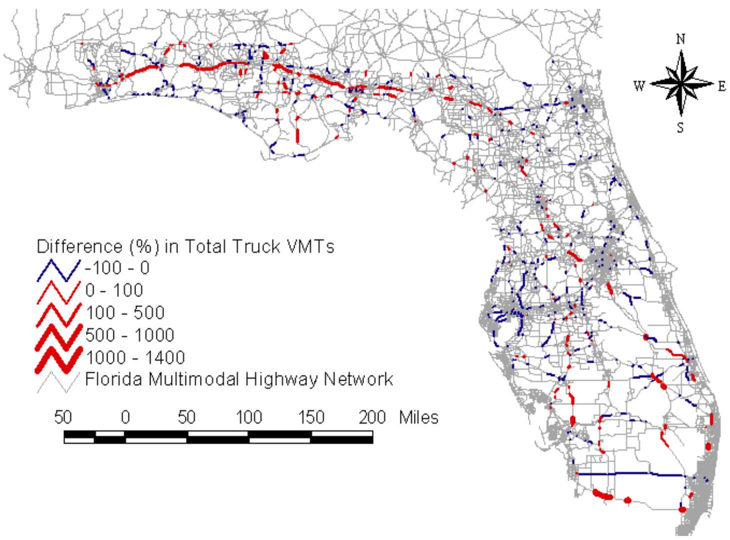
Lehman Center for Transportation Research (LCTR)
Oak Ridge National Laboratory (ORNL)

INTEGRATING DATA AND MODELS FOR ANALYSIS OF FREIGHT MOVEMENTS ON MULTIMODAL TRANSPORTATION SYSTEMS FOR FLORIDA

Final Report



July 2007

Integrating Data and Models for Analysis of Freight Movements on Multimodal Transportation Systems for Florida

Final Report

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16. Abstract

Freight transportation is both multimodal and intermodal in nature, involving highways, railways, waterways, air transportation, terminals, and intermodal transfers. Multimodal and intermodal orientation holds major promise in significantly improving freight transportation efficiency. This project developed the Florida Multimodal Network (FMN), an integrated multimodal network for Florida that combines airway linkages, highways, railways, waterways, and intermodal facilities. The project also developed an impedance function based on both time and cost to characterize mode preferences and a multimodal and intermodal routing procedure. This was done to establish multimodal freight flow patterns on the FMN utilizing the commodity flow O-D data from the 2003 TRANSEARCH database. The results are compared to the observed highway truck VMT data. Recommendations for future research include the development of better cost functions, consideration of congestion effects, refinement of O-D flow data, improvement in freight cost and delay data, and incorporation of the capacity of intermodal facilities.

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ACRONYMS

AAR	American Association of Railroads
ARIMA	Auto-Regressive Integrated Moving Average
BEA	Bureau of Economic Analysis
BTS	Bureau of Transportation Statistics
BNSF	Burlington North and Santa Fe Railway
CFS	Commodity Flow Survey
CN	Canadian National Railway
COFC	Containers on Flatcar
CP	Canadian Pacific Railway
CSX	CSX Transportation
FAF	Freight Analysis Framework
FDOT	Florida Department of Transportation
FEC	Florida East Coast Railway
FXE	Ferrocarril Mexicano (Ferromex)
FGDL	Florida Geographic Data Library
FHWA	Federal Highway Administration
FISHFM	Florida Intermodal Statewide Highway Freight Model
FMN	Florida Multimodal Network
FRA	Federal Railroad Administration
FTI	Florida Traffic Information
GIS	Geographic Information System
GTW	Grand Trunk Western Railroad
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
KCS	Kansas City Southern Railway
LTL	Less Than Truckload
MPO	Metropolitan Planning Organization
NAFTA	North American Free Trade Agreement
NCHRP	National Cooperative Highway Research Program
NORTAD	North American Transportation Atlas Data
NS	Norfolk Southern
NTAR	National Transportation Analysis Regions
NWGISDC	National Waterway GIS Design Committee
NWN	National Waterway Network
ORNL	Oak Ridge National Laboratory
UP	Pacific Railway
QRFM	Quick Response Freight Modeling
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCTG	Standard Classification of Transported Goods
SIC	Standard Industrial Classification
SIS	Strategic Intermodal System
SOO	Soo Line Railroad
SPO	Systems Planning Office (of Florida Department of Transportation)
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Code
STFM	Statewide Travel Forecasting Model

TAS	Transportation Annual Survey
TAZ	Traffic Analysis Zone
TBSFD	Transborder Surface Freight Data
TCI	Traffic Characteristics Inventory
TEA 21	Transportation Equity Act for the 21st Century
TFM	Transportación Ferroviaria Mexicana
TIUS	Truck Inventory and Use Survey
TOFC	Trailer on Flatcar
UP	Union Pacific Railway
USACE	U.S. Army Corps of Engineers
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Mile Traveled

EXECUTIVE SUMMARY

Freight transportation is both multimodal and intermodal in nature, involving highways, railways, waterways, air transportation, terminals, and intermodal transfers. Multimodal and intermodal orientation holds major promise in significantly improving freight transportation efficiency. Wise investment in the development of multimodal and intermodal infrastructure can effectively remove major bottlenecks on freight networks, expand shipping alternatives, reduce congestion and environmental impact, and improve safety and efficiency of the entire transportation system.

The Systems Planning Office (SPO) of the Florida Department of Transportation (FDOT) has been working on providing better tools to facilitate SIS analysis and planning. Past efforts by the FDOT have generated some useful models, data, and tools, but they mainly focus on the highway modes and fall short of providing data on multimodal transportation systems that are required for intermodal transportation planning or taking intermodal freight into consideration, thus seriously limiting the ability to analyze intermodal freight movements and to evaluate the need for improving intermodal facilities.

In this project, a multimodal network that combines airway linkages, highways, railways, waterways, and intermodal facilities has been developed to form an integrated, analytical freight network, referred to as the Florida Multimodal Network (FMN). The network consists of five separate sub-networks, each of which represents a specific mode. The sub-networks are interconnected by special links that represent the intermodal transfer facilities and that allow freight movements to change mode by flowing from one sub-network to another.

An intermodal routing procedure has been implemented to establish multimodal freight flow patterns on the FMN. The project directly utilized the commodity flow O-D data from the 2003 TRANSEARCH database. To facilitate the flow assignment process, point locations or regional centroids were generated to represent flow origins and destinations. Access links were generated to link flow origins and destinations to the multimodal transportation network. For computational efficiency, five O-D tables were generated separately: 1) the intermodal O-D table, 2) the highway O-D table, 3) the railway table, 4) the waterway O-D table, and 5) the airway O-D table.

For intermodal commodity flow routing for different modes or for a combination of multiple modes, three basic impedance factors were evaluated: the transportation distance, the time spent on the shipment, and the cost involved. An impedance function that considers both the time and the cost was introduced to characterize the mode preference when the O-D table provides preference for a specific mode or modes. When mode preference was given to air transportation, travel time was utilized to assign the flows to the network. When mode preference was given to waterway transportation, travel cost would be utilized. When mode preference was given to highways or railways, cost and time were factorized together to provide a preference indicator to trucks or rail shipments. For intermodal, the same impedance preference for rail was utilized because, in the intermodal case, most of the intermodal shipments were originally listed in the rail O-D table. However, other modes (e.g., waterways and highways) were also allowed to serve as alternatives. Flow assignment with the five O-D tables, except for the highways table, all involved intermodal routes. For the waterway O-D table, for example, the flow loading process first identified routes that start with highways, then switch to waterways, and then come back to highways again. This is the same for railways and airways, while for the intermodal flow O-D table, routes were identified on the entire multimodal network with preference given to railways, waterways, and highways. The resulting flow patterns with the five O-D tables were then aggregated to a single network, which provides the finalized flow patterns on the FMN.

Due to limited data, the modeled flows cannot be effectively validated. Because highway data are available on slightly more than 2,000 count stations statewide, the model result was evaluated using the observed truck vehicle-mile-traveled (VMT). The total highway VMT is 13% less than the observed. Note that the TRANSEARCH database does not include commodity flows within counties, contributing to the difference in the VMT. In general, the model tended to over-assign flows to roads of a higher function class because the traffic assignment was based on shortest paths and congestion was not considered. This and the exclusion of intra-county commodity flow in the TRANSEARCH database also contribute to the generally under-assigned VMT on urban roads.

Many challenges remain in commodity flow analysis on multimodal transportation networks. The methods and models developed to generate the flow patterns are still theoretical and have limited accuracy to address application needs. There are several areas that are perceived as valuable for future research. One is the characterization of mode preference on the multimodal transportation system to derive preference functions by linking the mode choice decisions when O-D tables are generated. Information on congestion, intermodal bottlenecks, and some other cost or time constraints may also be helpful when the mode preference functions are determined.

The second area is to improve the flow loading process when multimodal freight flows are assigned to the network. Some of the simple improvements may include the incorporation of information on roadway capability or observed traffic counts into the loading procedure. That is, when flows reach capacity or observed flow limits, alternative routes would be considered. This will help reduce the overloading of links. Other measures, such as added cost or time for congestion, can be used to allocate flows to less-utilized links. In this way, consideration can be given to factors such as competition between different modes or system flow adjustment for congestion reduction.

The third area is in the data. Because of the lack of data on transportation networks, O-D flows, cost, delay, and capacity of the intermodal facilities, it is difficult to drill down the model to a detailed level. The most demanding data, of course, are the commodity O-D tables. The adaptation of the FAF O-D tables for use by state DOTs is certainly possible, but how about to adapt the county level O-D tables to traffic analysis zones? Much of the existing data are still too aggregated and lacking details, making them less useful for planning decisions. In particular, many of the intermodal transportation decisions involve pubic and private partnerships. The use of more accurate data is critical in gaining public confidence when these transportation decisions are made by the government.

1. INTRODUCTION

Freight transportation is both multimodal and intermodal in nature, involving highways, railways, waterways, air transportation, terminals, and intermodal transfers. Multimodal and intermodal orientation holds major promise in significantly improving freight transportation efficiency. Publicly funded transportation projects, particularly those concerning freight transportation, are no longer restricted to highways. Instead, more focus has been placed on freight corridors, ports, terminals, and intermodal connectors and facilities. Wise investment in the development of multimodal and intermodal infrastructure can effectively remove major bottlenecks on freight networks, expand shipping alternatives, reduce congestion and environmental impact, and improve safety and efficiency of the entire transportation system. Recent legislations such as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Transportation Equity Act for the 21st Century (TEA 21), enacted in 1998, and the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy For Users (SAFETEA-LU) have highlighted the needs for inclusion of freight transportation in the transportation planning process. Florida also passed its own legislation (s. 341.053) that established an Intermodal Development Program (Dewey *et al*. 2003). The Florida Department of Transportation (FDOT) is currently required by law to develop a statewide transportation plan based on principles outlined in ISTEA, for which intermodalism is a major focus.

Despite the increasing attention to freight transportation, freight data that are required to support intermodal transportation decisions are still lacking. A large portion of the data that are available come from heterogeneous sources such as private databases, census surveys, or results derived from analytical models. These data, in many cases, have an uneven quality and gaps. Recent efforts by the FDOT, such as urban highway freight modeling and the development of the Florida Intermodal Statewide Highway Freight Model (FISHFM) have generated some useful models (Cambridge Systematics 2003a, FDOT 2003b). These models will facilitate data development for freight flow generation, distribution, model choices, and flow assignment. Nevertheless, data derived from these models are mainly for highways. The methodologies also only focus on the highway modes. When transportation projects go beyond highways, which is the case for intermodal transportation that focuses more on freight corridors and intermodal facilities, these models fall short of providing data on multimodal transportation systems that are required for intermodal transportation planning or taking the intermodal freight into consideration. Thus, the ability to analyze the intermodal freight movements and evaluate the needs for improving intermodal facilities is seriously limited. To support SPO's SIS activities, integrated data and models for freight analysis covering the entire transportation system, which includes highways, railways, waterways, air transportation, terminals, and intermodal facilities, are needed.

The goal of this project is to build on the results from past freight modeling efforts to expand the freight network from a highway-only network to a multimodal and intermodal network that includes air, sea, waterway, and rail modes in addition to the highway mode. The specific objectives of the project are to:

1) Gain an understanding of the challenges in intermodal and multimodal freight modeling;
2) Identify and evaluate data that are useful for intermodal and multimodal freight modeling;

3) Design and develop procedures to construct an interconnected multimodal model network, and use this model network to facilitate freight data integration from different sources;
4) Develop procedures to implement freight flow modeling functions; and
5) Develop insights into future improvements in freight modeling data and techniques.

