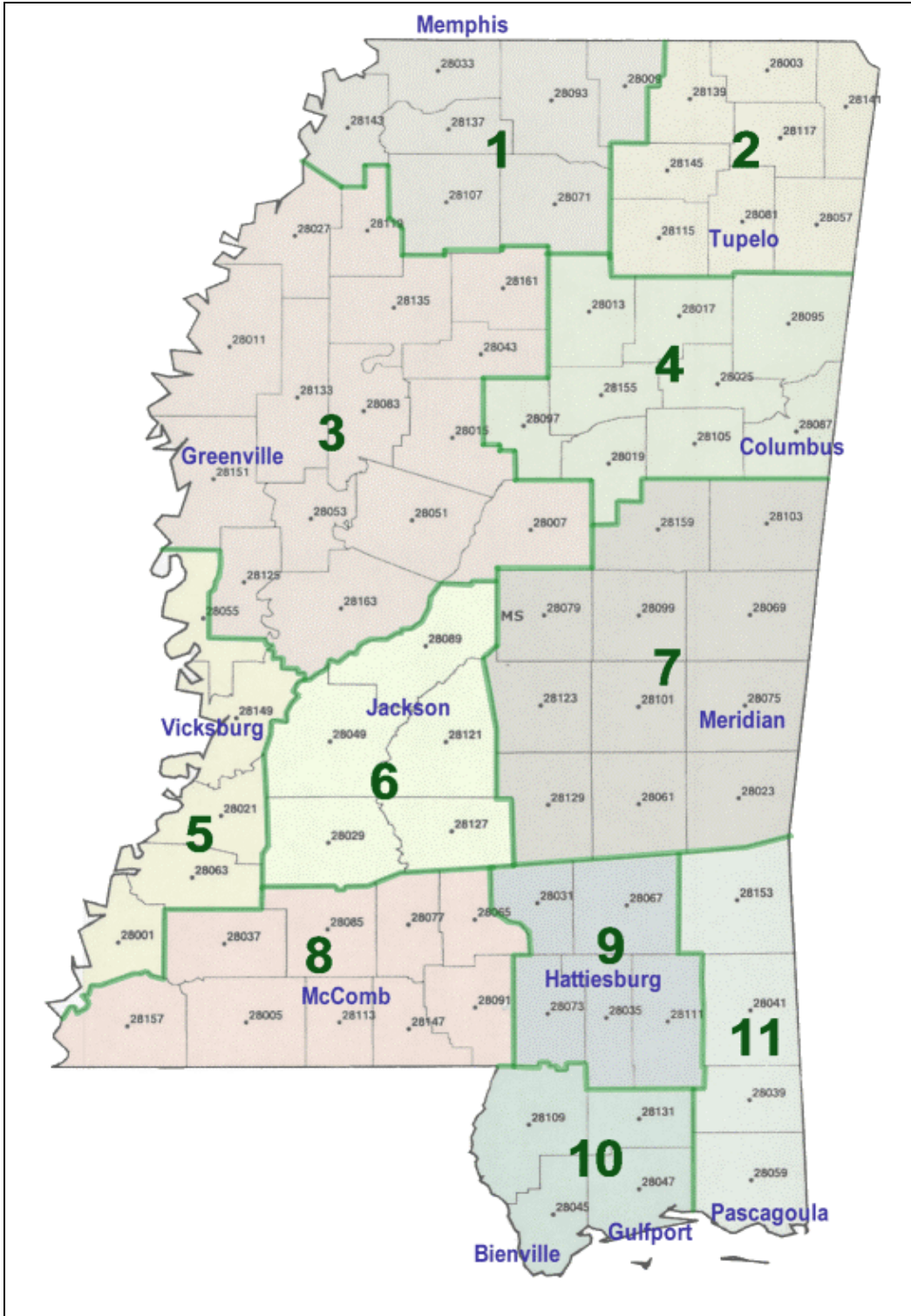
The macroscopic simulation component is based on the traffic assignment results where only the arrival locations (similar to an origin) and the destination locations are needed. The simulation model covers only what's going on within the state. The following describes the locations:

- For “coming-into” traffic, arrival locations are the locations on the Mississippi state boundaries. The centroids defined for the simulation (within the simulation traffic zones) are the destinations.
- For “going-out” traffic, the destination locations are the boundary locations and the centroids are the arrival points.
- For within traffic, the centroids for different zones represent both the arrival and destination locations.
- For through-traffic, the boundary locations represent both the arrival and destination locations.

The traffic analysis zones for the simulation are aggregated from the 82 counties in the state based on the population densities of the counties. The eleven traffic analysis zones are intended to distribute the traffic volumes (based on the attraction and production) evenly as shown in Figure 6-2.

Based on the simulation network, traffic assignment was done for Internal-External and External-Internal freight flow. We assigned 91% of the traffic flow between the 82 counties in Mississippi and the other 47 states to the 11 traffic zones in the simulation model.

A trip distribution model (Gravity model) based on the production and attraction of the 11 traffic zones and the 22 bordering points was conducted. The data preparation part will be discussed in the following sections. Figure 6-3 shows the grouping of boundary points into 10 groups numbered 12 to 21 (numbers 1 to 11 are used for naming the centroid of the 11 traffic zones). The grouping is necessary in order to reduce the complexity of the simulation OD derivation process.



**Figure 6-2: Traffic Analysis Zones in the Simulation Model (County Map Generated Using TransCAD and Zones added Using a Graphics Editor)**



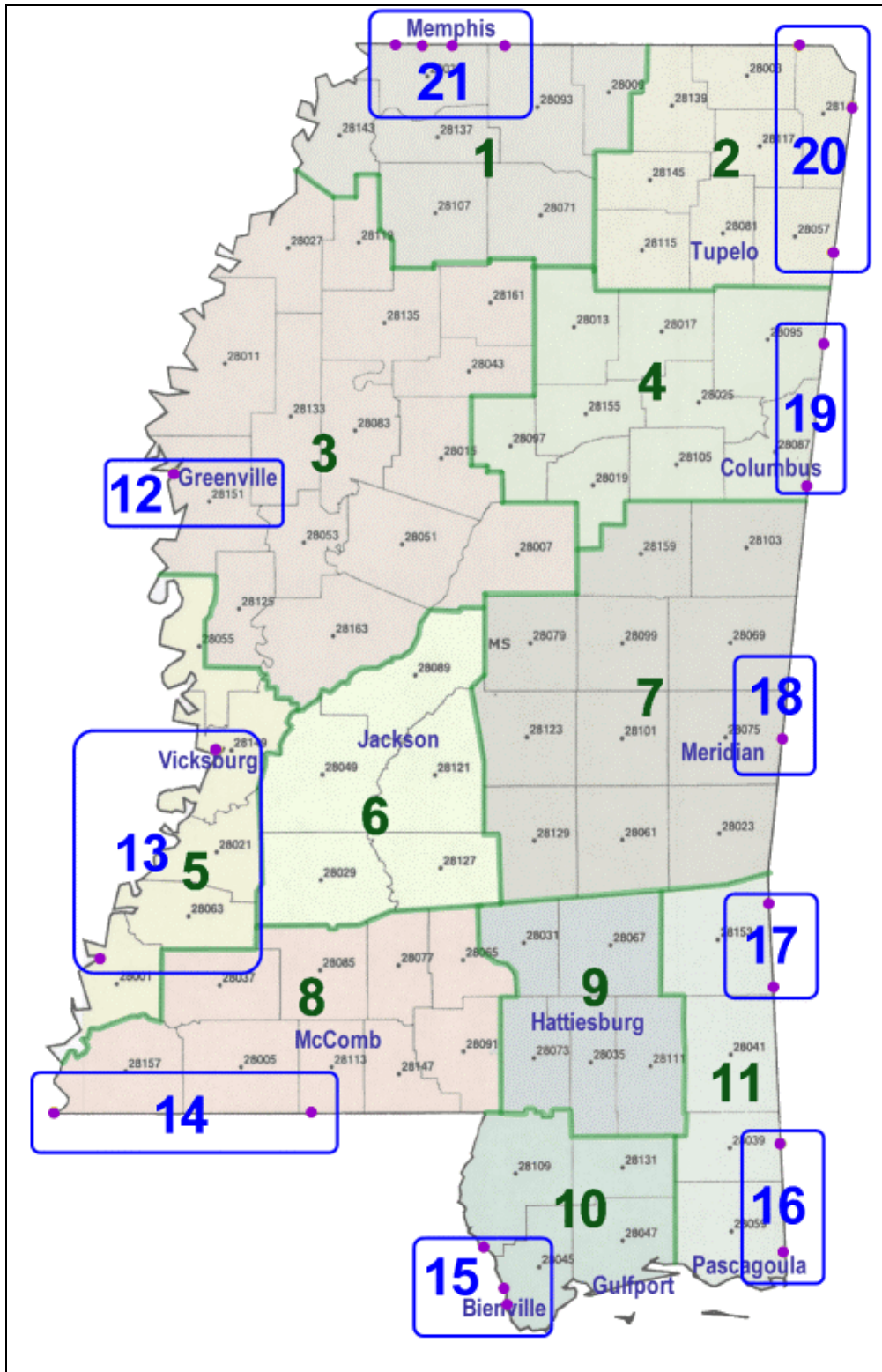


Figure 6-3: Boundary Points and the Groupings Used for Simulation Data Preparation Assignment

Based on the truck O&D data that is derived from the CFS database, Critical Link Analysis in TransCAD was used to transfer the remote origins and destinations to the state boundary points. The commodity data associated with the State of Mississippi is transferred from remote O&D to the O&D data based on the eleven traffic analysis zones and ten entry points O&D data. Figure 6-4 shows the network used in the critical link analysis.

The rail O&D data is derived following the same rules and the procedures. The water O&D are estimated based on the “Comprehensive Assessment of the Ports in Mississippi” report prepared by Parsons Brinckerhoff [45] with reference to the CFS database.

For commodity moved by truck, population and employment as the production and attraction index was used to disaggregate the state level O&D data to county level. The assignment results from different O&D pairs were combined to get the commodity tonnage on the network in the State of Mississippi. A methodology was developed to convert the freight flows to vehicle trips to facilitate model calibration and validation. Yearly truck traffic was converted to daily truck traffic based on the truck usage information in the VIUS Database.

A limitation of using the averaged daily truck traffic is that traffic pattern changes based on the hour of the day. Truck traffic is not spread out evenly over the entire 24-hour day. Therefore the simulation distributes the averaged daily truck traffic between daytime and nighttime hours as defined by the user.

For rail movements, the production and attraction points are based on the rail network and major rail-served intermodal facilities as identified by Mississippi’s Multiplan study. However since most railroads are privately owned and operated, the attraction and production percentage for different O&D are approximately based on the capacity of each rail-served intermodal facilities. With more specific data that includes schedules and commodities carried, more robust methodologies can be developed to supplement the incomplete data in the CFS database.

For water movements, all 17 ports active in the state are identified in the network. The percentage of tonnage handled in each port is based on the Comprehensive Assessment of the Ports of Mississippi study results. The total tonnage transported in the state from CFS data analysis, along with the results from Multiplan was used to determine the water O&D.

The data used for simulation focuses mainly on O&D data by different modes. The O&D data used for simulation include Truck O&D, Railcar O&D, and Barge O&D. Three intermodal scenarios are presented with the concept of transferring a certain amount of freight from single mode to intermodal, and then observing how the transference influences the performance measures used in the simulation model.