To achieve these objectives, the project utilizes the tools that have been developed at the Oak Ridge National Laboratory, such as analytical freight network development, freight routing, and freight flow assignment on the intermodal transportation network, and the tools and data resources that already exist at FDOT. The flow patterns established in this project are not only on highways, but also on other major transportation modes, e.g., railways, waterways, air transportation, and intermodal facilities. This will allow transportation planners and decision-makers to be able to use these data to evaluate the conditions and performance of freight transportation under different scenarios and to identify major bottlenecks and analyze congestion and delays in the multimodal transportation systems.

In the second chapter of this report, an overview of relevant freight transportation data and demand studies is provided. In Chapter 3, the locations of intermodal facilities are described. Chapter 4 is a summary of the development of the FMN, particularly the incorporation of air terminals and interconnection links into the FMN. The preparation of the commodity flow origin and destination (O-D) data, including the construction of the O-D centroids and access links between O-D centroids and the multimodal network is the focus of Chapter 5. In Chapter 6 the intermodal routing mechanisms used in this research are explained, particularly the development of the impedance factors used to evaluate decisions on the mode preference during the flow loading process. The model validation results are presented in Chapter 7. Finally, conclusions are provided in Chapter 8, along with discussions on the need for future research that may help bridge gaps between research and applications.

2. LITERATURE REVIEW

This chapter provides an overview of the freight transportation demand studies. Section 2.1 provides a description of various sources of existing freight data, including their update frequency and availability. The data sources include the federal government, local governments, and proprietary databases. Section 2.2 is a summary of current freight modeling techniques, including trend and time series analyses and aggregate demand models. In Section 2.3, selected statewide freight transportation demand models are described. Finally, the CUBE CARGO program is reviewed in Section 2.4.

2.1 Freight Data

Appropriate use of existing data helps reduce time and effort in the development of statewide models. This chapter describes several data sources available in both the public and private domains that may be used in freight transportation demand analysis.

2.1.1 Commodity Flow Survey

The Commodity Flow Survey (CFS) is perhaps the most complete public domain source for freight flow data in the U.S. Mandated by Congress, the CFS is conducted through a partnership between the U.S. Census Bureau and Bureau of Transportation Statistics (BTS) and is designed to collect shipment data from approximately 100,000 freight shippers in the economic sectors of mining, manufacturing, and wholesales in the U.S. every five years (Southworth and Peterson 2000). Retail mail-order houses, auxiliary warehouses, administrative offices, and other multi-establishment companies are also included. Industries that are not covered in the CFS include (BTS 2002):

- Most retail,
- Services,
- Transportation,
- Farms and fisheries,
- Government,
- Construction,
- Oil and gas extraction, and
- Foreign establishments.

In the CFS, a shipment is an individual movement of commodities from an originating establishment to one customer or to another location of the same multiple-establishment firm. Imports are not accounted for until they reach the first domestic shipper covered by the CFS, nor are shipments “in-transit” through the United States. In the survey, shipments were sampled quarterly in the reference year. Samples in the CFS are selected based on a three-stage sampling design. In the first stage, establishments available from the U.S. Census Bureau Business Register are stratified by industry, geography, firm size, and type of organization. A stratified simple random sampling is then performed to select establishments in each stratum. In the second stage, the selected establishments are sorted by geography, industry, and size. Each selected establishment is then systematically assigned a reporting week for which the establishments must report their shipments in each of the quarters. The final stage is for each selected establishment to sample its outbound shipments by first creating a complete and unduplicated sampling frame of shipments made in the reporting week. The selected establishments then sample the shipments systematically based on the rates given in Table 2-. Finally, the establishment reports the data on selected shipments. Information on origin and destination (O-D) zip codes, the five-digit standard classification of transported goods (SCTG) code, weight, value, modes of transport, and mode sequence for each sampled shipment is collected and reported. However, because original routing information is not collected in the CFS, the mileage for moving freight from one place to another may not be obtained directly. The CFS shipment distances are computed using the Oak Ridge National Laboratory (ORNL) routing models and a version of the ORNL Multimodal North American Transportation Network database. Shipment mileages and ton-mileages reported in the CFS are based on these distance computations. Export shipment distances are also based on this approach. In this case, only the portion of shipment distances within the U.S. is reported.

Table 2-1 Shipment selection rates by total number of shipments

Total number of Shipments	Selection Rate	Total number of Shipments	Selection Rate
1-40	1	801-1600	40
41-80	2	1601-3200	80
81-100	3	3201-6400	160
101-200	5	6401-12,800	320
201-400	10	> 128,00	Call Census for Instruction
401-800	20		

Although the data are collected at the zip code level, the original data are not available to the public. Data that are released to the public are at the state level. Data are also available for 89 National Transportation Analysis Regions (NTARs), with each NTAR representing one or more Bureau of Economic Analysis economic areas.

CFS is updated every five years covering years ending in 2 and 7. The most recent CFS available was conducted in 2002.

The ORNL's routing model, used in computing the shipment- and ton-mileages, was developed by Southworth and Peterson (2000). Southworth and Peterson first developed two intermodal networks, truck–rail–waterways (TRW), and truck-air (TA) networks to allow routes to be enumerated based on reported mode sequences between any pair of zip codes. The TRW network, as illustrated in Figure 2-1, was built by combining the following digital databases:

- The ORNL National Highway Network and extensions to the main highways in Canada and Mexico,
- The Federal Railroad Administration's (FRA) National Rail Network and extensions to the main rail lines in Canada and Mexico,
- The U.S. Army Corps of Engineers National Waterways Network,
- The Trans-Ocean Network,
- The National Intermodal Terminals Database, and

- The five-digit zip code boundary.

A "most-likely" route is generated by linking the shortest paths in two single-mode networks through additional links representing an intermodal truck-rail (TR), truck-water (TW), or water-rail transfer terminal. A set of terminal access and egress links is then generated to connect the transfer terminals (or links). Figure 2-2 illustrates the connections built for a truck-rail-truck (TRT) shipment. As shown in the figure, a set of access links is generated on the highway sub-network, where the shipment's origin is located. Similarly, a set of egress links is created on the destination's highway sub-network. Several sets of intermodal truck-to-rail transfer links within the terminal are also created to allow commodity shipments to transfer between truck and rail modes.

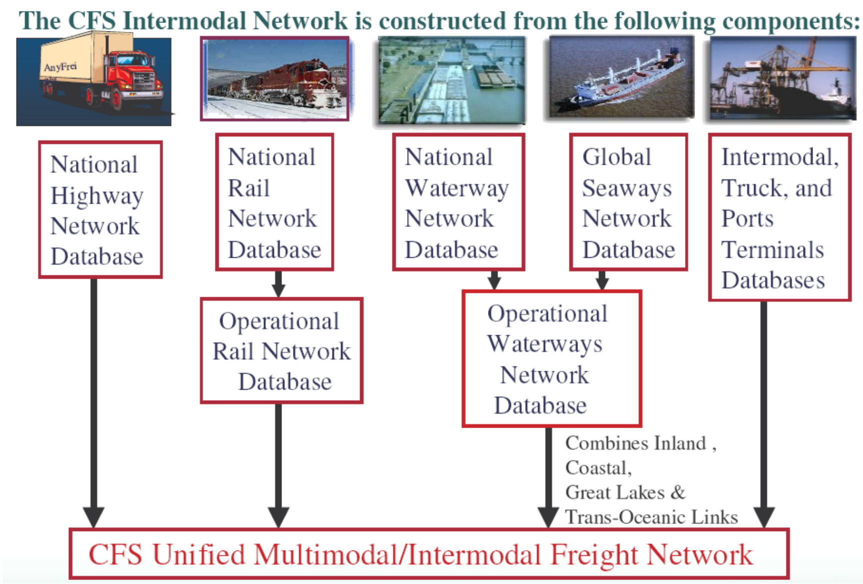

Figure 2-1 Components of CFS intermodal network database (Southworth and Peterson 2003)

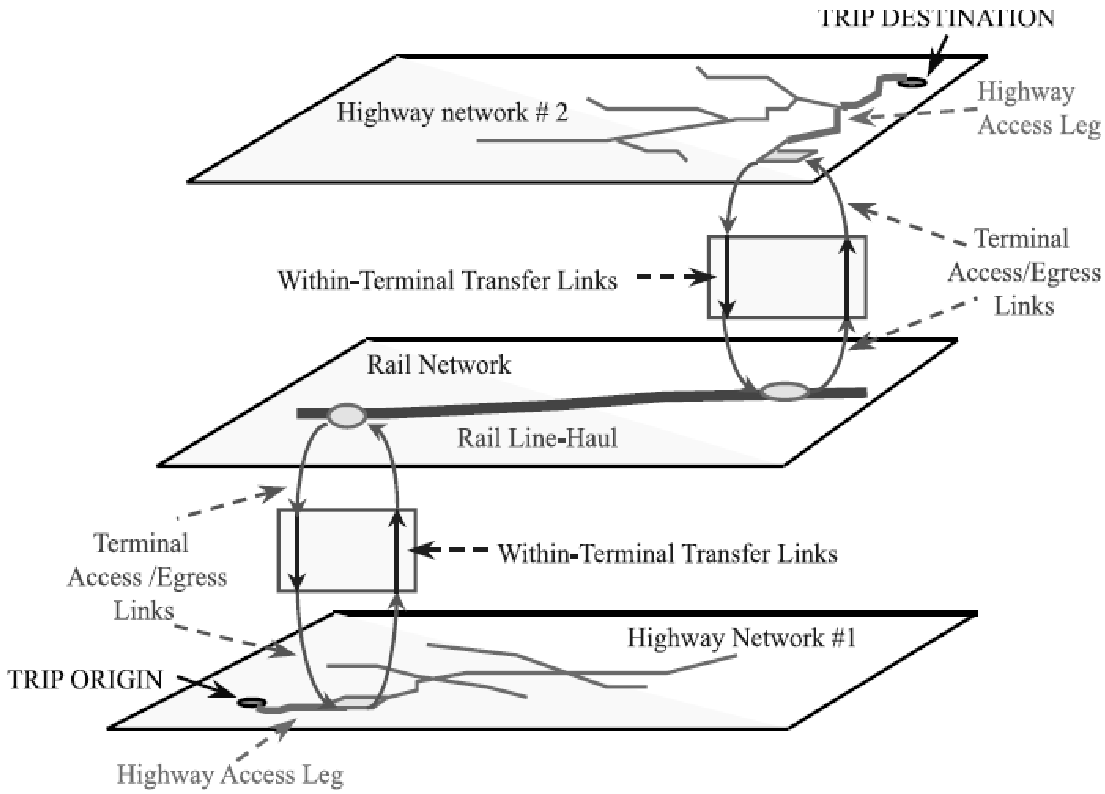

Figure 2-2 Construction of a multi-layer intermodal shipment routing (Southworth and Peterson 2000)

The routing algorithm searches for appropriate network access or egress connections within a buffer area defined by Equation (1):

$$R_z = RMAX_z + 2e + p \tag{1}$$

where:

R_z = radius of the buffer area around the centroid of zip code area z;
$RMAX_z$ = straight-line distance from the centroid to the farthest point on the zip code area boundary,
e = root mean square geographic error in the network's representation of link locations; and
p = maximum length of a local access connector that is not included in the mode-specific network databases.

The initial values used in Equation (1) to search for possible network access or egress points are shown in Table 2-2. For highway access, for example, the access distance is approximated by finding the straight-line distance from the zip code zone centroid to the nearest point on the network in three mutually exclusive sectors, as illustrated in Figure 2-3. The sectors are defined by finding the nearest point on the highway network. The point is then used as the center of the first sector to determine the boundaries of the other two sectors. In the presence of river barriers, the resulting network access distances are multiplied by 1.2 to represent the local highway network circuitry.

Table 2-2 Mode specific default values of access model parameters (Southworth and Peterson 2000)

Parameter	Highway[1]	Rail	Inland & Great Lakes	Deep Sea
p	0.00 (0.00)	4.97 (8.00)	4.97 (8.00)	6.22 (10.00)
$2e$ (Domestic)	0.22 (0.35)	1.86 (3.00)	1.86 (3.00)	1.86 (3.00)
$2e$ (Foreign)[2]	6.22 (10.00)	18.65 (30.00)	31.08 (50.00)	31.08 (50.00)

Notes:
1. Distances are in miles (kilometers in parentheses).
2. For Canada and Mexico.