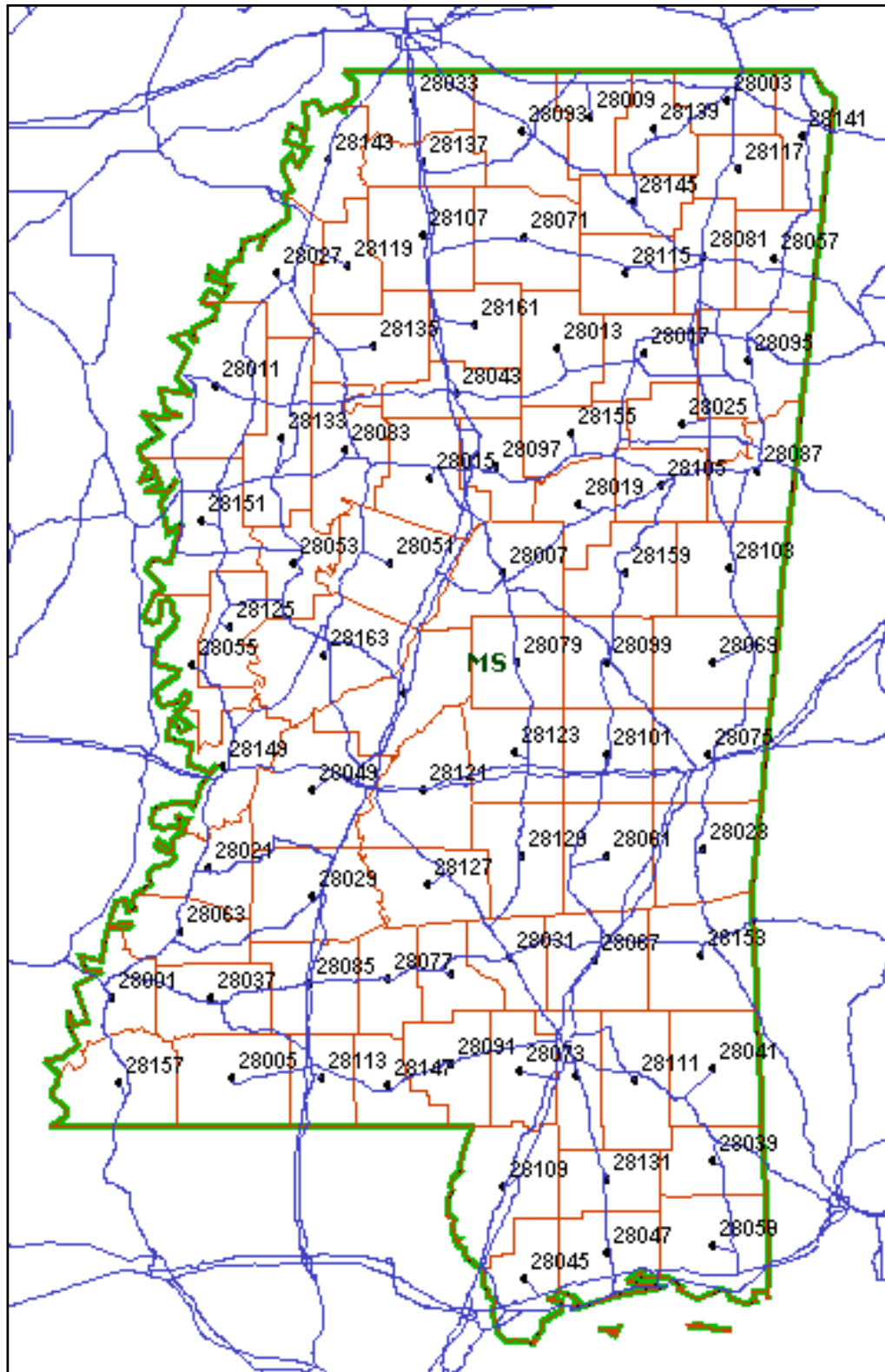


Figure 6-4: Network Used for Critical Link Analysis in TransCAD

## 6.2 Building of the Simulation Transportation Network

Alternatives in ProModel [46] were evaluated to determine the best way of representing highway, railway, and waterway networks. Path Networks in Promodel were selected to simulate entities moving in both directions, passing, as well as speeding up and slowing down. The network in the model covers all Interstate Highways, all US Highways, and key State Highways to ensure highway freight movement coverage of over 91%. Also included are all active rail lines (includes both Class I and regional short lines) as well as the Mississippi River, Tenn-Tom waterway, and the Gulf Coast waterway.

Intersections between links, which are often major towns or cities, are modeled as Promodel locations where speed calculations are made and various statistics are collected. Some statistics collected pertains to the pre-defined 11 traffic zones. The traffic zones were divided based on factors such as population density and estimated traffic densities. Key locations that include major cities and ports along the waterways are also connected to the transportation network.

Information concerning the capacity (number of lanes) and speed limits are contained in an Excel spreadsheet to initialize the simulation (refer to Simulation User Guide in the appendix for more details). This allows for changes to the capacity as well as speed limits to observe the impact on the transportation system.

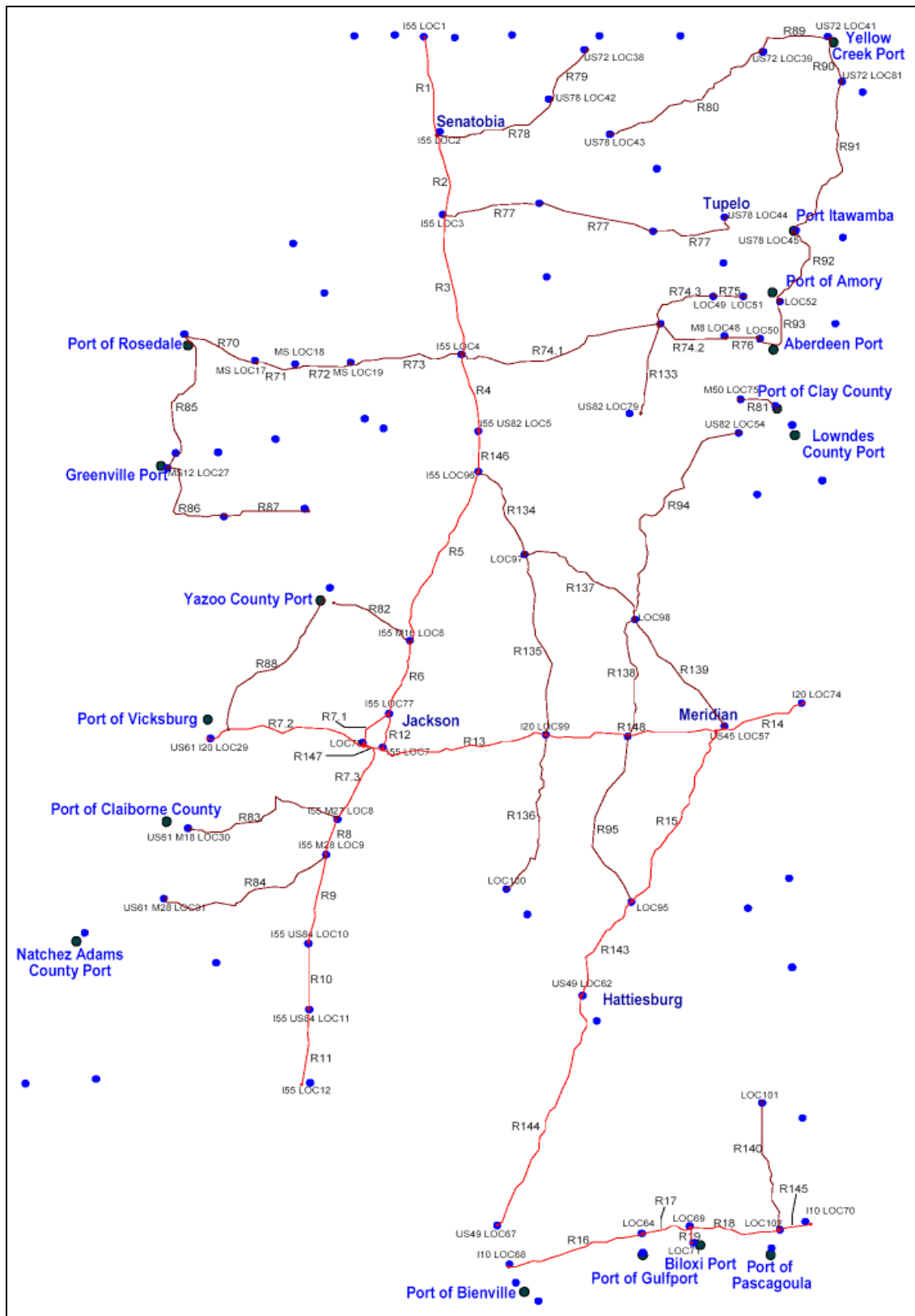
The networks are color coded for easier reference (to represent the different classes). Refer to Table 6-1 below for more detail. The following pages show diagrams of the networks used in the simulation model (Figures 6-5, 6-6, 6-7, and 6-8).

**Table 6-1: Color Code for Network Links**

<b>Link Color Code</b>	<b>Type/Classification</b>
Red	Interstate Highways
Green	US Highways
Brown	State Highways
Pink	Rail
Blue	Waterways

The bright blue dots in those diagrams represent locations in the model that are connected to the entire network (that consists of multiple modes). They may not be shown as being connected in some figures depending upon the mode being displayed. The highways are labeled as R1, R2, R7.2, etc. The numbers corresponds to the name of the highways and the decimals, if applicable, refers to the different branch of that highway link. For more detail on the names used in the model for representing a highway segment, please refer to the Simulation User Guide in the appendix. The locations in the model are usually named after the highway link it resides on, with a unique number such as I55\_M6\_LOC3. The highway names are used as reference only but the last number uniquely identifies the location throughout the model and it's accompanying spreadsheets. Therefore, I55\_US82\_LOC5, I55\_M27\_LOC8, and US90\_LOC73 are more simply known as locations 5, 8, and 73, respectively. In the input spreadsheet for example, the notation of O5-D73 will denote an origin at location 5 to a destination at location 73.