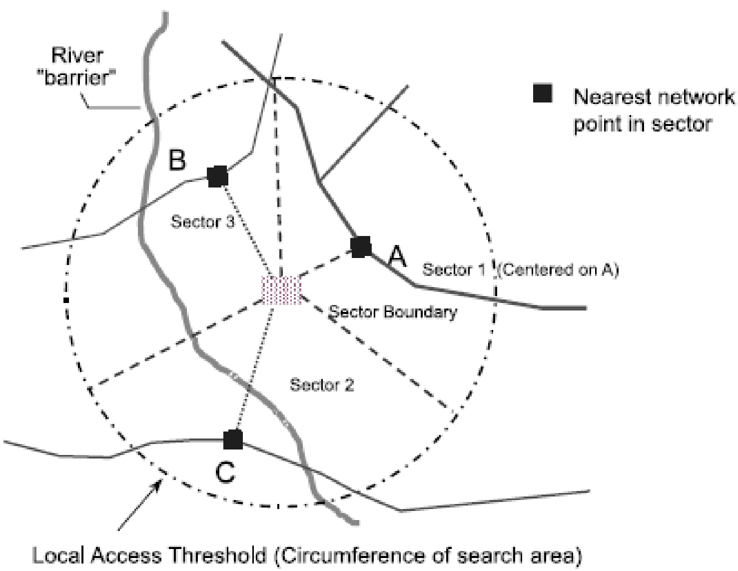

Figure 2-3 Buffer for searching access links (Southworth and Peterson 2000)

In addition to searching for the network access/egress links, explicit transfer facilities for various modes and the network-to-terminal access links are also identified at specific geographic locations. Although different from connecting two different modes of transport directly, the transfer facilities allow the changes in any components of transfer cost to be specified without recalculating the composite cost associated with each bi-modal link. The approach, thus, allows a more realistic representation of within-terminal versus outside-terminal operation. Multiple terminal sets or models may be specified on the same network to improve the efficiency in searching for shortest paths.

Link specific impedances are subsequently developed to represent the generalized cost of different en-route activities and ensure the selection of sensible routes. The costs include:

- Local access to major traffic ways and terminals;
- Within-terminal transfer activities such as loading and unloading between modes, vehicles, and railroad carriers;
- Negotiation of border crossings; and
- Line-haul costs in different corridors.

In finding the shortest path for a given commodity shipment, the impedance for a link of a specific mode is first determined. For example, the impedance for a highway link is basically a surrogate of travel time, determined by considering the following link attributes:

- Distance,
- Urban and rural functional class,
- Link traversal speeds in terms of traffic conditions,
- Access controls,
- Toll,
- Designated/unconstrained truck route, and
- Divided/undivided roadway.

For railroad routing, a railroad route is determined by "main line class," a subjective classification established primarily based on traffic volumes. Table 2-3 shows the line classifications and the relative impedance factors used to estimate the impedance on a given railroad link. Impedances are also assigned to the interline points, where railcars are transferred between separate railroad companies.

For waterway routings, the differences in impedances and the costs of transferring cargo from or to shallow draft barges are incorporated in the path building process. After the impedance for the links in each mode-specific network is quantified, the relative costs of transport between different modes are applied to obtain the unified intermodal impedance at the route level. The relative modal impedance weighting factors, as shown in Table 2-4, are used to multiply the impedance associated with the links of interest in the network.

Table 2-3 Railroad line haul classifications (Southworth 2003)

Line-Class	Annual Gross Tonnage	Relative Impedance Factor
A-Main	> 20 million	1.00
B-Main	10 – 20 million	1.15
C-Main	5 – 10 million	1.25
A-Branch	1 – 5 million	1.90
B-Branch	≤ 1 million	4.00

Table 2-4 Relative modal impedance factors (Southworth 2003)

Mode	Modal Impedance Weight
Highway	1/1.0
Railroad	1/3.5
Inland Water	1/5.8
Great Lakes	1/6.6
Ocean	1/7.0

The single shortest paths identified on the highway and waterway networks are then used to assign commodity shipments. For the railroad network, however, it is common to identify more than one carrier-specific route in the path searching process. As a result, shipment volumes are spread across a limited number of rail routes using a logit assignment model that is calibrated with the data collected from the Surface Transportation Board's annual railcar waybill survey. The model is shown as follows (Southworth 2003):

$$P(r) = \frac{\exp(a.Ir)}{\sum_{r=1,R} \exp(a.Ir)} \tag{2}$$

where:

a = a model parameter to be determined that represents the sensitivity of route choice to additional impedance units;

Ir = impedance (generalized travel time) of a route, r; and

R = the total number of routes for a given pair of origin and destination.

A route is considered unreasonable when one or more of the following criteria are met:

- A high route circuitry factor,
- An unlikely split between different modal mileages, or
- A contradiction to engineering knowledge.

Unlikely splits between modal mileages occur when the routing algorithm selects paths with long mileages on a more expensive mode rather than a less expensive one. The paths in question typically involve truck–rail intermodal movements. To deal with this problem, two models, the "major terminals" model and "distributed terminals" model, are developed for searching for the shortest path for shipments with rail in their reported mode sequences. As illustrated in Figure 2-4, containerized freight is processed by the major terminals model where transfers between truck and rail modes are allowed to occur only at one of 256 truck–rail containerized cargo terminals, identified from more than 2,900 records in the 1997 ORNL intermodal terminals database.

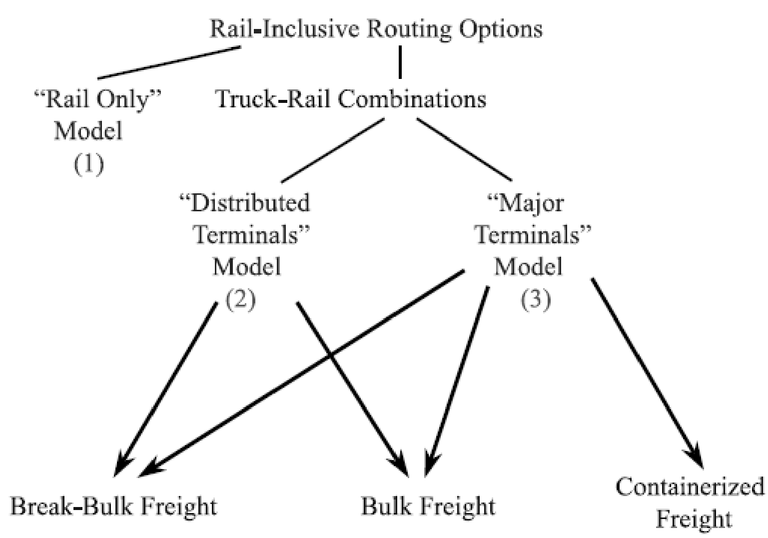

Figure 2-4 Family of rail-inclusive freight shipment routing models (Southworth and Peterson 2000)

For non-containerized freight, the complete ORNL terminals database is used as the input to the major terminals model for route search. The distributed terminals model is subsequently applied when the paths given by the major terminals model are unreasonable in terms of high circuitry and/or a high proportion (25%) of highway distance among the entire route length. The model first identifies the closest node within 90 miles of the shipment origin or destination in each rail company's sub-network as the location of a hypothetic transfer facility. A highway route is then constructed to connect the shipment origin/destination with the terminal.

When mode sequence information is missing or incomplete, the intermodal network is used to derive the missing intermodal connections and mileages with appropriate routing algorithms. For example, U.S. port-of-exit data are missing from the original data source. In this case, the route-searching algorithm determines the exit port based on the minimum impedance, calculated by adding the deep sea impedance with those estimated within the U.S. for the truck, rail, and/or waterway modes for a given shipment. The resulting route mileages are then used to estimate the ton-miles and dollar-miles of freight activities by modes and commodity types at the national, state, and regional levels.

2.1.2 Transborder Surface Freight Dataset

The Transborder Surface Freight Dataset (TBSFD) contains freight flow data by commodity type and by surface mode of transportation (rail, truck, pipeline, or mail) for U.S. exports to, and imports from, Canada and Mexico with geographic detail (BTS 2005a). The dataset is extracted from the Census Foreign Trade Statistics Program. The dataset, updated monthly and available since April 1993, is composed of two sets of tables; one is commodity-based while the other provides geographic detail at the state and port levels. Its objective is to provide transportation information on North American trade flows. Shipments, which neither originate nor terminate in the U.S., are not included in the dataset. Currently, the TBSFD are being used to monitor trans-border freight flows since the beginning of the North American Free Trade Agreement (NAFTA) in 1994. Other uses of this database include trade corridor studies, transportation infrastructure planning, logistics strategy analysis, etc. Currently, March of 2007 is the most recent month with TBSFD.

2.1.3 Transportation Annual Survey

The Transportation Annual Survey (TAS), formerly known as the Motor Freight Transportation and Warehousing Survey, is carried out annually by the U.S. Census Bureau (Census 2005a). It provides detailed national estimates of operating revenues and expenses for the for-hire trucking and public warehousing industries, as well as inventories of revenue-generating freight equipment for the trucking industry. The survey excludes private motor-freight carriers operating as auxiliary establishments to non-transportation companies and independent owner-operators with no paid employees. This annual sample survey represents all firms identified by the Standard Industrial Classification (SIC) code 42 with one or more establishments that are primarily engaged in providing commercial motor freight transportation or public warehousing services. The SIC code 42 has the following subgroups:

- SIC 421 - Trucking and Courier Services, except Air;

- SIC 422 - Public Warehousing and Storage; and
- SIC 423 - Terminal and Joint Terminal Maintenance.

The results of this survey are summarized by the SIC codes. The most recent data year is 1998.

2.1.4 Vehicle Inventory and Use Survey

The data available from the Vehicle Inventory and Use Survey (VIUS), known before 1997 as the Truck Inventory and Use Survey (TIUS), provide the physical and operational characteristics of the nation's private and commercial truck population (Census 2005b). Its primary goal is to produce national and state-level estimates of the total number of trucks. The data are collected from a mail survey of private and commercial truck companies. This survey is conducted every five years. It covers private and commercial trucks registered (or licensed) in the U.S., excluding vehicles owned by federal, state, or local governments. Ambulances, buses, motor homes, farm tractors, unpowered trailer units, as well as trucks reported to have been sold, junked, or wrecked prior to July 1 of the year proceeding the survey are also excluded. The dataset includes the following physical characteristics of a truck:

- Date of purchase,
- Weight,
- Number of axles,
- Overall length,
- Type of engine, and
- Body type.

The data on operational characteristics include:

- Predominant type of use,
- Lease characteristics,
- Operator classification,
- Base of operation,
- Gas mileage,
- Annual and lifetime miles driven,
- Weeks operated,
- Commodities hauled by type, and
- Hazardous materials carried.

The VIUS data may be used to determine the average cargo weight for various truck configurations to convert commodity tons to trucks. The latest data year for the VIUS is 2002. The Geographic Area Series of the VIUS include 52 data releases available for the United States, each state, and the District of Columbia.

2.1.5 Carload Waybill Sample

The Surface Transportation Board (STB) Waybill Sample is an annual sample of freight movements terminating on railroads in the U.S. (STB 2005). Railroad carriers are required to submit waybill samples to the STB if more than 4,500 revenue carloads are carried in any of the three preceding years. The sample size is approximately 2.5~3.0% of all rail traffic, and in recent years has exceeded 550,000 records per year. The sample includes waybill information from Class I, Class II, and some of the Class III railroads. Freight railroads are classified by the American Association of Railroads (AAR) based on annual gross operating revenue. The defining revenue cutoff points are updated periodically to adjust for inflation. For example, as of late 2004, Class I railroads are line haul freight railroads with an annual gross operating revenue over approximately $277.7 million (FRA 2005). Class I railroads in the U.S. include the Union Pacific Railway (UP), Burlington North and Santa Fe Railway (BNSF), CXS Transportation (CXS), Norfolk Southern (NS), Canadian National Railway (CN), Grand Trunk Western Railroad (GTW, part of Canadian National Railway), Soo Line Railroad (SOO, part of CN), Canadian Pacific Railway (CP), TFM (a subsidiary of Grupo Transportación Ferroviaria Mexicana), Ferrocarril Mexicano (Ferromex) (FXE), and Kansas City Southern Railway (KCS). According to the AAR (2000), in 2000 the Surface Transportation Board defined a Class I railroad as one with annual gross revenue of at least $261.9 million. Class II railroads are those with an annual gross operating revenue between $21.0 million and $261.9 million. Class III railroads are those with an annual gross operating revenue below $21.0 million. Exclusions of the Waybill Sample are:

1) Regional Railroad – a non-Class I, line-haul railroad operating 350 or more miles of road or with revenues of at least $40 million or both.
2) Local Railroad – a railroad that is neither a Class I nor a Regional Railroad, and is engaged primarily in line-haul service.
3) Switching and Terminal Railroad – a non-Class I Railroad engaged primarily in switching and/or terminal services for other railroads.