**Figure 6-6: All State Highways and Interstates Used in the Model**

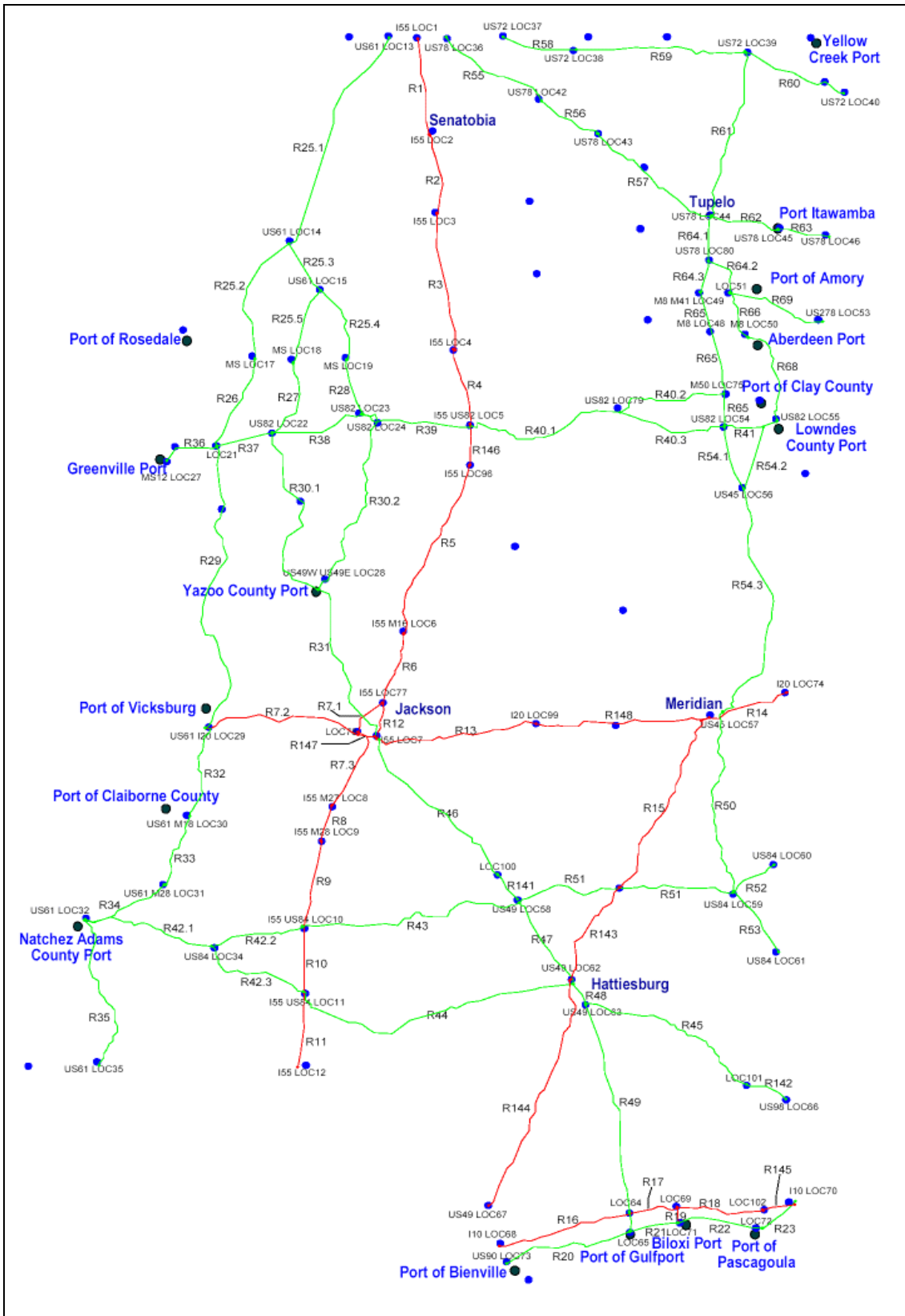
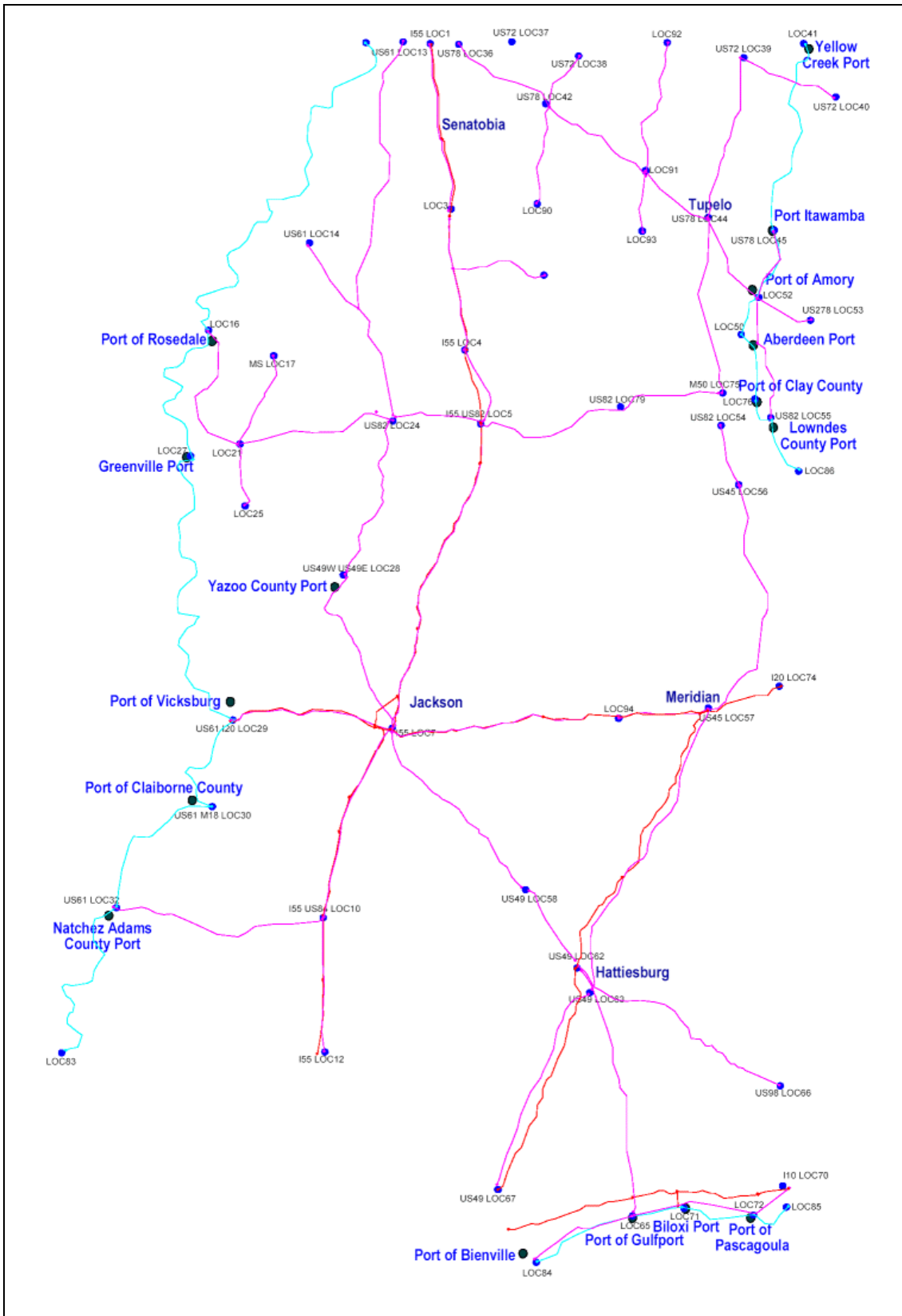


Figure 6-7: All US Highways and Interstates Used in the Model



**Figure 6-8: All Rail and Waterway Networks (Also Includes Interstates As Reference)**



## 6.3 Simulation Assumptions/Considerations

In this section, we review the assumptions made to build the prototype VITS. Please note that future versions of VITS can be constructed with fewer assumptions as specified by MDOT.

### 6.3.1 Truck Mode Assumptions

- Routes are chosen at the beginning of the trip and do not change dynamically thereafter. Routing decision can be based on several criteria but in this study, the shortest path was chosen to relate to our traffic assignment procedure, which was done using shortest path in an “all-or-nothing” rule.
- Trucks that arrive at the final destination exit the system. Less-than-truckload situations for the return trips are considered using an estimated expansion factor derived base on a study conducted by Monsere et. al. [12].
- Background traffic levels (passenger cars) for each highway network class are calculated by specifying a ratio of trucks to passenger cars. These ratios are predefined by the user for Interstates, US Highways, and Mississippi Highways. A study of passenger flows would be needed to more accurately include background traffic.
- Truck speeds can be varied according to the normal distribution with the mean speed being the computed speed using the Bureau of Public Roads (BPR) traffic volume equation and a user specified standard deviation. Three standard deviations are specified for Interstates, US Highways, and Mississippi Highways. Truck speeds are governed by the BPR equation and thus are subject to the assumptions and constraints of the BPR model.
- Trains and barges are always available at a location to load incoming freight from trucks for the intermodal scenario.
- Specific highway link capacity reflects the number of lanes that are most prevalent on that link.
- Truck traffic pattern is assumed to have a daytime duration and a nighttime duration. The beginning of the simulation signifies the beginning of the day.

### 6.3.2 Rail Mode Assumptions

- Railcars per train vary depending on the type of locomotive used, commodity carried, gradient, and rail track conditions. As such, we use an average count of railcars per train that can be adjusted if needed. We assume, in this model that all trains consists of 60 one hundred-ton railcars.
- With the limited information available on train schedules, it is possible to observe two trains in the simulation passing each other on a single track. While this is not

possible, the rail freight movement captured in the model shows only the tonnage and direction. As such, the arrivals of the trains may not match actual schedules, but are assigned randomly over the run-length of the simulation. The frequency of arrivals, however, is estimated based on annual averages (tonnage).

- Regional rail lines serving industries within Mississippi appear to carry only a small percentage of the total tonnage of freight within Mississippi. With limited data, we did not consider these flows at the present iteration of the model.
- Through traffic and mixed mode flows were not considered in the simulation due to limitation of data.
- By assigning attraction points within the state of Mississippi to estimate the volume of freight on each assigned rail link, we assume that the train moves directly from the point of entry to the point of destination without any interruptions, such as those which may be encountered at a switching station.
- All trains are moving with a full load based on user-defined characteristics (refer to the “Simulation User Guide” on vehicle specifications in the appendix).

### **6.3.3 Water Mode Assumptions**

- The barges along the Tenn-Tom and Mississippi River are assumed to be break-bulk barges with an average capacity of 1500 tons. In the simulation, we model barge movements as single unit movements.
- The cargo ship along the gulf coast are standardized for the simulation model as a 630’ First Generation class with capacity of 1000 TEUs (Approx. 24,000 tons)
- Due to data limitations, through flows and mixed-mode freight flows that involve freight were not included in the model.

### **6.3.4 Intermodal Assumptions**

Many factors affect the transfer time from one mode to another such as capacity of the terminal and traffic conditions of the surrounding area. In this model, we assume that a terminal’s capacity is not a limiting factor. All loading and unloading times for the trucks, rail, barges, and ships (at exchange points) are approximated as uniformly distributed times and are user-definable in the model (mean unloading times used in the model for a barge, the entire train, and truck is 16, 16, and 0.625 hours respectively). Future VITS versions can include detailed models of terminals to simulate delays based on realistic terminal capacity constraints. This feature would be particularly useful for assessing the need for upgrades at an intermodal transfer facility and how the upgrade would affect the movement of freight in the region.

### 6.3.5 Fuel Consumption Assumption

We assume an averaged, fixed fuel efficiency for each mode. This means that trucks carrying the same load will consume the same amount of fuel whether moving in free flow speed, or moving in congested traffic. With more data available it is possible in the future to code a more accurate vehicle fuel consumption model that responds to traffic conditions and terrain variances.

### 6.4 Speed Calculation

Highway entities (trucks) in the simulation model carry a speed attribute that governs their speed on any particular link in response to congestion. To achieve this functionality in ProModel, the BPR Equation is executed at time intervals specified by the user to update the speeds on all links in the model. Values of parameters for speed determination in the simulation model are explained in more detail in the Simulation User Guide.