The master waybill file contains specific station, railroad, and revenue information. Consequently, access to the master file is restricted to railroads, federal agencies, state governments, transportation practitioners, consultants, and law firms with formal proceedings before the STB or State Boards. A potential user of the master waybill file must first obtain permission from the STB for a particular use. There is also a Public Use file that contains aggregate non-confidential rail shipment data such as origin and destination points, intermediate railroads and junctions, type of commodity, number of cars, tons, revenue, length of haul, and interchange locations. Movements are reported at the Bureau Economic Analysis (BEA)-to-BEA level and the five-digit Standard Transportation Commodity Code (STCC) level. A BEA area consists of one or more economic nodes that serve as regional centers of economic activities and the surrounding counties that are economically related to the nodes. The Waybill Sample data may be used to develop the conversion factor of freight tons to railcar number and to determine the most common types of railcars used to transport commodities. The latest data year available is 2002. However, on November 17, 2004, the Bureau of Economic Analysis (BEA) redefined the BEA economic areas to better reflect changes in economic growth and population in U.S. regions (Johnson and Kort 2004). Caution should be used to ensure consistency in geographic units when the Waybill Sample data are used along with other freight data.

2.1.6 North American Transportation Atlas Data

The North American Transportation Atlas Data (NORTAD) is a geographic database for transportation facilities in Canada, Mexico, and the U.S. The database is designed for use with Geographic Information System (GIS) software packages to locate transportation features. The geospatial information for transportation modal networks and intermodal terminals and related attribute information contained in the database are most useful at the national level. They may also be applied in the applications at the regional, state, and local scale. However, no specific connections between modes and terminals are provided. The data dictionary and data format are described in (BTS 2005b). The most current data year is 1998.

2.1.7 U.S. Waterway Data

The U.S. Waterway Data comprise a public accessible dataset related to the navigable waters in the U.S., including inland waterways, offshore waters, the Great Lakes, and the Saint Lawrence Seaway (NDC 2005). Data on commerce, facilities, locks, dredging, imports and exports, and accidents are included, along with the geographic waterway network. The data are available in both text delimited and DBF formats that may be easily imported into spreadsheets, databases, or GIS applications. The following subsections describe the data subjects included in the waterway data that may be useful in statewide freight modeling.

2.1.7.1 Foreign Cargo

The foreign import and export files are predominately cargo flows between overseas ports and U.S. ports located on coasts, inlands, and waterways. They contain shipment tonnage information at the port level for every calendar year between 1997 and 2004. The combined tonnage of all ports will not equal the national total for imports or exports because cargo flows in-transit through the U.S. are also included.

2.1.7.2 Principal Ports

The principal port file contains port codes, geographic locations in longitude and latitude, port names, and commodity tonnage summaries in total tons, as well as the tonnage in terms of domestic, foreign, imports, and exports for principal ports. The most recent data year is 2005. Table 2-5 describes the data attributes contained in both the foreign import and export files.

Table 2-5 Data attributes in foreign cargo import and export files

Attribute	Description
YEAR	Statistical year of the file
TYPE_PROC	Regular or in-transit
PORT	U.S. port code
PORT_NAME	Description of the U.S. port code
SCHED_K	Five-digit foreign port code known as Schedule K
CTRYCODE	Four-digit foreign country code known as Schedule C
CTRYNAME	Description of the four-digit foreign country code
PMS_COMM	Two-digit code for describing commodities
TONNAGE	Cargo tonnage in short tons (2,000 lbs)

2.1.7.3 Schedule K Classification of Foreign Ports

The data provide port and country codes and names of the major ports of the world that directly handle waterborne shipments to and from U.S. ports. Table 2-6 describes the data attributes contained in the database. The most recent data year is 2005.

Table 2-6 Data attributes in schedule K classification of foreign ports

Attribute	Description
FPRTCODE	Port code for major foreign port
FPRTNAME	Description of the foreign port
PRIMPORT	"1" for the primary port and "2" for the secondary ports assigned with the same foreign port code
CTRYNAME	Description of the country
CTRYCODE	Four-digit foreign country code known as Schedule C
LATITUDE	Latitude of the foreign port with five decimal digits
LONGITUDE	Longitude of the foreign port with five decimal digits

2.1.7.4 State Tonnages

The database contains annual waterborne tonnage between states, within states, and to foreign locations in units of k-tons (1000 tons). Table 2-7 lists the data attributes contained in the database. The most recent data year is 2005.

Table 2-7 Data attributes in state tonnage file

Attribute	Description
STATE	State name of origin
GRANDTOT	Grand total k-tons
SDOMTONS	Shipping to domestic in k-tons
SFORTONS	Shipping to foreign in k-tons
RDOMTONS	Receiving from domestic in k-tons
RFORTONS	Receiving from foreign in k-tons
INTRATON	Intrastate k-tons

2.1.7.5 State-to-State and Region-to-Region Commodity Tonnages

The public domain data files provide state-to-state and region-to-region tonnages by origin and destination for the 14 major commodity groups listed in Table 2-8.

Table 2-8 Public domain major commodity groups

Commodity Code	Description
1000	Coal, Lignite, and Coal Coke
2100	Crude Petroleum
2229	Petroleum Products
3100	Chemical Fertilizers
3200	Chemicals excluding Fertilizers
4142	Lumber, Logs, Wood Chips, and Pulp
4349	Sand, Gravel, Shells, Clay, Salt, and Slag
4400	Iron Ore, Iron, and Steel Waste and Scrap
4600	Non-Ferrous Ores and Scrap
5155	Primary Non-Metal Products
5354	Primary Metal Products
6168	Food and Food Products
7000	Manufactured Goods
8099	Unknown and Not Elsewhere Classified Products

Table 2-9 shows the data attributes in both state-to-state and region-to-region tonnage files. The most recent data year for both databases is 2005.

Table 2-9 Data attributes in state-to-state and region-to-region tonnage files

File	Attribute	Description
State-to-State	Origin	Origin state in abbreviation
	Dest.	Destination state in abbreviation
	Commodity	Public domain commodity code
	Tons	Annual tonnage
	Year	Four-digit year
Region-to-Region	Origin	Origin region
	Dest.	Destination region
	Commodity	Public domain commodity code
	Tons	Annual tonnage
	Year	Four-digit year

2.1.7.6 Waterborne Commerce

Four files, each for a specific geographical area, contain the statistics for the foreign and domestic waterborne commerce moved on the U.S. waters in k-tons. Table 2-10 describes the data attributes in each file. The most recent data year is 2005.

Table 2-10 Data attributes in water commerce file

Attribute	Description
TRANS_TYPE	1 = cargo, 2 = ton-miles, 3 = trips
REC_TYPE	0 = Non-published cargo, 1 = Cargo, 2 = Foreign in-transit, 3, 4 = Cargo, 5 = Trips, 6 = Unpublished trips, 7 = Passengers/Units, 8 = Totals
TRAFFIC	00 = Foreign Trip & Draft, 01 = Domestic T&D, 11 = Foreign Imports, 12 = Foreign Exports, 21 = Canadian Imports, 22 = Canadian Exports, 30 = Coastwise, 40 = Lakewise, 50 = Internal, 70 = Local, 80 = Intraterritory, 90 = Ferry
WTWY	WCSC Waterway Code
PUB_GROUP	Publication Commodity Group
ALLO1	1 = Inbound Receiving, 2 = Outbound
ALLO2	1 = Upbound or East or North, 2 = Downbound or West or South
TONS	Short tons in thousands (0 means less than 500 tons)
Year	Calendar year the movement took place based on date of unloading

2.1.7.7 National Waterway Network

The National Waterway Network (NWN) is a geographic database of navigable waterways in and around the U.S. The network is composed of links and nodes, with links representing either actual shipping lanes or serving as representative paths in open water and with nodes representing physical entities such as ports/facilities and intermodal terminals. The metadata are available at http://www.iwr.usace.army.mil/ndc/data/dictionary/ddnwn.htm. The databases were developed by ORNL and Vanderbilt University, with input from the National Waterway GIS Design Committee (NWGISDC). The latest data-publishing year is 2006.

2.1.7.8 Waterway Network Link Commodity Data

The data contain the tonnage summarized for each link on the NWN by commodity and direction (i.e., upbound and downbound). The commodities include coal, petroleum products, chemicals, crude materials, manufactured goods, farm products, machinery, waste, and unknown. The most recent data year is 2005.

2.1.8 TRANSEARCH and Freight Locater

In addition to the public-domain data sources described in the preceding sections, two proprietary freight databases, TRANSERCH and Freight Locater, are also widely used in freight transportation modeling. The TRANSEARCH database contains origin-destination freight movements of major modes of transport in the U.S. Data in various geographic markets are now available in TRANSEARCH, including county, five-digit zip code, metropolitan area, and state/province levels. Goods are classified by the commodity or Standard Industrial Code (SIC), with volumes in terms of loads, tonnage, or value. TRANSEARCH has been compiled and produced on an annual basis since 1980 by Reebie Associates. The most recent data year is 2003. Records are kept for freight traffic shipments across geographic markets and commodities for seven modes of transport, including truckload, less than truckload (LTL), private truck, rail, intermodal, rail carload, waterborne, and air. The database contains information on the U.S. domestic, Canada/U.S., and Mexico/U.S. freight activities.

Freight Locater is also a commercial database available from Reebie Associates. It contains detailed information on the type of freight being transported and the shippers at different levels of spatial aggregation. It also contains information on annual tons and sales, as well as the number of employees of individual establishments. The establishments are classified based on industry, commodity, and vehicle type requirements.

2.1.9 Local Surveys

Local governments at the county, Metropolitan Planning Organization (MPO), and state levels also sometimes collect data, which are described in the following sections. These data are helpful in identifying key passenger and freight generators locally they often describe the location, characteristics, and importance of the local components of a statewide freight transportation system.

2.1.9.1 Broward County Freight and Goods Movement Study

In the past few years, the Broward County Metropolitan Planning Organization (MPO) has undertaken several freight-specific studies and research efforts. They include:

- The Freight and Goods Movement Industry Outreach Initiative (CH2M Hill 1998a),
- The Commercial Vehicle Driver Survey and Truck Stop Terminal Facility Research Project (CH2M Hill 1998b),
- The Freight and Goods Movement Industry Outreach Initiative (CH2M Hill 1998b), and
- The Freight and Goods Movement Study (Cambridge Systematics 2002).

As shown in Figure 2-5, trucks were the dominant mode for all freight shipments in Broward County by weight (Cambridge Systematics 2002). In Broward's 2002 Freight and Goods Movement Study, it was concluded that the diverse land use patterns would continue generating truck trips throughout the region. Additionally, service and retail employment, as well as population density, were the contributing factors for truck trips. As a result, truck trips in the region stemmed not only from the major trip generators such as Port Everglades, Fort Lauderdale-Hollywood International Airport, and the surrounding industrial areas, but also from rapidly-growing employment and population hubs within the county. These factors help identify potential truck trip generators in other urban areas in Florida with similar land use patterns.

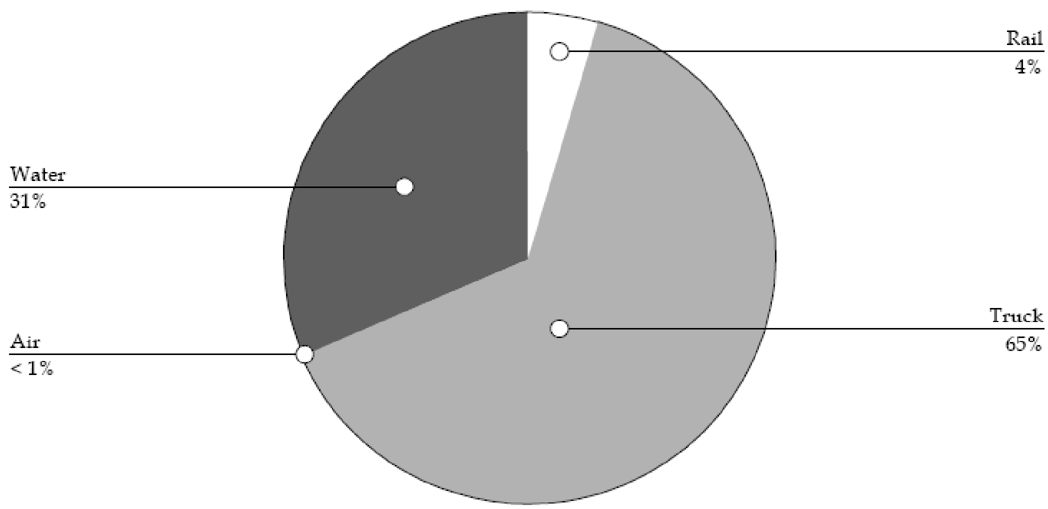

Figure 2-5 Mode split by weight (Cambridge Systematics 2002)

2.1.9.2 Miami-Dade Freight Movement Study

In 1996, the Miami-Dade MPO launched a study that was aimed at gaining an understanding of cargo movements, then developing recommendations for improving freight movements on the surface transportation network (Corradino Group 1996). In the study, a mail-back questionnaire was sent to over 800 local freight-associated firms to collect information on trucking and freight business patterns. A roadside origin-destination survey and a truck volume count were also conducted at several sites with high truck movements. The results from the survey indicated significantly high truck traffic between the Port of Miami and west Miami-Dade County. There were also significant truck movements between Broward and Miami-Dade counties.