The BPR equation used in the simulation model is as follows:

$$\text{Calculated Travel Time} = t_i \left[ 1 + \alpha \left( \frac{x_i}{C_i} \right)^\beta \right] \quad (6-1)$$

where,

$i$  = Denotes links 1, 2, 3... n;

$t_i$  = Free flow travel time on link  $i$ ;

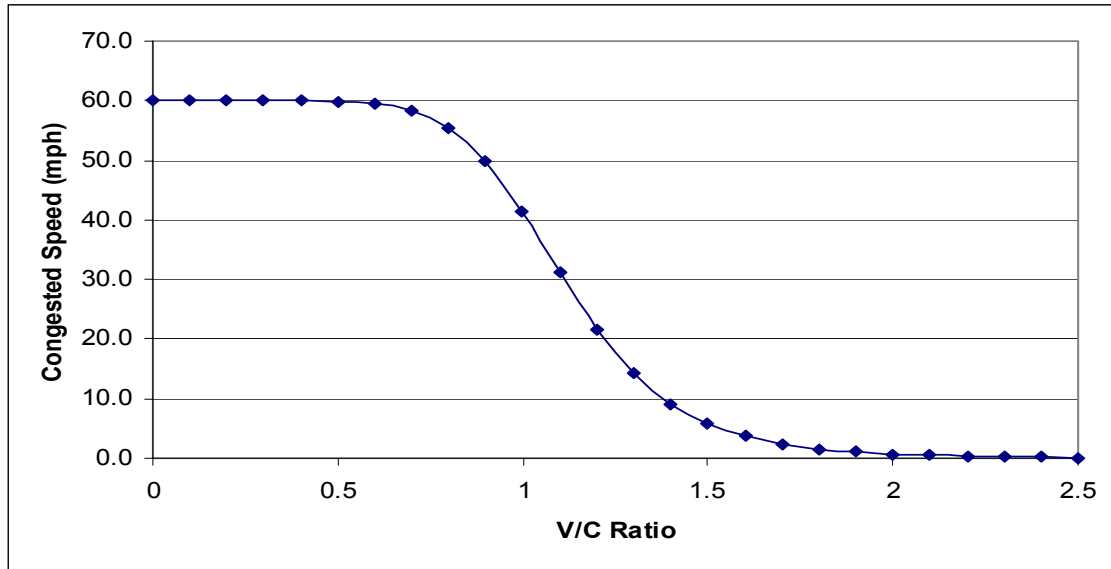
$C_i$  = Capacity of link  $i$ ;

$x_i$  = Flow on link  $i$ ;

$\alpha$  = Constant;

$\beta$  = Constant.

A plot of speed and its relationship with the volume over capacity ratio (relating to the BPR equation) is shown in Figure 6-9.



Source: Volume-Delay Function and Roadway Capacity, Review of The Regional Transportation Commission of Southern Nevada’s Draft 2003-2025 Regional Transportation Plan & 2003-2005 Transportation Improvement Plan Conformity Finding, July 2002.

**Figure 6-9: Interstate Speed-Flow Curve for  $\alpha=0.45$  and  $\beta=7.5$**

Free flow travel time is based on the free flow speed for the particular link. Table 6-2 defines the free flow speeds and capacities used in the simulation model.

**Table 6-2: Speed Limits**

Highway Classification	No. of Lanes (both directions)	Free Flow Speed (MPH)	Capacity (PCPHPL)*
Interstate	2,3	50	2200
Interstate	4,5	70	2400
Interstate	6,7	65	2350
Interstate	8,9	60	2300
US Highway	2	55	2250
US Highway	4	65	2350
State Highway	2	50	2200
State Highway	4	55	2250

\*Basic uninterrupted flow capacity in “Passenger Cars per Hour per Lane” [47]

Flow is defined as the number of vehicles passing a point per unit time. In this case, the unit time is the user-defined speed update interval.

According to Grady, the default  $\alpha$  and  $\beta$  values have traditionally been 0.15 and 4, respectively. He elaborated that these traditional coefficients have been replaced following more recent research. In his report, the values of 0.45 and 7.5 respectively were used to reflect upon the more current body of research [48]. We used the modern values in our simulation model.

Due to the macroscopic nature of the simulation model when traffic flow is concerned, individual truck entities you see in the animation represent more than just a single truck. Although the user can change the number of actual trucks a single entity represents, this entity resolution influences the outcome of the speed calculation. This issue is not so

much of problem for a macro level simulation model as it is for a micro level simulation where the behavior of individual vehicles needs to be modeled.

An entity’s speed can only be set at locations where logic can be executed. In the case of using ProModel, the codes for setting the speed is implemented at the move logic section of all the locations in the model. The move logic section allows the speed to be set before the entities are released onto the highway links. This means that once the speed is set at a location, its speed can no longer change until it reaches the next location. Since the speed of the entity is directly influenced by the traffic preceding it on that link, the inability to drastically change speeds while on a link is not a significant issue for a macro level simulation model.

While the data derived from the CFS Database is in terms of trucks, the capacities on the highways are expressed in terms of passenger cars. An equivalent factor of 1 truck to 2.5 passenger cars was chosen after an examination of Mississippi terrain and highway characteristics. Future versions of VITS can include more detail such as a variable factor that accounts for the terrain conditions in different traffic zones. Table 6-3, adapted from “Traffic Engineering; Second Edition” by Roess et. al. [42,47], was used in the estimation of the passenger car equivalent factor:

**Table 6-3: Passenger Car Equivalents on Extended General Highway Segments**

Category	Type of Terrain		
	Level	Rolling	Mountainous
Trucks/Buses	1.5	3.0	6.0
Recreational Vehicles	1.2	2.0	4.0

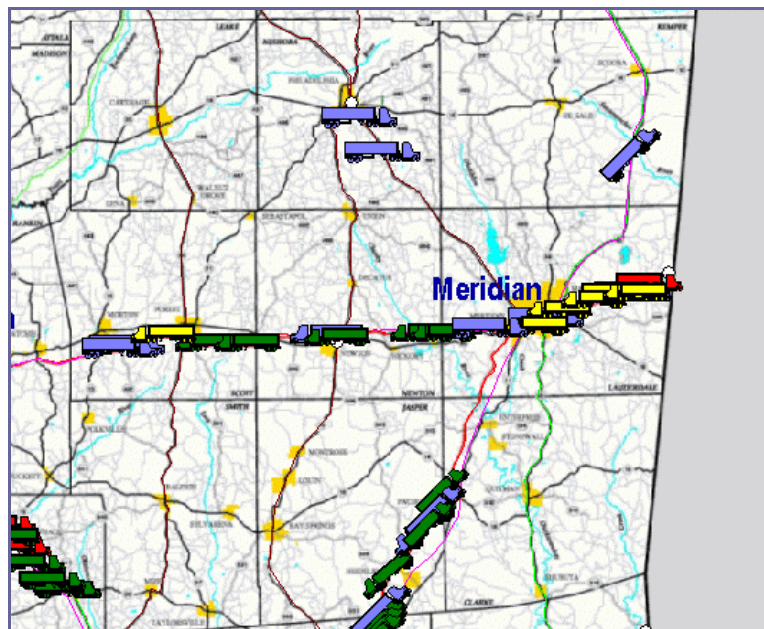
Another issue concerns passenger car traffic on the simulation network. Since this study is focused on freight traffic, passenger car traffic is estimated as a ratio of truck to passenger cars on different classes of highways. According to the Nevada Department of Transportation, it is estimated that 10% of urban interstate highway traffic involves trucks, but the figure is higher at 31% for rural interstate highways in 2001. Our estimate for the State of Mississippi, for the interstates (considering both rural and urban) is around 25%. Similarly for other major arterials, the estimate is 9% and 21% respectively for the state of Nevada. Our estimate for Mississippi is 17% (a weighted average for both rural and urban arterials). These estimates assume that the majority of non-truck traffic can be treated as passenger car traffic [49], and the values can be easily adjusted in the model. It is feasible to include actual ground counts of passenger cars as background traffic in future versions of VITS.

Animation properties for indicating slowdowns and congestions are done via several customized graphics for the truck entities. Threshold levels (expressed as a percentage of free flow speed) are used to determine when these entities change colors to reflect that they are traveling at lower speeds. Table 6-4 describes the colors codes used for the truck entity.

**Table 6-4: Color Coding for Truck Entity in the Simulation Model**

Truck Entity Color Code	Description
Green	Non-congested
Yellow	Medium congestion
Red	Heavy congestion
Purple	Trucks carrying wood products (Commodity 25 & 26)

The simulation has the ability to display entities carrying different commodities using additional color codes. Figure 6-10 illustrates the color coded animation of the simulation around the Meridian region.



**Figure 6-10: Screenshot of Entity Color Coding**

## 6.5 Truck Traffic Pattern

To handle the varying truck traffic pattern over a 24hr day, the simulation model varies the truck traffic generation depending upon the time of the day by adjusting the time between arrivals (TBA) of trucks into the network. We define the beginning of the day to be 7am and the daytime period from 7am to 5 pm (10 hours) as default values, although the user can define the beginning of the day, the duration of the daytime hours, and the percentage of traffic during that period. Details are available on the user inputs that define the traffic pattern in the Simulation User Guide.

The data preparation step provided the TBA for the trucks over a period of 24hrs. Let's denote this as TBA<sub>24</sub>, as well as TBA<sub>dt</sub> and TBA<sub>nt</sub> as the TBA for daytime and nighttime hours, respectively. Equations 6-2 and 6-3 describe the relationship between TBA<sub>24</sub> with TBA<sub>dt</sub> and TBA<sub>nt</sub>.

$$TBAdt = \gamma TBA24 \quad (6-2)$$

$$TBAnt = \beta TBA24 \quad (6-3)$$

where,

$$\gamma = \left\{ \frac{(24 - t_1)(c + 1)}{\left( \frac{576}{t_1} - 24 \right) c} \right\};$$

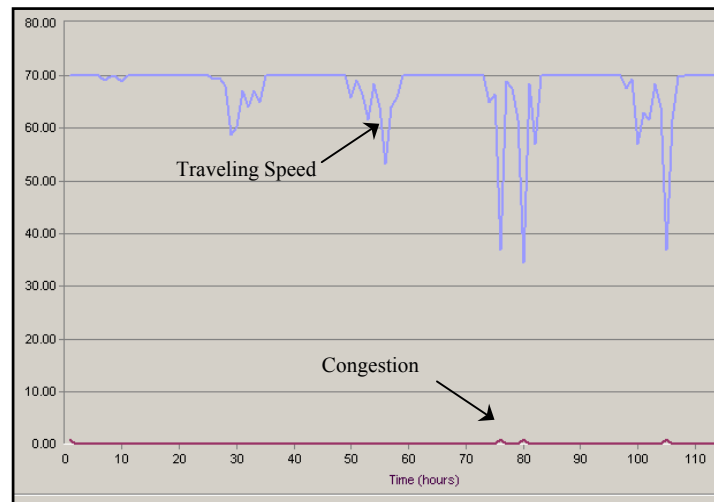
$$\beta = \left( \frac{24c}{t_1} \gamma - c\gamma \right);$$

$t_1$  = the length of the daytime period in hours;

$c$  = the ratio of truck traffic percentage during daytime hours over the truck traffic percentage during the nighttime hours.

The modulus function in Promodel is used to alternate the TBA of trucks between TBAdt and TBAnt based on the system clock. These sets of equation hold true only for cases involving just two periods of “daytime” and “nighttime”.

Figure 6-11 shows a plot of a highway link’s traveling speed and congestion during a simulation run. Notice that the congestion plot cycles between zero (not-congested) and one (congested), showing the influence of traffic flow during daytime hours. More about this will be explained in the following section on performance measures.



**Figure 6-11: Plot of Link Traveling Speed (Light blue) and Congestion (Dark maroon) over Time (Hours)**

## 6.6 Performance Measures Implemented

In this section we review the performance measures implemented in the prototype VITS. Additional performance measures could be implemented per MDOT specifications.

### 6.6.1 Link Average Speed and Congestion

The traveling speed (Miles per Hour) and congestion figures for each highway link are recorded in arrays within the model. Several key links in the model are assigned variables to which the changes to both the traveling speed and congestion can be observed via dynamic plots when the simulation is running. The statistics for these travel speed and congestion variables for the links can be obtained from the standard Promodel output report at the end of the simulation run.