In addition to the regional truck movement study, a truck survey was also conducted for an entire week from 7 a.m. to 5 p.m. at the Port of Miami to collect information on the primary truck paths through downtown Miami. The study indicated that much of the truck travel in the county occurred north of SR 836. The Port of Miami and Miami International Airport were the major freight intermodal hubs. The study also found that I-95, SR 112, SR 836, NW 25th Street, NW 74th Street, and Okeechobee Road were the major corridors with high volumes of truck traffic. The findings from such studies provide invaluable information in the calibration of freight demand models at the county, region, or state level.

2.1.9.3 Sarasota/Manatee MPO Freight Movement Study

The Sarasota/Manatee MPO launched a freight movement study in 2000 for the purposes of developing a database of freight movement characteristics and patterns; identifying both current and future needs for freight movements; and identifying possible improvements and actions to meet the freight movement needs (URS Corp. 2000). In the study, the 1992 TRANSEARCH data were used as the source of information on commodity and truck movements to, from, and through the Manatee/Sarasota area. Vehicle classification counts collected by the Florida DOT in 1997 were used to gain insight into truck movements within the study area. Additional classification counts were performed on selected major corridors in the study area. The study used the truck trips estimated from the travel forecast model, the commodity flow data from

TRANSEARCH, and the classification traffic counts from major corridors to identify heavy truck corridors for further operation studies.

2.1.9.4 Southeast Florida Regional Truck Movement Survey

The Southeast Florida Regional Travel Characteristics Study (SEFRTCS) included a truck movement survey (Corradino Group 2000). The survey was carried out in 2000 and collected information on freight company type, number and types of trucks owned, and number of employees. The information was then used to develop a regression model similar to a typical non-home-based trip generation equation for estimating production and attraction trips at a given zone in the tri-county area of Miami-Dade, Broward, and Palm Beach counties.

2.1.10 Summary

Table 2-11 provides a summary of the national freight data described earlier. The data from different sources may have different geographic units, updated time frames, and data years. Consequently, defining a global spatial unit to integrate the different data sources is important in the calibration of freight transportation demand models.

Table 2-11 Freight data summary

Data Source	Smallest Geographic Unit	Data Update	Data Year
CFS	Five-digit zip code	Annual	2003
TBSFD	State and port	Monthly	2004
TAS	Not applicable	Annual	1998
VIUS	State	Every five years	2002
Waybill Sample	BEA	Annual	2002
NORTAD	Facilities as lines and points	Not applicable	1998
Waterway Data	Varied	Annual	2002–2005
TRANSEARCH	Five-digit zip code	Annual	2003

2.2 Freight Models

This section provides an overview of freight models. Many freight models have been developed in the past, and they vary in their structures and methodologies. In the next subsection, model structures and methodologies of freight models are first classified. Based on this classification, various methodologies are described in Sections 2.2.2 and 2.2.3.

2.2.1 Model Structure

Freight demand is a derived demand because shipments are sent to fulfill a need at a specific location. The most basic influence on total freight demand is the volume of goods produced and consumed. Several factors that affect freight demand directly have been identified. They are (Cambridge Systematics 1996, 1997):

- Economy,
- Industrial location patterns,

- Globalization of business,
- International trade agreements,
- Just-in time inventory practices,
- Carrier-shipper alliances;
- Centralized warehousing,
- Packaging materials; and
- Recycling.

Several other factors that affect demand through their influence on costs and services have also been identified (Cambridge Systematics 1996, 1997):

- Economic regulation and deregulation,
- International transportation agreements,
- Intermodal operating agreements,
- Single-source delivery of international LTL shipments,
- Fuel prices,
- Publicly provided infrastructure,
- User charges,
- Other taxes,
- Government subsidization of carriers,
- Environmental policies and restrictions,
- Safety policies and restrictions,
- Effects of changes in truck size and weight limits,
- Congestion, and
- Technological advances.

In an effort to develop a comprehensive statewide framework for modeling freight transportation demand, Pendyala *et al.* (2000) categorized factors with direct and indirect effects on freight transportation demand, as illustrated in Figure 2-6. The key elements in a freight planning effort were identified as follows:

- Socioeconomic environment,
- Intermodal transportation network,
- Freight transportation demand,
- Freight transportation supply,
- Policy and regulatory environment, and
- Performance indicators.

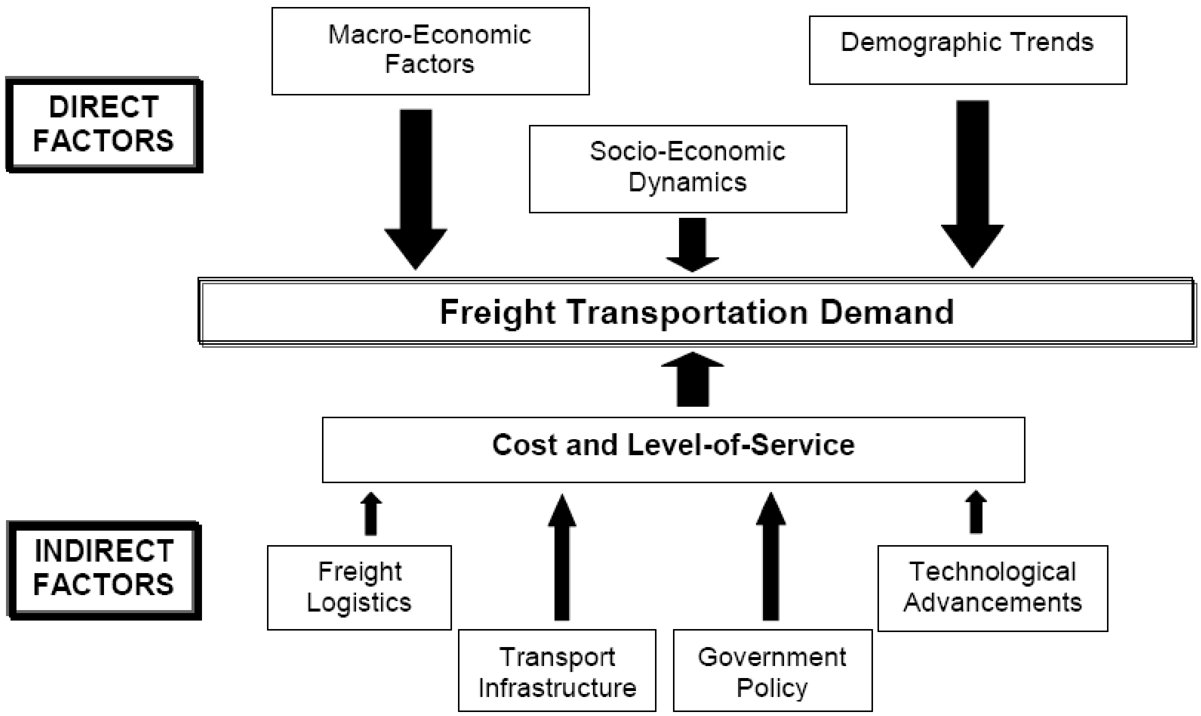

Figure 2-6 Factors affecting freight transportation demand (Pendyala *et al*. 2000)

The issues that need to be resolved in freight demand modeling are complicated and difficult to measure or quantify. Over the past few decades, various modeling methodologies have been developed to predict freight transportation demand between and within urban areas. Numerous classification schemes have been subsequently proposed in the literature to categorize these modeling methodologies. For example, Pendyala *et al.* (2000) classified long-term planning and forecasting demand models for freight movements as follows:

- Trend and time series analysis,
- Elasticity methods,
- Network models of economics and logistics,
- Aggregate demand models,
- Disaggregate models, and
- Economic input–output methods.

The first three types of models may be grouped together because they are all developed from econometric methodologies. The latest research effort sponsored by the National Cooperative Highway Research Program (NCHRP) proposed a general classification scheme as follows (Cambridge Systematics 2003b):

- Facility Traffic Flow Factoring Methods (Trend Analysis)
- Commodity-Based Origin-Destination (O-D) Trip Table Factoring
- Truck Trip Tables within Overall Passenger Flow Models
- Commodity-Based Four-Step Forecasting Models
- Economic Activity Models

This report adopts the following simplified classification scheme to categorize freight planning and forecasting models for statewide applications:

- Econometric methodologies, including trend and time series analysis, elasticity methods, and network models of economics and logistics.
- Aggregate models, including commodity-based four-step models and truck-based O-D factoring models.

A review of freight models in each of the categories above is provided in the following sections.

2.2.2 Trend and Time Series Analysis

Trend and time series models quantify the movement of goods in tons or other appropriate units for various commodities. The movement of goods is then allocated to a transportation mode, such as highway, rail, water, or air after it is converted from commodity tons to number of trucks, railcars, ships, or planes. The models, however, generally do not rely on a detailed description of the transportation network (Harker 1985). As a result, they do not produce freight routing information or other network measurements. The following subsections briefly describe the background of and applications for these models in each category.

Trend and time series analysis estimates the extrapolated freight activities in the future based on the past historical trends captured by a time series regression model, such as the auto-regressive integrated moving average model (ARIMA). The model allows the past behavior of a variable to be characterized and projected into the future. A time series model assumes that:

- All of the effects of a variable on future commodity flows are adequately captured by an analysis of the historic changes in the variable itself, and
- The influences of variables will not change during the forecast period.

The second assumption implicitly suggests that the time series technique would be more appropriate for short-term forecasting. Two types of models, which utilize trend and time series analysis for the freight transportation demand analysis, are discussed in the following text.

First, the *Quick Response Freight Manual* presents two growth factor approaches to forecast changes in freight demand (Cambridge Systematics 1996). The first approach applies an annual growth factor (AGF) calculated directly from historical traffic information. The equation to calculate an AGF is given below:

$$AGF = \left(\frac{T_2}{T_1}\right)^{\frac{1}{Y_2 - Y_1}} \tag{3}$$

where:

T_1 = freight demands in year Y_1,
T_2 = freight demands in year Y_2, and

T_3 = demand in future year Y_3.

Y_3 is estimated as

$$T_3 = T_2 \left(AGF \right)^{Y_3 - Y_2} \tag{4}$$

Another approach, as described in the NCHRP report 388 (Cambridge Systematics 1997), predicts changes in freight demand based on the forecasts of economic variables. The NCHRP Report 388 focuses on either the use of economic indicator variables, such as employment and population, or the development of a statistical time-series model for estimating future commodity flows for existing facilities based on their historical freight data. Forecasting future freight transportation demand in terms of economic indicator variables is a useful and relatively simple procedure. The approach assumes that demand for the transport of various commodity groups is directly related to variations in corresponding economic indicator variables. Examples of indicators include constant-dollar measures of output or demand, employment, population, real personal income, etc. The basic version of the procedure in using economic indicators for freight demand forecasts contains the following steps:

- Divide base-year transportation activity or facility use by commodity groups.
- Relate the production of or demand for a given commodity group with an economic indicator variable that may be estimated from some exogenous source.
- Calculate either a growth factor by dividing its forecast-year value by its base-year value or a forecast annual growth rate for each indicator variable.
- Estimate forecast-year demand by applying the factor determined from the preceding step.
- Aggregate estimated future demand across commodity groups.

Statistical techniques such as regression analysis, time-series models, etc., may also be implemented as alternatives to the economic indicator method in the forecast of future freight transportation demand at existing facilities. Similar to the economic indicator approach, regression techniques, including ordinary least squares (OLS) regression, leading indicator regression, seasonal decomposition, and weighted least squares regression, are relatively easy to understand and implement. Time-series models, such as ARIMA, exponential smoothing, and curve fitting may require additional statistical background and effort in model calibration and application. However, the methods developed using statistical techniques are typically available in regular commercial statistical applications, and the effort required to develop a standard modeling structure for freight transportation demand may be significantly reduced.

For new facilities, the demand forecast involved the following four steps (Cambridge Systematics 1997):

- Identify the potential freight market,
- Forecast changes in the market,
- Estimate the new facility's market share, and
- Evaluate the effects of alternative future scenarios.

It is assumed in the NCHRP Report 388 that new facilities will mostly share the market served by the existing facilities. For a new intermodal facility, the competing facilities include most or all of the facilities that have service areas overlapping the natural hinterland of the new facility. As a result, the first step in estimating the use of a new facility is to identify those competing facilities. The second step is to estimate expected changes identified in step 1 that are likely to occur during the forecast period, using either the economic indicator approach or one of the statistical procedures previously described. The potential demand of and shift to new facilities are then computed by estimating proximity and level of service measures on different approach corridors. Conceptual techniques for evaluating impacts of policy changes on freight demand forecasts have also been highlighted.

Trend and time series analysis is relatively simple and easy to understand and implement. It encompasses the most basic types of forecasting methods that establish trends or growth rates based on historical data to project future freight demand. These models are simplistic and generally not robust. The models also do not have much explanatory power because they lack sensitivity to all but a few selected variables. Theoretically, trend analysis methods are only capable of producing forecasts for existing facilities. The existing baseline cannot be projected into the future for facilities without historical data. Therefore, these models are best suited for short-term forecasts when the factors affecting transportation demand are likely to remain unchanged. The ARIMA model and other time-series methods also lack explanatory power because no underlying theoretical relationship is established between the dependent variable and those factors that might affect its value. One approach, known as the structural econometric time-series approach (SEMTSA) may be an alternative used to remove the limitations of regular time-series models (Cambridge Systematics 1997).

2.2.3 Aggregate Demand Models

Aggregate demand models estimate commodity flow volumes integrated to a specific geographic level such as county or zip code. In this subsection, the aggregate demand models from the NCHRP Report 260 (Memmott 1995) and the *Quick Response Freight Manual* (Cambridge Systematics 1996) are described.

NCHRP Report 260 describes an aggregate approach to estimate freight demand using the traditional four-step demand modeling structure. In the modeling process, a modal split model estimates the proportion of total traffic carried by a specific mode. The freight demand analysis/forecasting process is outlined as follows:

- Quantify freight flows by highway, rail, and water for the current year.
- Forecast the likely annual freight volumes and shifts among modes over the short term (five years or less).
- Provide origins and destinations by commodity within a corridor or region at 15 substate, state, or multi-state levels. This would prove useful for state DOTs in their forecasts and in the prediction of the deterioration of pavement surfaces due to repetitive loads.

The classic four-step process, as shown in Figure 2-7, is applied to modeling freight movements.

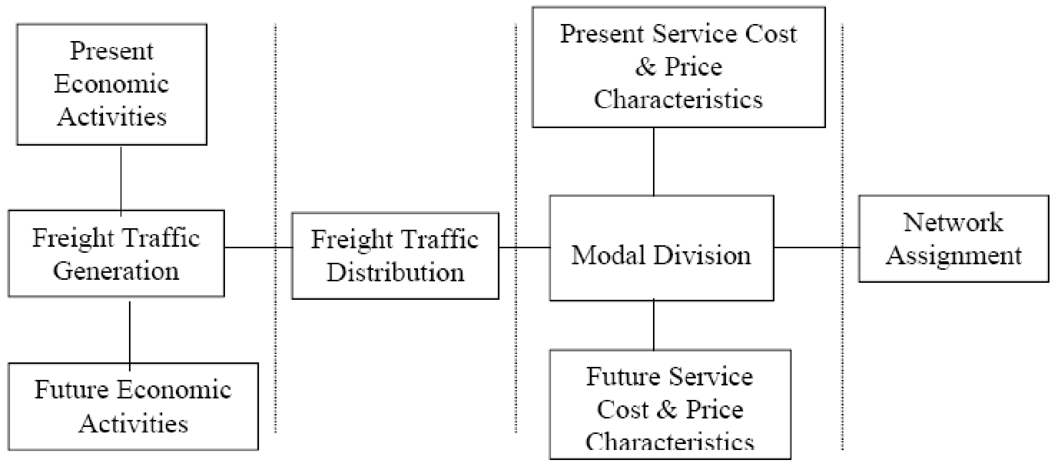

Figure 2-7 Classic four-step freight planning process (Memmott 1995)

Freight traffic generation involves the development of a base case commodity O–D flow data matrix, from which future flows may be predicted. Freight distribution, in terms of disaggregating freight origin data geographically, is carried out using data on county employment. Methods for forecasting the future-year freight O–D matrix may be classified into three categories: causal methods, time series analysis, and qualitative methods. The modal split model employs the least cost or rate strategy to split freight movement between highway and rail. Exhaustive costing procedures for these two modes are also provided. A conceptual technique is provided for converting commodity weights to vehicle equivalents. Sufficient allowance is given for different types of vehicles, maximum carriage capacities, and fronthaul/backhaul characteristics provided in the procedure.

A simplified quick-response procedure, also known as the vehicle-based model, is presented in the *Quick Response Freight Manual*. The procedure is designed to incorporate commercial vehicles into the travel forecasting processes used by planning agencies. As illustrated in Figure 2-8, the procedure consists of the following steps (Cambridge Systematics 1996):

1) Obtain data on economic activities for internal TAZs.
2) Apply trip generation rates to estimate the number of commercial vehicle trip destinations for each internal TAZ (trip generation).
3) Estimate commercial vehicle volumes at external TAZs.
4) Estimate the number of commercial vehicle trips between pairs of TAZs (trip distribution).
5) Assign trips to a network to develop an estimate of commercial vehicle VMT (assignment).
6) Develop control totals for commercial VMT.
7) Compare the results in Steps 5 and 6 and develop adjustment factors to trip generation and/or trips distribution if necessary.
8) Repeat steps 2–7 until the estimated commercial vehicle VMT is reasonably close to the control totals.

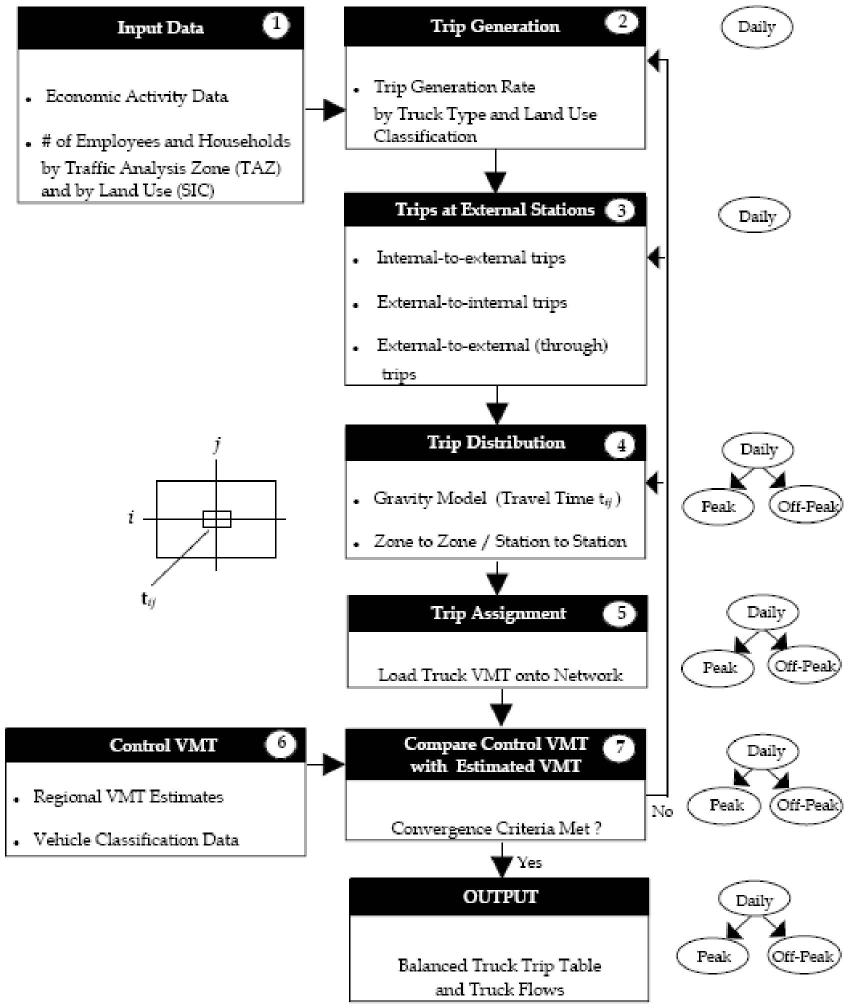

Figure 2-8 Simplified fright forecasting procedure (Cambridge Systematics 1996)

In the trip generation step, the number of daily commercial vehicle trips from each internal TAZ is calculated by applying the trip generation rates given in Table 2-12, based on employment and demographic data (Cambridge Systematics 1996).

Table 2-12 Trip generation rates (Cambridge Systematics 1996)

Variable	Commercial Vehicle Trips per Unit per Day			
	Four-Tire	Single Unit (6+ Tires)	Combination	Total
Agriculture, mining, and construction	1.110	0.289	0.174	1.573
Manufacturing, transportation, communications, utilities and wholesale trade	0.938	0.242	0.104	1.284
Retail trade	0.888	0.253	0.065	1.206
Office and service	0.437	0.068	0.009	0.514
Households	0.251	0.099	0.038	0.388

For external TAZs, commercial vehicle volumes are estimated by applying the default percentages or percentages calculated from local data for each of the three commercial vehicle types. This is based on the functional classification of highways. The default percentages are shown in Table 2-13.

Table 2-13 Default percentages by vehicle class (Cambridge Systematics 1996)

Functional Class		Commercial Vehicle Trips per Unit per Day		
		Four-Tire	Single Unit (6+ Tires)	Combination
Rural	Interstate	3.3%	2.9%	12.2%
	Principal arterials	4.7%	3.2%	4.9%
	Minor arterials/collectors/local	5.3%	3.6%	2.6%
Urban	Interstate	5.5%	1.8%	4.5%
	Freeways and expressways	5.5%	1.7%	2.3%
	Principal arterials	6.6%	1.7%	2.2%
	Minor arterials	6.4%	1.7%	1.5%
	Collectors	6.4%	1.8%	1.5%
	Local	6.4%	1.8%	0.8%

A standard gravity model is then applied to allocate commercial vehicle trips between a given zone pair. The following friction factors are used as the default for the different types of commercial vehicles. For the four-tire:

$$F_{ij} = e^{-0.08t_{ij}} \tag{5}$$

For the single unit:

$$F_{ij} = e^{-0.10t_{ij}} \tag{6}$$

For the combination:

$$F_{ij} = e^{-0.03t_{ij}} \tag{7}$$

To conduct separate traffic assignments for different time periods, the manual also provides a temporal distribution of commercial vehicles in urban areas by time of day. Table 2-14 shows the temporal distribution compiled by the Federal Highway Administration (FHWA) (Cambridge Systematics 1996).

The *Guidebook on Statewide Travel Forecasting* (Horowitz 1999) describes a process similar to four-step models for passenger forecasting. The process, also known as the commodity-based four-step model (Cambridge Systematics 2003b), has been adapted by numerous states in the U.S. for freight modeling. Trip generation in commodity-based models is usually calculated by converting the annual commodity tonnage data into daily truck trips using a payload conversion factor (Fischer and Han 2001). The steps included in the process of building a freight model are described by Horowitz (1999) and are summarized below.