Note that for the congestion measure, a severe congestion on a link (noted by red trucks when the model is running) is reflected by a value of one whereas the non-congested condition is simply represented by a value of zero. By doing so, an average congestion value for a link will simply denote the percentage of time the link is congested.

### 6.6.2 Fuel Efficiency

One consideration when selecting modes is fuel efficiency, which is also closely related to vehicle emissions. While modes such as water may be slower in transit compared to trucks, concepts such as “warehouse-in-transit” (for which constant and reliable deliveries are required) make water a good mode choice [50].

To see the effects of mode choice on fuel efficiency, we calculate the ton-miles of each mode as well as the gallons consumed per mode. With this information, the ton-mile per gallon for the entire system can be calculated to show the impact of changes to the system. This calculation is updated every time the speed calculation is initiated, thus the updates are done every speed update time interval. Note that the gallons consumed are derived from the average fuel efficiency of that particular mode as shown in Table 6-5.

**Table 6-5: Fuel Efficiencies**

Mode	Ton-Miles per Gallon
Rail	202.0
Highway	59.2
Waterway	514.0

(Source: Fuel Efficiency in Freight Transportation, Samuel Ewer Eastman)

System ton-mile are calculated as follows:

$$\text{System Ton-Miles per Gallon} = \frac{TM_{tot}}{G_{tot}} \quad (6-4)$$

where,  $TM_{tot}$  is the total ton-miles transported by all the three modes and  $G_{tot}$  is the total gallons consumed by the three modes. This value may increase or decrease as the simulation model is running, responding to changes in the mix of modes and their distance traveled during the simulation run.



### 6.6.3 Zone Utilization of Highways

Utilization of highways in the 11 simulation TAZs are calculated by first totaling the capacities of the highways included in each zone, followed by the calculation of the ratio of total truck flow in the zone over the total capacity as shown in Equation 6-5.

$$Utilization_i = \frac{Flow_i}{Capacity_i} \quad (Equation\ 6-5)$$

where,

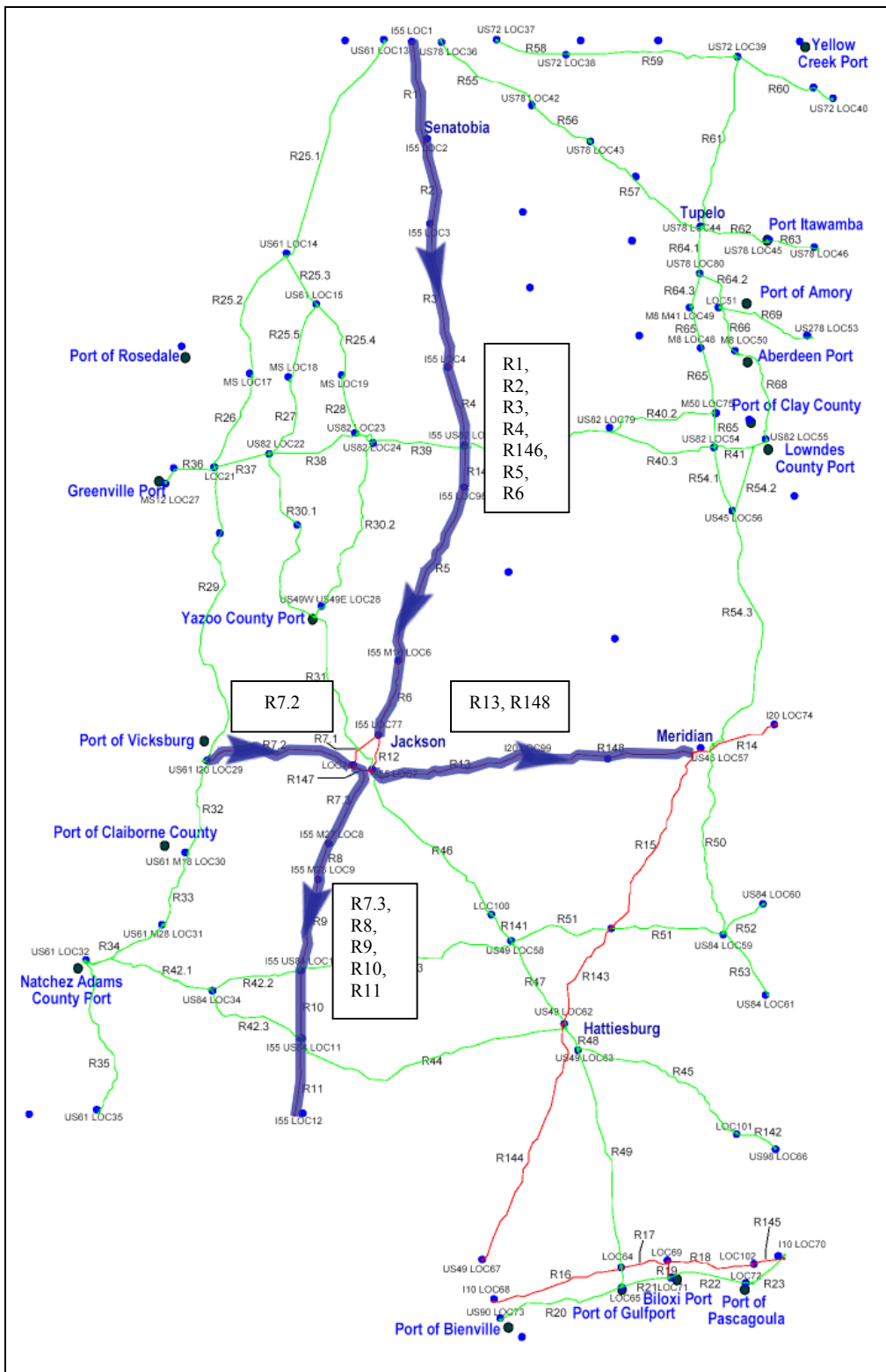
$$i = zone\ 1, 2, 3... 11.$$

Note that the total flow in each zone is updated each time that truck speeds are updated (e.g. every half-hour). Since the capacities are defined as an uninterrupted flow capacity under prevailing conditions, it is possible under situations of heavy traffic to have utilizations of over 100%. Refer back to Figure 6-8 to see how a volume/capacity ratio that is approaching or exceeds 1 impacts the speed of the vehicle. In instances where a network link overlaps two zones, truck count is incremented for both zones. This condition can be avoided by establishing distinct network links within the zones.

### 6.7 Scenarios for Simulation Model

We present a series of simplistic scenarios to illustrate the utility of a VITS planning tool. The first scenario is driven by our 1997 freight volume data and is considered the base condition. The second scenario is a future scenario where the freight volume is doubled, and the third scenario is similar to the second except that some freight is handled by intermodal shipments. A fourth scenario was also created in response to the simulated results from the third scenario.

For each scenario, the simulation model is run for 60 days including 6 hours for warmup using a single replication for the purpose of demonstration. Figure 6-12 presents the links and the direction of freight flow (highlighted in blue) that are of particular interest in the scenarios. The boxes next to the highlighted links contain the link codes for reference.



**Figure 6-12: The Selected Highway Links and the Direction of Flow for Traveling Speed, and Congestion.**

### 6.7.1 Scenario 1: Base Condition

In the base condition, data from the previous steps in the study was used to drive the simulation model. The land and water modes present in Mississippi’s transportation system are represented in the model to reflect current conditions. Table 6-6 summarizes the performance of the system with respect to the performance measures described earlier.

**Table 6-6: Summary of Results for Base Condition (Scenario 1) Simulation**

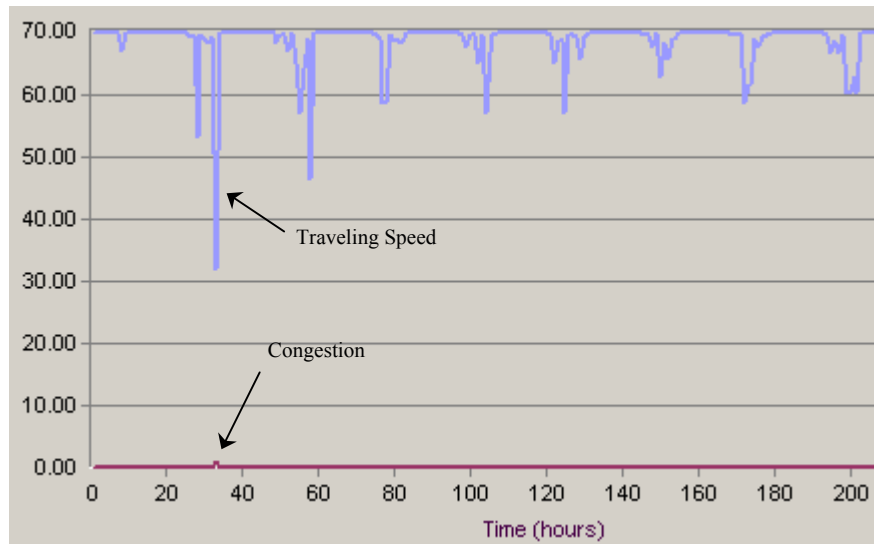
<b>Zone</b>	<b>Avg. Zone Highway Utilization</b>	<b>Mode</b>	<b>Avg. Daily Ton-Miles</b>	<b>Avg. Daily Gallons</b>
<i>1</i>	15.59%	<i>Water</i>	490,903	955
<i>2</i>	4.02%	<i>Rail</i>	4,431,333	22,028
<i>3</i>	7.20%	<i>Highway</i>	171,525,000	2,897,383
<i>4</i>	5.46%	<b>System Ton-Miles per Gallon</b>		60.42
<i>5</i>	8.46%			
<i>6</i>	23.34%			
<i>7</i>	12.82%			
<i>8</i>	13.69%			
<i>9</i>	15.86%			
<i>10</i>	15.43%			
<i>11</i>	10.89%			

Note that the “Average Zone Highway Utilization” is the time-weighted average of the utilization for highways links that are included in the model within the particular zones. The Ton-Miles and Gallons values are the average daily values. Also, note that no passenger car information is included for the links without truck traffic, and therefore, the passenger cars count on those links is neglected. As a result, the percentage utilizations reported in the output are expected to be lower for some zones.

Table 6-7 summarizes the average traveling speed (Miles per Hour) and congestion statistics for the 15 selected links in the scenario. We can see that for the base scenario, link R1 for example (an I-55 link above Senatobia), experiences very little congestion with an average traveling speed of 69 mph. The link was never congested over the simulation time. Because the average link congestion is a time-weighted average figure, a dynamic plot is useful in displaying the status of congestion (in dark maroon) for a link over the simulation run as shown in Figure 6-13. This plot allows us to observe how congestion and speed changed for link R1 during the simulation.

**Table 6-7: Summary of Average Traveling Speed and Congestion Statistics for the Base Condition**

Link Code	Link Name	Avg. Link Traveling Speed	Average Link Congestion
R1	I55_Net1	69	0.00
R2	I55_Net2	69	0.00
R3	I55_Net3	69	0.00
R4	I55_Net4	69	0.00
R146	I55_Net146	69	0.00
R5	I55_Net5	69	0.00
R6	I55_Net6	69	0.00
R7.2	I55_I20_I220_Net7 Path 2	67	0.01
R13	I20_Net13	70	0.00
R148	I20_Net148	70	0.00
R7.3	I55_I20_I220_Net7 Path 3	69	0.00
R8	I55_Net8	69	0.00
R9	I55_Net9	69	0.00
R10	I55_Net10	69	0.00
R11	I55_Net11	70	0.00



**Figure 6-13: Plot of Scenario 1 Traveling Speed (Light Blue) and Congestion (Dark Maroon) over Time (Hours) for Link R1**

**6.7.2 Scenario 2: Future 2X Increase in Overall Tonnage Transported**

In this scenario, a 2X increase in overall traffic was assumed as the future condition. This assumes that the transportation infrastructure remains identical to the base scenario and vehicle characteristics and their route choices remain constant.