Table 2-14 Temporal distribution of commercial vehicles in urban areas

Hour		Commercial Vehicles		
From	To	Four-Tire	Single Unit	Combination
12	1	0.7%	0.7%	2.3%
1	2	0.4%	0.6%	1.8%
2	3	0.4%	0.6%	1.5%
3	4	0.4%	0.5%	1.7%
4	5	0.6%	1.1%	2.3%
5	6	2.0%	3.0%	3.7%
6	7	6.9%	5.0%	4.3%
7	8	6.6%	7.3%	6.0%
8	9	6.4%	7.2%	5.1%
9	10	5.2%	7.8%	7.1%
10	11	5.7%	7.0%	6.3%
11	12	5.4%	7.5%	6.8%
12	1	5.5%	6.8%	6.9%
1	2	5.8%	7.1%	6.3%
2	3	6.4%	7.7%	6.2%
3	4	7.8%	7.7%	5.3%
4	5	8.6%	6.6%	5.1%
5	6	7.1%	5.1%	4.0%
6	7	5.8%	3.5%	3.9%
7	8	3.3%	2.4%	3.0%
8	9	2.9%	1.6%	2.9%
9	10	2.6%	1.3%	2.6%
10	11	2.0%	1.0%	2.5%
11	12	1.3%	1.0%	2.3%
Total		100.0%	100.0%	100.0%

Step 1 —Build Freight Modal Networks

The first step in developing a statewide freight model is to create a network that visually and mathematically represents modes, routes, links, and intersections. Most statewide freight models have been used to create a TAZ for each county within a state, plus an additional zone for each of the remaining contiguous 48 states, as well as each external station at the U.S. border. Currently, modes considered in a freight modal network vary among states. The modes defined in the CFS are listed as follows:

- Parcel, U.S. Postal Service, or courier
- Private truck
- For-hire truck
- Air
- Rail
- Inland water
- Great Lakes

- Deep sea water
- Pipeline
- Private truck and for-hire truck
- Truck and air
- Truck and rail
- Truck and water
- Truck and pipeline
- Rail and water
- Inland water and Great Lakes
- Inland water and deep sea
- Other and unknown modes

Step 2 —Develop commodity groups

The second step is to aggregate commodity categories into a limited number of groups to reduce the complexity of the modeling process. Many existing models have used two-digit STCCs (or SCTGs), which seem to provide enough detail without overburdening computations. Most data sources report commodities in ways that are consistent with two-digit STCCs, and two-digit SICs are roughly comparable. Because different data sources report the amount of goods by different measures, conversion factors must be developed to reconcile the various scales. The CFS provides data in both tons and dollars and may be used to develop those conversion factors for listed commodities. A truck-only model may bypass this step entirely. However, the truck-only method is best suited to metropolitan areas with relatively small spatial coverage.

Step 3 —Relate commodity groups to industrial sectors or economic indicators

Separate economic indicators should be adopted to estimate production and consumption of each commodity. For example, employees and population may be related to commodity production for forecasting future flows because forecasts for these particular input variables are readily available.

Step 4 —Find base year commodity flows between TAZs

One of the following approaches may be used to estimate base year commodity flows:

- Adjustment factors may be applied to an existing freight flow matrix, or the matrix may be expanded by splitting large zones into smaller ones.
- A gravity model may be constructed and calibrated using state-to-state data, then applied at the county-to-county level.

Further adjustments to flow matrices may also be needed to account for information not already included because the CFS does not contain all commodities. The Fratar method is a widely used growth factor technique for generating a future year trip table, given the base year trip tables and zone-level growth estimates (Garber and Hoel 2002). However, because the method relies on an existing O-D matrix, it cannot be used to forecast freight movements between zone pairs without existing cargo flows in the base year. Furthermore, one of the assumptions of this method is that the modal split for any given commodity and for any given O-D pair is a constant. Thus, the growth factor method cannot reflect changes in travel time between zones. This becomes an issue if the shipping characteristics of commodities change (Rebovich 2004).

When the gravity model is used for building flow matrices, it is necessary to obtain information on the amount of production and consumption for each TAZ and for each commodity group. Production rates may be established, for example, by simply dividing the tons of goods produced in a commodity group by the number of people employed. Other models, such as linear regression, may also be implemented to estimate total productions and attractions at a given zone. A typical gravity model for allocating commodities to each zone pair is given as follows (Horowitz and Farmer 1999):

$$V_{ij} = P_i A_j X_i Y_j f\left(d_{ij}\right) \tag{8}$$

where:

- V_{ij} = commodity flow from i to j,
- P_i = production of goods for a given commodity group in zone i,
- A_j = attraction of goods for a given commodity group in zone j,
- X_i, Y_j = balance factor, and
- d_{ij} = distance from i to j.

Step 5 —Forecast growth in industrial sectors

The future growth of the freight production and attraction for a given zone or a region need to be estimated. Forecasts may be obtained from a variety of governmental, private, and educational organizations.

Step 6 —Factor commodity flows

The forecasted growth factors are applied to estimate future commodity flows of production and attraction for a given TAZ.

Step 7 —Develop modal costs for commodities

Modal split is usually determined by cost considerations. Before modes may be considered for shipping a commodity between zones, the cost associated with each mode must be determined.

Step 8 —Split commodities to modes

This step is to determine the proportion of commodity flows that is transported from an origin TAZ to a destination TAZ utilizing a particular mode. The major factors in modal split models include:

- Commodity characteristics;

- Cost;
- Time, dependability, and frequency of shipment;
- Quality; and
- Access.

Examples of mode split models used in freight modeling include aggregate demand formulations, logit, pivot point, and simple elasticities. A typical aggregate demand model for truck volume (*VT*) is given as

$$VT = SR^{a} LR^{b} ST^{c} LT^{d} VAL^{e} TR^{f} TT^{g} \tag{9}$$

where:

SR	=	average rail shipment size,
LR	=	average truck shipment size,
ST	=	average length of a rail haul,
LT	=	average length of a truck haul,
VAL	=	average value of the commodity,
TR	=	rail unit cost,
TT	=	truck unit cost, and
a, b, c, d, e, f, g	=	calibrated constants.

The pivot point is derived from a logit model. However, the pivot point models require less information to operate and are less sensitive to calibration errors. This is because only one independent variable (i.e., cost) is incorporated in the model. The model assumes the following form:

$$p_j = \frac{p_{bj} \exp\left(\alpha \Delta c_j\right)}{\sum_k p_{bk} \exp\left(\alpha \Delta c_k\right)} \tag{10}$$

where:

p_j	=	forecast mode share mode j,
p_{bj}, p_{bk}	=	existing shares for modes j or k,
a	=	calibrated coefficient varied by commodity, and
Δc_k	=	changes in the full costs of transporting a ton of goods on mode k.

As defined earlier, elasticity is the fractional change in output divided by the fractional change in input. For some commodities, modal split may be best accomplished with cross elasticities. For example, a cross elasticity between truck and rail might be the percent change in rail demand given a 1% change in truck costs.

Step 9 — Find daily vehicles from load weights and days of operation

In this step, freight trip tables in weight units (e.g., tons) are converted into truck trip tables using factors similar to AOFAC in FSUTMS. These tables are then assigned to the network. Refer to Section 2.1 for possible data sources for the conversion factors.

Step 10 —Assign vehicles to modal network

Several techniques have been considered in assigning truck trips onto a freight network, including all-or-nothing, capacity restrained equilibrium, and stochastic multi-path capacity restraint techniques. Among these techniques, a stochastic multi-path assignment is probably a better choice because it allocates some trips along the shortest path and the remaining trips to other reasonable paths.

Vehicle-based truck trip generation rates used in statewide and regional travel demand models are generally estimated using land use and employment variables. However, as stated by Fischer and Han (2001), the assumption of a linear relationship between truck trips and variables such as employment, floor area, or acreage needs to be re-examined. This is the case because industrial productivity relationships have a strong impact on truck trips, and a number of truck trip generating activities are driven by economies of scale. Commodity-based trip generation models generally begin with an estimate of commodity flow tonnage, generally county-to-county or state-to-state flows. The annual tonnage flows are then converted to daily truck trips using payload factors. Commodity-based models may do a reasonable job of estimating the number of truck trips associated with the production end and the consumption end of commodity moves. This type of truck model, however, tends to underestimate trips in urban areas because trip chaining and local pickup and delivery activities are not accounted for.

2.3 Statewide Freight Models

The statistics from the 1993 CFS indicate that a significant amount of freight movement occurs within the boundaries of individual states (Pendyala *et al.* 2000). As a result, statewide freight transportation planning is important. In general, statewide freight transportation demand models may be classified as either commodity-based or vehicle-based. Commodity-based models use data on commodities as their base unit for distributing flows. The units are either weight-based or value-based. Commodity-based models may be further classified into four-step and origin-destination factoring models. The major difference between these two modeling approaches is the procedure for obtaining a future freight flow table. Vehicle-based models are based on vehicle trips, similar to the passenger modeling paradigm. Statewide freight models usually use a TAZ structure detailed at the county level. In the following sections, selected statewide practices in the U.S. for freight modeling are briefly described.

2.3.1 Commodity-Based Four-Step Models

With this approach, the procedures described in the *Guidebook on Statewide Travel Forecasting* (Horowitz 1999) are applied to model freight flows. These models include four steps of trip generation, trip distribution, modal split, and traffic assignment. In trip generation, commodity production and consumption rates are applied to each traffic analysis zone. Commodity flows are subsequently and typically distributed by a gravity model. Modal split may be accomplished by a number of methods, including familiar models such as the logit and pivot point models. The traffic assignment step is often performed using all-or-nothing assignment techniques with manual adjustments.

2.3.2 Commodity-Based Origin-Destination (O-D) Trip Table Factoring Models

A commodity-based origin-destination (O-D) trip table factoring model generally includes the following steps. First, the study area is divided into TAZs at the county level. Base year O-D tables are then established for each commodity. The O-D tables contain some measure of commodity flows between each pair of zones, which do not have to be truck volumes. Most applications of this type of models use commodity data from the TRANSEARCH database to create trip tables. Economic forecasts are then obtained and correlated with the growth in each zone for each of the commodities. These growth rates are then applied to the trip tables to factor them to the planning horizon using the Fratar method or some similar growth factor technique.

The transportation process in the Mississippi statewide intermodal transportation model conforms to the traditional four-step procedure of transportation planning (Zhang *et al.* 2003). In the process, the state-level O-D trip tables by commodity and by mode are first obtained from the 1997 CFS data. The procedure also includes the following steps:

1) Population and employment are used as the attraction and production indices, respectively, to break down state-level commodity O-D data to the county level.
2) A gravity model is used to distribute commodity flows between pairs of TAZ within the state.
3) Traffic assignments by commodity are performed using an all-or-nothing assignment.
4) Assignment results from different O-D pairs are combined to obtain the commodity tonnage on the network in the state.
5) The freight flows are converted to vehicle trips to facilitate model calibration and validation. Yearly truck traffic is converted to daily truck traffic based on the truck usage information for the VIUS.
6) The truck volume determined by the model and the ground truck counts on the network are compared to calibrate and validate the model.
7) The transportation characteristics are forecast for future years (2005, 2010, and 2020) based on the developed base year model and time series population and employment data. Future year commodity flows are then estimated and assigned to the base year network.

The flow chart of the analysis procedure of the Mississippi model is given in Figure 2-9.

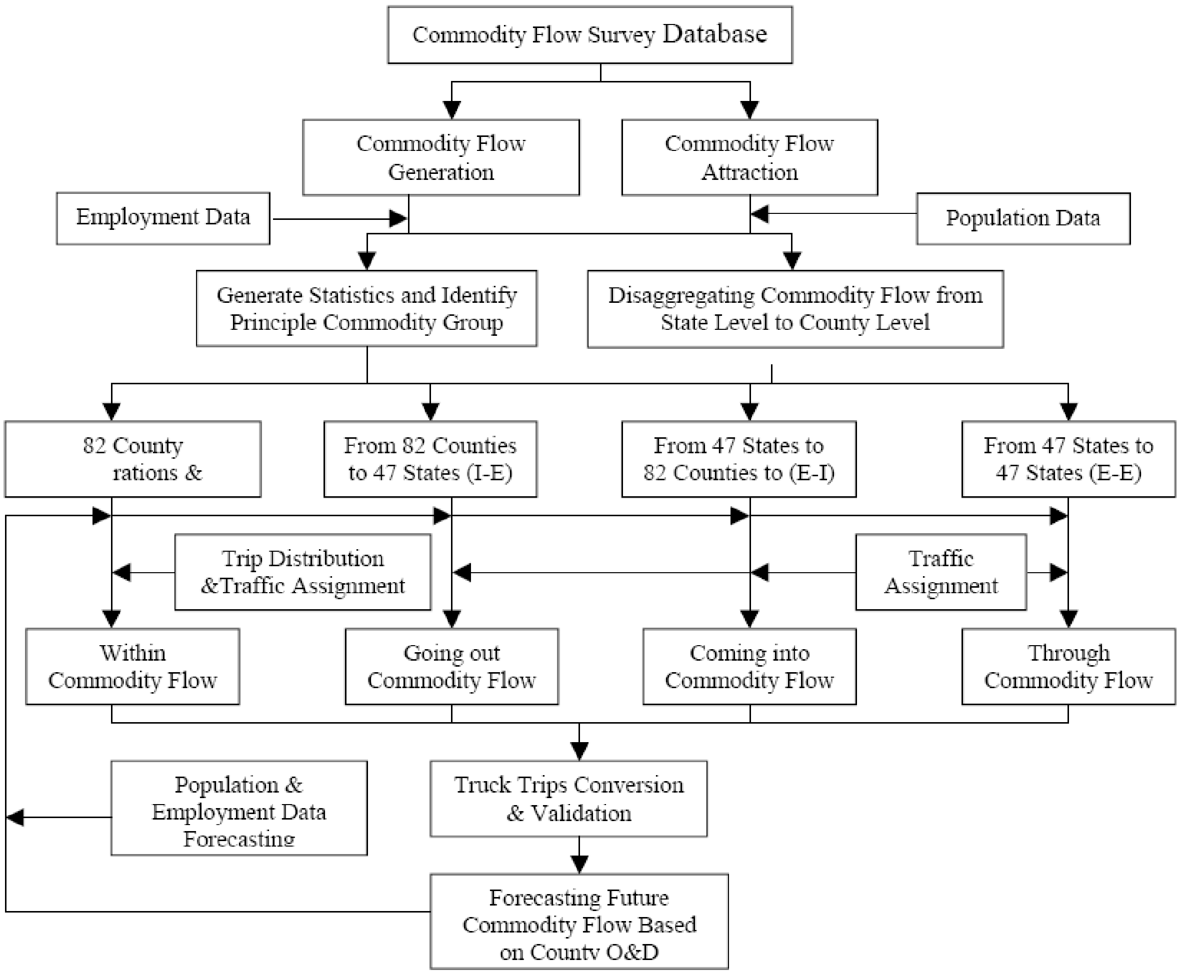

Figure 2-9 Mississippi intermodal transportation modeling process (Zhang et al. 2003)