Again, all land and water modes are represented in this scenario. Tables 6-8 and 6-9 summarize the performance of the system.

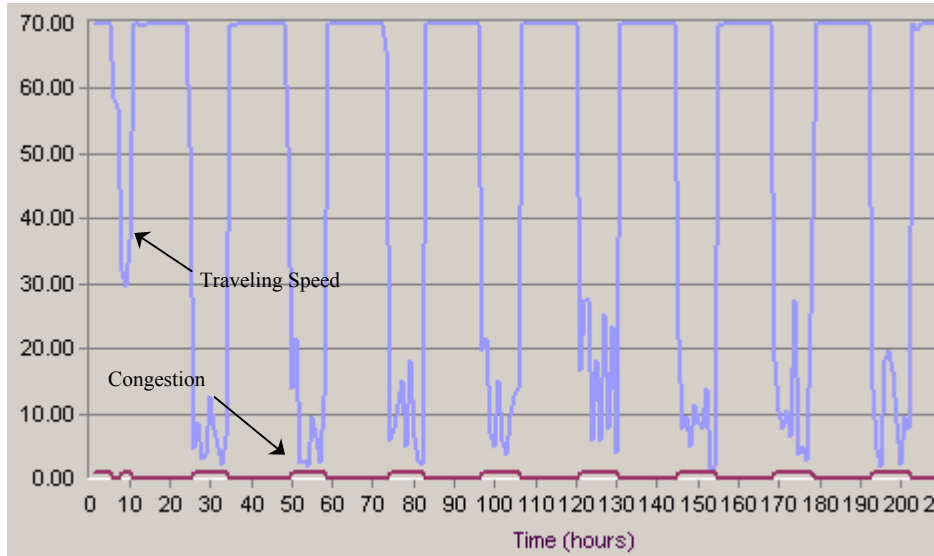
**Table 6-8: Summary of Results for Scenario 2 Simulation (2X Increase)**

<b>Zone</b>	<b>Avg. Zone Highway Utilization</b>	<b>Mode</b>	<b>Avg. Daily Ton-Miles</b>	<b>Avg. Daily Gallons</b>
1	32.12%	<i>Water</i>	990,045	1,926
2	8.35%	<i>Rail</i>	8,781,217	43,689
3	14.75%	<i>Highway</i>	350,766,667	5,925,117
4	11.29%	<b>System Ton-Miles per Gallon</b>		60.38
5	17.49%			
6	47.25%			
7	26.32%			
8	27.58%			
9	32.60%			
10	31.39%			
11	22.02%			

**Table 6-9: Summary of Average Traveling Speed and Congestion Statistics for Scenario 2 (2X Increase)**

<b>Link Code</b>	<b>Link Name</b>	<b>Avg. Link Traveling Speed</b>	<b>Average Link Congestion</b>
R1	I55_Net1	47	0.39
R2	I55_Net2	53	0.26
R3	I55_Net3	53	0.25
R4	I55_Net4	52	0.29
R146	I55_Net146	53	0.26
R5	I55_Net5	55	0.24
R6	I55_Net6	55	0.24
R7.2	I55_I20_I220_Net7 Path 2	44	0.40
R13	I20_Net13	69	0.02
R148	I20_Net148	69	0.00
R7.3	I55_I20_I220_Net7 Path 3	54	0.25
R8	I55_Net8	53	0.27
R9	I55_Net9	52	0.28
R10	I55_Net10	53	0.27
R11	I55_Net11	70	0.00

It can be clearly seen from Table 6-9 above that a future increase of 2X in traffic flow creates a more congested highway transportation system. The average traveling speed on link R1 is now 47 mph and it is congested 39% of the time (The utilization and congestion plot for this link can be seen in Figure 6-14). This is an important aspect when conducting transportation planning because the simple truck traffic average over a 24hr period excludes how traffic fluctuates over time. The system performance at such high traffic volumes is very poor, creating stop-and-go traffic conditions on this link during peak times.



**Figure 6-14: Plot of Scenario 2 Traveling Speed (Light Blue) and Congestion (Dark Maroon) over Time (Hours) for Link R1**

### **6.7.3 Scenario 3: Future 2X Increase in Overall Tonnage Transported with Intermodal Shifts**

This future scenario experiences the same increase in tonnage as described in section 6.7.2. However, in this case, the freight normally arriving into the state by trucks through Location 1 and traveling by highway to Location 12 is changed to arrive using barges through Location 1 and travels down to Location 29 (Vicksburg) via the Mississippi River (see Figure 6-15). We assume, for the sake of discussion that the all the trucks are carrying a general commodity for Location 12 to be used by the local industry. Another assumption is that the Mississippi river and the port at Vicksburg have sufficient capacity to handle the influx of barges.

It is possible that the industries (could be the plastics or packaging manufacturers) located in McComb (near Location 12) are looking into alternative modes of transportation in getting raw materials from their suppliers north of Mississippi. This is consistent with the supply chain principle where the manufacturers play an active role with their suppliers in coordinating shipments to best serve their production needs. Some industry experts have mentioned the idea of “warehouse-in-transit”. The slower moving barges are an excellent example of this concept.

After the trucks are loaded with freight from the barges, the journey is then resumed using from Location 29 to Location 7. From Location 7, they travel to the final destination at Location 12.

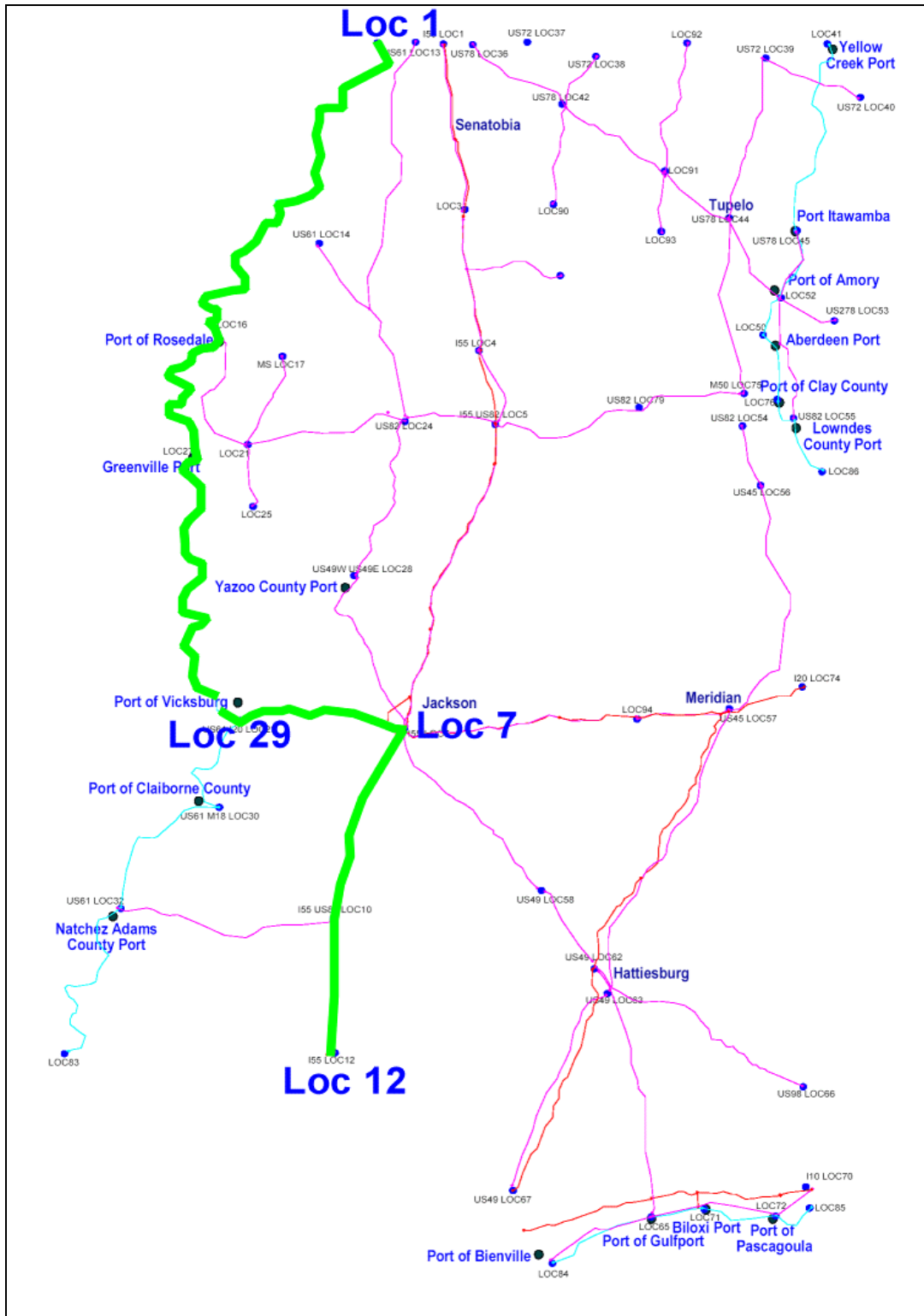


Figure 6-15: Route Shift (Intermodal) for Future Scenario

Table 6-10 and Table 6-11 summarize the performance of the system for Scenario 3. Comparing this scenario with Scenario 2, we can see an increase in the System Ton-Miles per Gallon from 60.38 to 66.80. This is an increase of 10.63%, which is a significant difference, considering the limited intermodal use in this scenario.

**Table 6-10: Summary of Results for Scenario 3 Simulation (With Intermodal)**

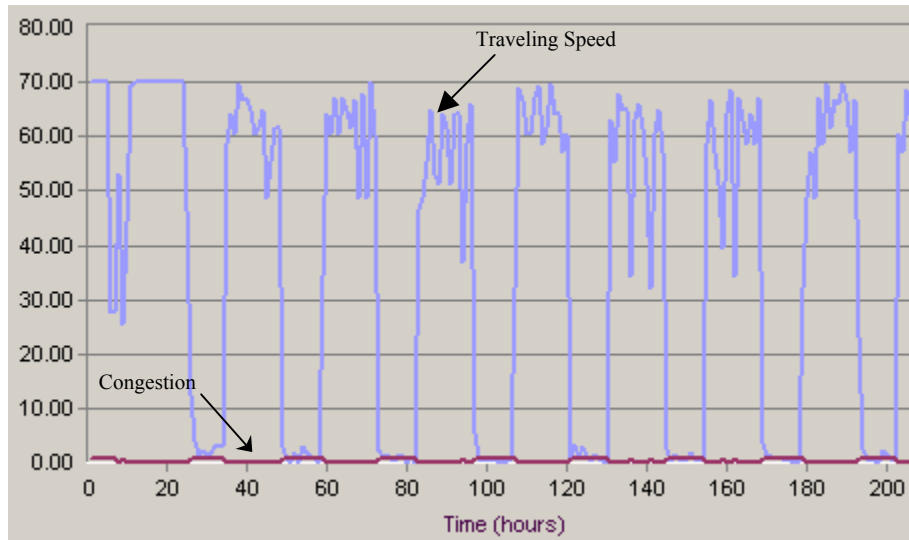
<b>Zone</b>	<b>Avg. Zone Highway Utilization</b>	<b>Mode</b>	<b>Avg. Daily Ton-Miles</b>	<b>Avg. Daily Gallons</b>
1	22.31%	<i>Water</i>	40,204,500	78,219
2	8.31%	<i>Rail</i>	8,781,217	43,689
3	9.71%	<i>Highway</i>	318,280,000	5,376,350
4	7.85%	<b>System Ton-Miles per Gallon</b>		66.80
5	20.91%			
6	41.97%			
7	26.17%			
8	25.51%			
9	32.49%			
10	31.24%			
11	21.89%			

**Table 6-11: Summary of Average Traveling Speed and Congestion Statistics for Scenario 3 (With Intermodal)**

<b>Link Code</b>	<b>Link Name</b>	<b>Avg. Link Traveling Speed</b>	<b>Average Link Congestion</b>
R1	I55_Net1	70	0.00
R2	I55_Net2	70	0.00
R3	I55_Net3	70	0.00
R4	I55_Net4	70	0.00
R146	I55_Net146	70	0.00
R5	I55_Net5	70	0.00
R6	I55_Net6	70	0.00
R7.2	I55_I20_I220_Net7 Path 2	35	0.46
R13	I20_Net13	69	0.01
R148	I20_Net148	69	0.01
R7.3	I55_I20_I220_Net7 Path 3	57	0.21
R8	I55_Net8	58	0.19
R9	I55_Net9	57	0.20
R10	I55_Net10	57	0.19
R11	I55_Net11	70	0.00

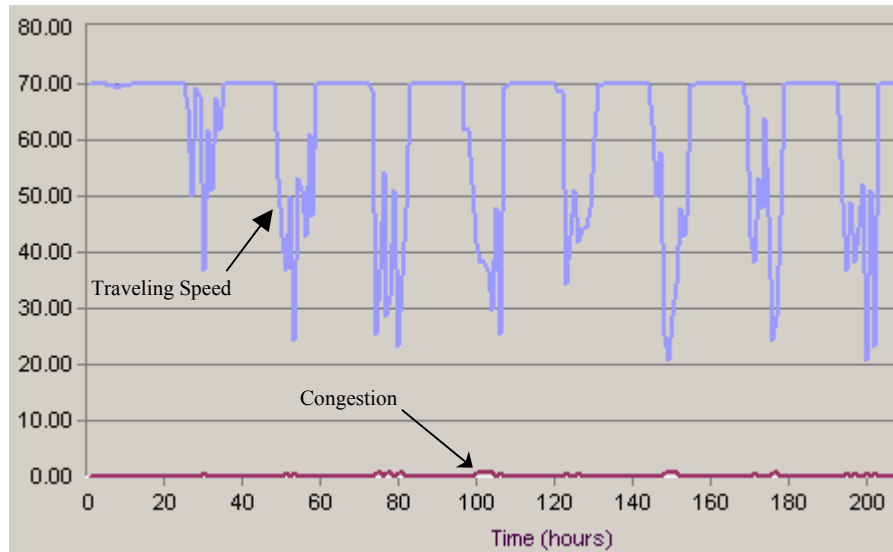


Looking at the average traveling speed and congestion for the highway links from Table 6-11, we can see that traffic is taken from highway designated R1, R2, R3, R4, R146, R5, and R6 when compared with the previous scenario. While this significantly reduces the congestion on Interstate 55 north of the city of Jackson (notice that R1 is no longer congested), the unloading of the barges onto truck at Vicksburg (Location 29) creates a huge traffic bottleneck for trucks moving from Vicksburg to Jackson. The result is frequent gridlock on that link R7.2 with an average speed of 35 mph, and being congested 45.76% of the time (see Table 6-11). Figure 6-16 illustrates this new dilemma, indicating the traveling speed and congestion for Link R7.2 during the simulation run.



**Figure 6-16: Plot of Scenario 3 Traveling Speed (Light Blue) and Congestion (Dark Maroon) over Time (Hours) for Link R7.2**

Realizing that link R7.2 is too heavily congested, we doubled its capacity to examine if that will help (let's call this Scenario 4). While the average traveling speed increases from 35 mph to 60 mph on this link (see Table 6-12 and Figure 6-17), it is certain that some other strategy or combinations of strategies can be applied to further improve the traffic flow on this link, since there are instances where the traveling speed is significantly below the free-flow speed.



**Figure 6-17: Plot of Scenario 4 Traveling Speed (Light Blue) and Congestion (Dark Maroon) over Time (Hours) for Link R7.2**

Although this scenario is relatively simple, this is an example of how a simulation model can bring attention towards unanticipated results of intermodal policy changes. Table 6-12 shows the overall summary of comparison between the four scenarios.

**Table 6-12: Overall Summary of the Four Scenarios**

	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Scenario 4</i>
<b>Avg. Daily Ton-Miles</b>	176,447,236	360,537,929	367,265,717	370,437,383
<b>Avg. Daily Gallons</b>	2,920,366	5,970,732	5,498,258	5,551,841
<b>System TMPG</b>	60.42	60.38	66.80	66.72
<b>Link Codes</b>	<b>Average Link Traveling Speed</b>			
R1	69	47	70	70
R2	69	53	70	70
R3	69	53	70	70
R4	69	52	70	70
R146	69	53	70	70
R5	69	55	70	70
R6	69	55	70	70
R7.2	67	44	35	60
R13	70	69	69	69
R148	70	69	69	69
R7.3	69	54	57	61
R8	69	53	58	61
R9	69	52	57	61
R10	69	53	57	61
R11	70	70	70	70

This overall examination yields an interesting observation. The system ton-miles per gallon is slightly lower for Scenario 4 than in Scenario 3. This can be attributed to the lowering of congestion on the critical link (in this case), R7.2, thus allowing more truck movement on that link in Scenario 4. With the increase in truck flow, the truck mode ton-miles is now slightly higher. Because the system ton-mile per gallon is calculated by taking the total ton-miles for the water, rail, and highway modes, and dividing that by the total gallons consumed, the result is a slightly lower system ton-miles per gallon value. Note that the ton-miles for the water and rail modes (in Table 6-13) are the same across Scenarios 3 and 4. The ton-miles per gallon is 66.72 for Scenario 4, which translates to a 10.5% increase over Scenario 2.

**Table 6-13: Summary of Results for Scenario 4 Simulation (With Intermodal)**

<b>Zone</b>	<b>Avg. Zone Highway Utilization</b>	<b>Mode</b>	<b>Avg. Daily Ton-Miles</b>	<b>Avg. Daily Gallons</b>
1	22.44%	<i>Water</i>	40,204,500	78,219
2	8.38%	<i>Rail</i>	8,781,217	43,689
3	9.81%	<i>Highway</i>	321,451,667	5,429,933
4	7.93%	<b>System Ton-Miles per Gallon</b>		66.72
5	19.42%			
6	41.05%			
7	26.39%			
8	26.04%			
9	32.87%			
10	31.44%			
11	22.10%			

Figures 6-18, 6-19, 6-20, and 6-21 show the close-up screenshots of the VITS animations for the four scenarios, which was taken at hour 95 of the simulation time. They show the traffic activity in the area surrounding Jackson for the four scenarios (look closely at the traffic conditions on link R7.2 between Vicksburg and Jackson across all four scenarios).

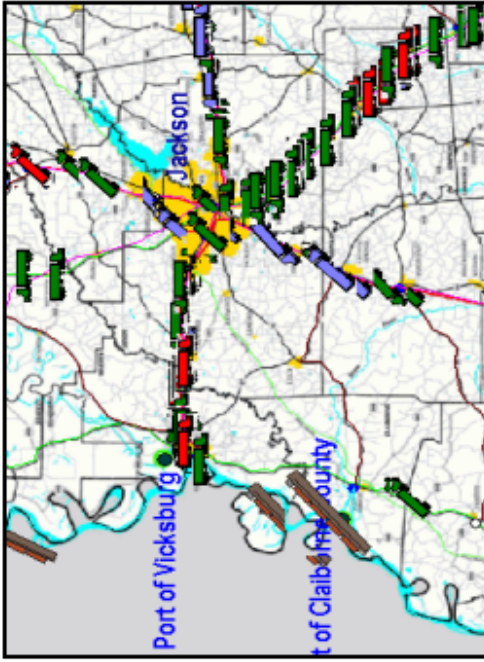


Figure 6-19: Screenshot of VITS Animations for Scenario 2

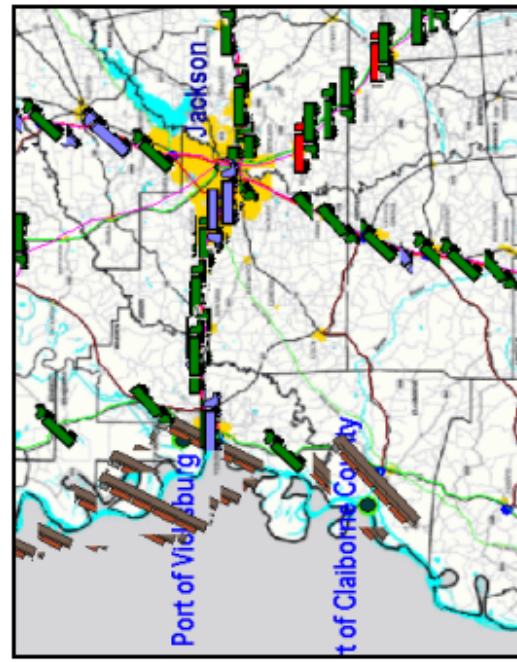


Figure 6-21: Screenshot of VITS Animations for Scenario 4

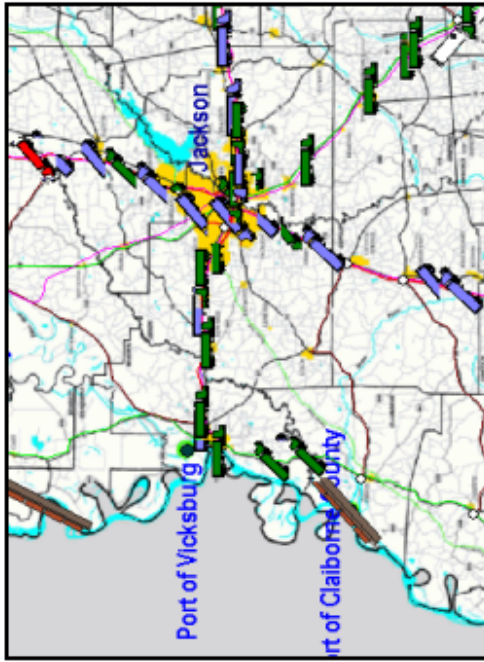


Figure 6-18: Screenshot of VITS Animations for Scenario 1

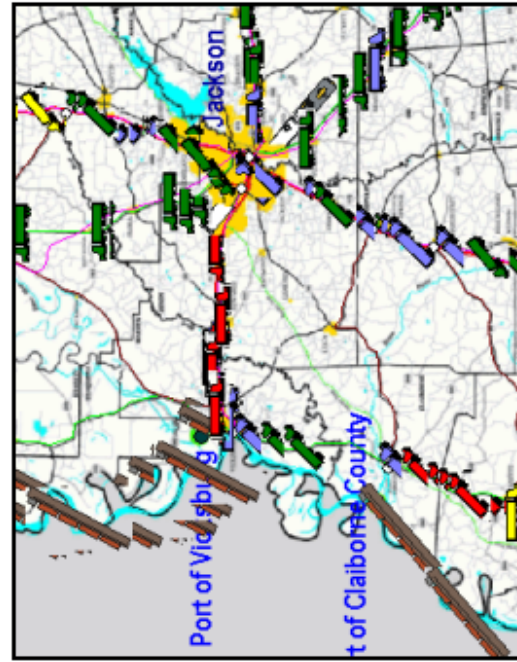


Figure 6-20: Screenshot of VITS Animations for Scenario 3

#### ***6.7.4 Conclusion from Simulation Scenario Results***

In general, it is demonstrated that congestion and average utilization (both for affected individual links and zones) show significant increase when the total tonnage of freight moved in the state is doubled. By shifting freight from truck to intermodal barge/truck, significant differences are observable in the system, namely the System Ton-Miles per Gallon and congestion levels in the affected links. The prototype VITS also indicated an unanticipated consequence of the new intermodal policy on the transportation network and allowed us to quickly evaluate a new scenario.

We realize that freight transportation systems involve more infrastructures than is included in the VITS prototype. Factors such as terminal capacity/throughput and the quality of intermodal connectors will certainly need more examination and can be implemented in future versions. Newer versions of the VITS can provide a more in-depth look into the behavior of the system as well as providing additional performance measures defined by MDOT.

## 7 CONCLUSIONS AND FUTURE WORK

This study successfully demonstrates a feasible methodology for using CFS data to estimate statewide truck travel demand. 1997 Commodity Flow Survey database is used as the main database to get the commodity flows for the State of Mississippi. The flexibility and availability are two most important incentives to use CFS database in the study. The analysis results show the methodology described in this report is valid with satisfying results, and is a good example of using public domain data. The “unbalanced” network developed for the project is different from what have been used in the past by other research and shows many advantages. On the issue of conversion from commodity flows to truck trips, a new methodology was developed and contributes to the state of practice. Future research will be focused on developing more robust forecasting methodologies.

In addition to this report, other deliverables include the Simulation User Guide for the prototype VITS, and the intermodal transportation database for the State of Mississippi. The intermodal transportation database can be used for future studies on intermodal issues for the State of Mississippi.

Our purpose in developing the Mississippi VITS prototype was to evaluate the feasibility of building a tool that can simulate an entire region’s transportation network, including intermodal connector points, in sufficient detail for intermodal transportation planning and design. We believe that the prototype proves the VITS concept. Further research and development is needed to make VITS a valid and user-friendly simulator for transportation planning. The National Center for Intermodal Transportation would welcome the opportunity to work with MDOT to produce the Mississippi VITS per MDOT specifications.

A complete Mississippi VITS will help MDOT planners identify and quantify future problems in the transportation network, evaluate proposed changes to the transportation infrastructure, and help decision makers conduct cost/benefit analyses. Furthermore, the VITS animations will help MDOT illustrate the need for transportation projects to the public and government officials.

The intermodal planning methodology developed using Mississippi as a sample state can be further refined and applied to other states. The VITS prototype can also be expanded to demonstrate the full potentials and benefits of integrated intermodal transportation. The research effort in those areas is currently continuing.

## REFERENCES

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- 1 National Transportation Library. The Intermodal Transportation Efficiency Act of 1991 (ISTEA), Originally accessed at <http://ntl.bts.gov/DOCS/ste.html>, Nov.19, 2001.
- 2 Federal Highway Administration website. TEA-21 Moving Americans into 21<sup>st</sup> century. Originally accessed at <http://www.fhwa.dot.gov/tea21/> Nov.19, 2001.
- 3 Wilbur Smith Associates, Inc. “*Latin America Trade and Transportation Study, Mississippi Report*”, Mar. 2001.
- 4 Brogan, J.J., Brich, S.C., and Demetsky M. J. Identification and Forecasting of Key Commodities for Virginia, Transportation Research Board, National Research Council, Washington D.C. 2002.
- 5 Sivakumar A., and Bhat C. A Fractional Split Distribution Model for Statewide Commodity Flow Analysis. Transportation Research Board, National Research Council, Washington D.C. 2002.
- 6 Fischer M., Ang-Olson J., and La A. A Model of External Urban Truck Trips Based on Commodity Flows, Transportation Research Board, January 2000.
- 7 Jose A. Sorratini, and Robert L. Smith, Jr. “Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients.” Transportation Research Board, National Research Council, Washington D.C. 2000.
- 8 Black, W.R. “Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment, Phase 2.” Transportation Research Center, Indiana University, Bloomington, July 15, 1997.
- 9 Horowitz, A.J., and Farmer, D.D. “A Critical Review of Statewide Travel Forecasting Practice” Originally accessed at <http://my.execpc.com/~ajh/Statewid.pdf> Nov.30,2001.
- 10 Black, W.R. “Commodity Flow Modeling”. Final Report. Originally accessed at <http://www.nas.edu/trb/publications/ec011/black.pdf> Dec. 20,2001.
- 11 Lawrence, K., and Kleinman G. “The Development of a Model and Decision Support System to Use in Forecasting Truck Freight Flow” Originally accessed at <http://kimon.njit.edu/nctip/publications/Research Reports/Freight Forecasting Model.pdf> Dec. 20,2001
- 12 Christopher Michael Monsere “A GIS-based Multi-Commodity Freight Model: Typology, Model Refinement and Field Validation” Dissertation submitted to graduate school of Iowa State University, 2001.
- 13 Shin-Miao Chin, Ho-ling Hwang, and David L.G. In, Out, Within and Through: The Geography of Truck Freight in the Lower 48, Transportation Research Board, January 2001.
- 14 Faris, J.M., and Ismart D. “Freight Modeling Techniques for Small and Medium-Sized Areas” Originally accessed at: [http://ntl.bts.gov/data/6\\_conference/00780082.pdf](http://ntl.bts.gov/data/6_conference/00780082.pdf) Dec. 20, 2001.
- 15 Travel Model Improvement Program. “Quick Response Freight Manual” U.S. Department of Transportation, U.S. Environmental Protection Agency. Sep. 1996
- 16 Nijkamp, R.P., and Tsang W.F. “European Freight Transport Analysis Using Neural Network and Logit Models” Originally accessed at <ftp://zappa.ubvu.vu.nl/19970035.pdf> Jan. 20, 2002.
- 17 Rizzonli, A. E., Fornara,N. and Gambardella L.M. “A Simulation Tool for Combined Rail-Road Transport in Inter-Modal Terminals.” 1998.
- 18 Mastrolilli M., Fornara, N. ,Gambardella L. M., Rizzoli A., and Zaffalon M. “Simulation for Policy Evaluation, Planning and Decision Support in an Intermodal Container Terminal” 1998.

- 
- 19 Gambardella L.M., Rizzoli A. and Zaffalon M. "Simulation and Planning of an Intermodal Container Terminal." SIMULATION, Special Issue on Harbour and Maritime Simulation, 1998.
- 20 Commodity Flow Survey CD-Rom, U.S Department of Transportation bureau of Transportation Statistics. Issued May 2000.
- 21 James J. Brogan, Stephen C. Brich, and Michael J. Demetsky. "Identification and Forecasting of Key Commodities for Virginia," Transportation Research Board, National Research Council, Washington D.C. 2002.
- 22 Eatough, C.J., Brich, S.C., and Demetsky M. J. A methodology for Statewide Intermodal Freight Transportation Planning, Report submitted by Virginia Transportation Research Council to Virginia Department of Transportation. 1998.
- 23 Eatough, C.J., Brich, S.C., and Demetsky M. J. A Statewide Intermodal Freight Transportation Planning Methodology, Transportation Quarterly, Eno Transportation Foundation, Inc. Volume 54, Number 1. 2000.
- 24 Aruna Sivakumar, and Chandra Bhat. "A Fractional Split Distribution Model for Statewide Commodity Flow Analysis." Transportation Research Board, National Research Council, Washington D.C. 2002.
- 25 Michael Fischer, Jeffrey Ang-Olson, and Anthony La, "A Model of External Urban Truck Trips Based on Commodity Flows," Transportation Research Board, January 2000.
- 26 "User Guide for the 1997 Surface Transportation Board Waybill Sample." Association of American Railroads, Washington D.C., July 1998.
- 27 TransCAD-Transportation GIS software, User Guide. Caliper Corporation, Newton, Massachusetts, 2001.
- 28 Official website of Census of Bureau, State and County Quick facts for the State of Mississippi. Originally accessed at <http://quickfacts.census.gov/qfd/states/28000.html>, Feb.20,2002.
- 29 Official website of U.S Census of Bureau on County Business patterns. Originally accessed at <http://www.census.gov/epcd/cbp/view/cbpview.html>. Feb.20,2002.
- 30 1997 Economic Census, Vehicle Inventory and Use Survey. U.S. Department of Commerce. December 1999.
- 32 Freight Transportation in Mississippi- Selected Data from Federal Sources. U.S. Department of Transportation, Bureau of Transportation Statistics. October 1997.
- 33 U.S Department of Transportation, "A Shipper's Guide to Stowage of Cargo in Marine Containers" 1982.
- 34 Official website of Census of Bureau, State and County Quickfacts for the State of Mississippi. <http://quickfacts.census.gov/qfd/states/28000.html>
- 35 Official website of U.S Census of Bureau on County Business patterns. <http://www.census.gov/epcd/cbp/view/cbpview.html>.
- 36 Official website of Occupational Safety & Health Administration of U.S. Department of Labor. <http://www.osha.gov/oshstats/sicser.html>.
- 37 Travel Estimation Techniques for Urban Planning, National Cooperative Highway Research Program (NCHRP) report 365, 1998.



- 
- 38 Black, W. Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2. Transportation Research Center, Indiana University, Bloomington. July 1997.
- 39 Michael Fischer, Jeffrey Ang-Olson, and Anthony La, "A Model of External Urban Truck Trips Based on Commodity Flows," Transportation Research Board, January 2000.
- 40 Gerhardt Muller, "Intermodal Freight Transportation," 4<sup>th</sup> edition, Eno Transportation Foundation, Inc. 1999.
- 41 Krishnan, V., and K. Hancock. "Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems," Transportation Research Record 1625, TRB, National Research Council, Washington D.C., 1998.
- 42 U.S Department of Transportation. "Highway Capacity Manual 2000".
- 43 Alan J. Horowitz, and David D. Farmer. "A Critical Review of Statewide Travel Forecasting Practice," Transportation Research Board, National Research Council, Washington D.C. 1998.
- 44 Woods and Pool Economics. "The Complete Economic and Demographic Data Sources (CEDDS)." Washington D.C. 2001.
- 45 Parsons Brinckerhoff Quade & Douglas, Inc. "Comprehensive Assessment of the Ports of Mississippi," Final report submitted to Mississippi Department of Transportation, January 2000.
- 46 PROMODEL Software Distributed By PROMODEL INC. 2001.
- 47 R. P. Roess, W. R. McShane, and E. S. Prassas. "Traffic Engineering" 2<sup>nd</sup> Edition, Prentice Hall, 1990.
- 48 B. Grady. "Review of the Regional Transportation Commission of Southern Nevada's Draft 2003-2025 Regional Transportation Plan & 2003-2005 Transportation Improvement Plan Conformity Finding," Smart Mobility Inc. 2002.
- 49 Vehicle Classification, Traffic Report, Nevada Department of Transportation. Last accessed on 10/15/2002 [[http://www.nevadadot.com/reports\\_pubs/traffic\\_report/2001/pdfs/Funcclass01.pdf](http://www.nevadadot.com/reports_pubs/traffic_report/2001/pdfs/Funcclass01.pdf)]
- 50 Gulf/Rivers Intermodal Partnership (GRIP), "Where the Rudders Meet the Roads," 2002.