The Virginia freight model is also an application of the commodity-based O-D factoring method. In the modeling process, the 1998 TRANSEARCH commodity flow O-D database at the county level was procured (Brogan *et al.* 2001). The 1997 CFS and the Port of Virginia Import and Export Statistics were also acquired to verify the accuracy of the final list of Virginia's key commodities. A GIS database in TransCAD was developed, which included freight volumes, county-level population and employment information, and Virginia's freight transportation network. Future flows of freight were forecasted using regression models. The estimated future freight flows were then converted into flows between O-D pairs using a typical gravity model and finally assigned to the freight transportation network.

The spatial analysis unit in a commodity-based model is typically established at the county level because data for the smaller TAZ scales are generally not available. In addition to Florida's statewide and urban models, the current freight modeling in states such as Iowa, Nebraska, Wisconsin, and Vermont are also commodity-based four-step models. These models are sophisticated but require significant resources and extensive data collection efforts. Examples of commodity-based O-D factoring models include the Ohio, Oklahoma, Kentucky, Kansas, and Louisiana statewide models. Vehicle-based models have often been used in the modeling of urban freight transportation, but are seldom seen in statewide freight modeling applications because the relationship between economic production and a given commodity flow is not specifically considered. Among the models, the difference often lies in the techniques used. For example, the Mississippi model does not include a conventional trip generation step. Instead, the future year freight flows are directly forecasted using a growth factor procedure, where the growth factors are calculated by econometric models. A limitation of commodity-based models is that in the assignment step, the possibility of congestion is not addressed. Regardless of modeling approaches, these models are most likely not transferable due to unique characteristics of different states.

2.3.3 Florida State Freight Modeling Process

The Florida statewide freight model structure follows the basic framework of the four-step transportation demand forecasting process (FDOT 2006). In 2002, Cambridge Systematics, Inc. completed the development of the Statewide Travel Forecasting Model (STFM). The model of 508 zones was designed to work within the TRANPLAN based FSUTMS to estimate long-distance freight volumes.

In 2003, Caliper Corporation converted the STFM into a TransCAD based model. At the same time, Caliper converted the model to the newly developed zone and network system (4,008 zones and 90,836 highway links). In 2004 and 2005, the Corradino Group revised the Statewide Passenger Model (STPM), and Cambridge Systematics, Inc. updated the TransCAD version of the freight model by replacing the truck trip table estimation for non-freight truck trips with the vehicle-based model described in the *Quick Response Freight Manual*. The STFM was then integrated with the STPM so that passenger cars and trucks were assigned together to the statewide highway network.

In 2006, Cambridge Systematics, Inc. completed the conversion of the STFM to Cube after the Model Task Force adopted Cube as the FSUTMS engine. Cambridge Systematics, Inc. developed a Florida statewide freight model using the four-step transportation demand forecasting process, which requires that commodities be generated and distributed by tonnage, that a mode split component be included, and that trucks, identified after the mode split process, be assigned to the statewide highway network (FDOT 2005). Figure 2-10 shows the flowchart of the Florida statewide freight model. The model has components of freight tonnage generation, freight tonnage distribution, mode choice, tonnage to truck conversion, and non-freight truck estimations.

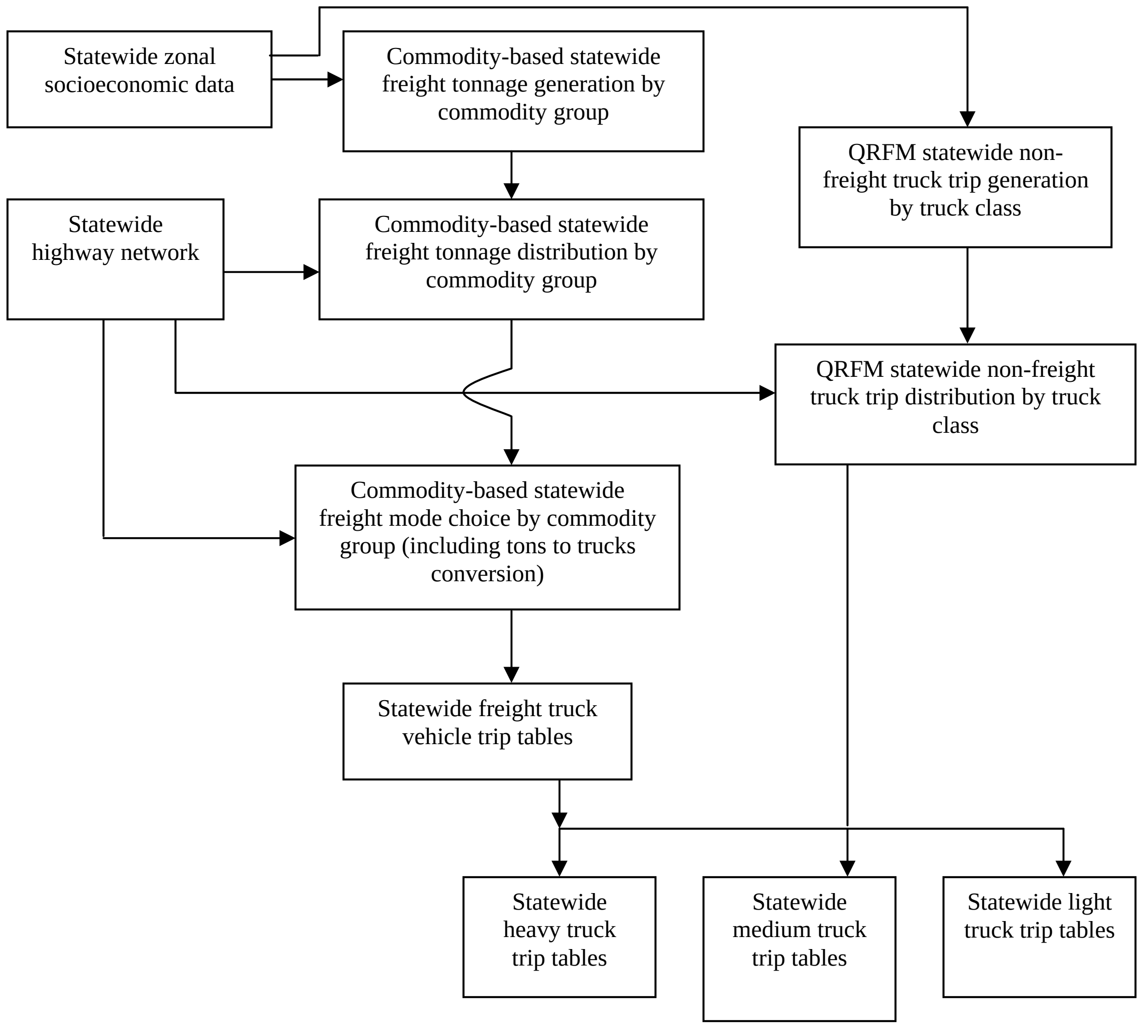

Figure 2-10 Florida statewide modeling process

In the freight tonnage generation model, regression equations for tons produced and attracted are estimated for 14 commodity groups with demographic information (mainly employment by type) as the independent variables. Table 2-15 shows the 14 commodity groups associated with the SCI codes. The equations are estimated using the 1998 TRANSEARCH database.

In the freight tonnage distribution model, a gravity model has been developed with parameters estimated for each of the 14 commodity groups using the data from the TRANSEARCH database. The outputs are production-attraction tables of freight tons for each commodity group.

The tonnage production-attraction tables are inputs into the mode choice model, which splits them into tables by mode. Five modes are used: truck, rail, water, air, and intermodal. The base mode shares from the TRANSEARCH database are used in the model. An incremental logit model is used to adjust these mode shares to reflect changes in the highway level of service.

The tonnage tables for trucks are converted to truck vehicle trips using payload factors derived from the U.S. Census Vehicle Inventory and Use Survey. This module is described in more detail in Section 7.2. This is because the conversion factors have to be applied to the tonnage resulting from the intermodal freight model for the commodity categories in the TRANSEARCH database.

Table 2-15 Commodity groups in STFM

Index	Commodity Groups	SIC Codes
01	Agricultural	SIC07
02	Nonmetallic Minerals	SIC10-14
03	Coal	None
04	Food	SIC20
05	Non-Durable Manufacturing	SIC21,22,23,25,27
06	Lumber	SIC24
07	Chemicals	SIC28
08	Paper	SIC26
09	Petroleum Products	SIC29
10	Other Durable Manufacturing	SIC30,31,33-39
11	Clay, Concrete, Glass	SIC32
12	Waste	All
13	Miscellaneous Freight	SIC42,44,45
14	Warehousing	SIC50,51

The non-freight truck volumes are estimated using techniques from the QRFM. The estimation process for truck volumes is performed by accounting for three vehicle classes: light, medium, and heavy trucks. The three truck classes are defined as follows:

- Light – two-axle, four tire trucks
- Medium – single unit trucks with more than four tires
- Heavy – multi-unit trucks (four or more axles)

Three truck trip tables are estimated by the QRFM method, and the trip tables for heavy trucks are added with the truck volumes from commodity-flow models. When integrating with the STPM, these three types of trucks are assigned together with passenger cars in the joint assignment module.

2.4 Cube Freight Demand Software

Cube by Citilabs has been adopted in Florida as the standard modeling software. Cube Cargo is a module for freight modeling, which uses a commodity-based approach to forecasting matrices of tons of goods by commodity type and by mode for use in the analysis of commodity flows. The commodity flow matrices are then converted to matrices of the number of trucks by truck type. These matrices are then assigned to the freight transportation network for estimating truck vehicle flows. Figure 2-11 illustrates the various sub-models within Cube Cargo. The sub-models are summarized below (Citilabs 2005):

1) Generation Model. The generation model produces freight volume and forecasts the number of tons by commodity group produced and consumed for each coarse-level zone. The freight volumes are segmented into internal productions and exports.

2) Distribution Model. The distribution model allocates the forecasted freight volumes from their zones of origin to their zones of consumption using the gravity model. The productions and consumptions are split into short- and long-haul trips with different generalized cost functions.

3) Mode Choice. The multinomial logit choice models are used to split long-haul trips by modes such as truck, rail, inland waterway, and combined transport. The general cost functions incorporate time, distance, and cost. Short-haul trips are assumed to be traveled by road.

4) Transport Logistics Node Model. Transport logistics nodes (TLN) are places where trip chaining occurs. For example, major goods yards, multi-modal terminals, railway stations, and ports are considered TLN. The TLN model partitions the matrices resulting from the modal choice model into direct transport and transport chain trips.

5) Fine Distribution Model. The fine distribution model uses gravity formulations to convert the trips by commodity group and means of transportation into a fine level zone system. Therefore, the trucks at zonal levels are sufficient for estimating the truck flows at the link-level.

6) Vehicle Model. The vehicle model estimates the number of daily vehicle trips, given the mode and commodity group matrices from the previous model steps. The results of truck volumes by truck type may then be used with other vehicle trips in traffic assignment.

7) Service Traffic Model. The “CitiTrans” model in the flow chart is a model for estimating the amount of local delivery and non-goods related truck traffic. The model uses linear regression for trip generation and the gravity model for trip distribution to produce local truck flows.

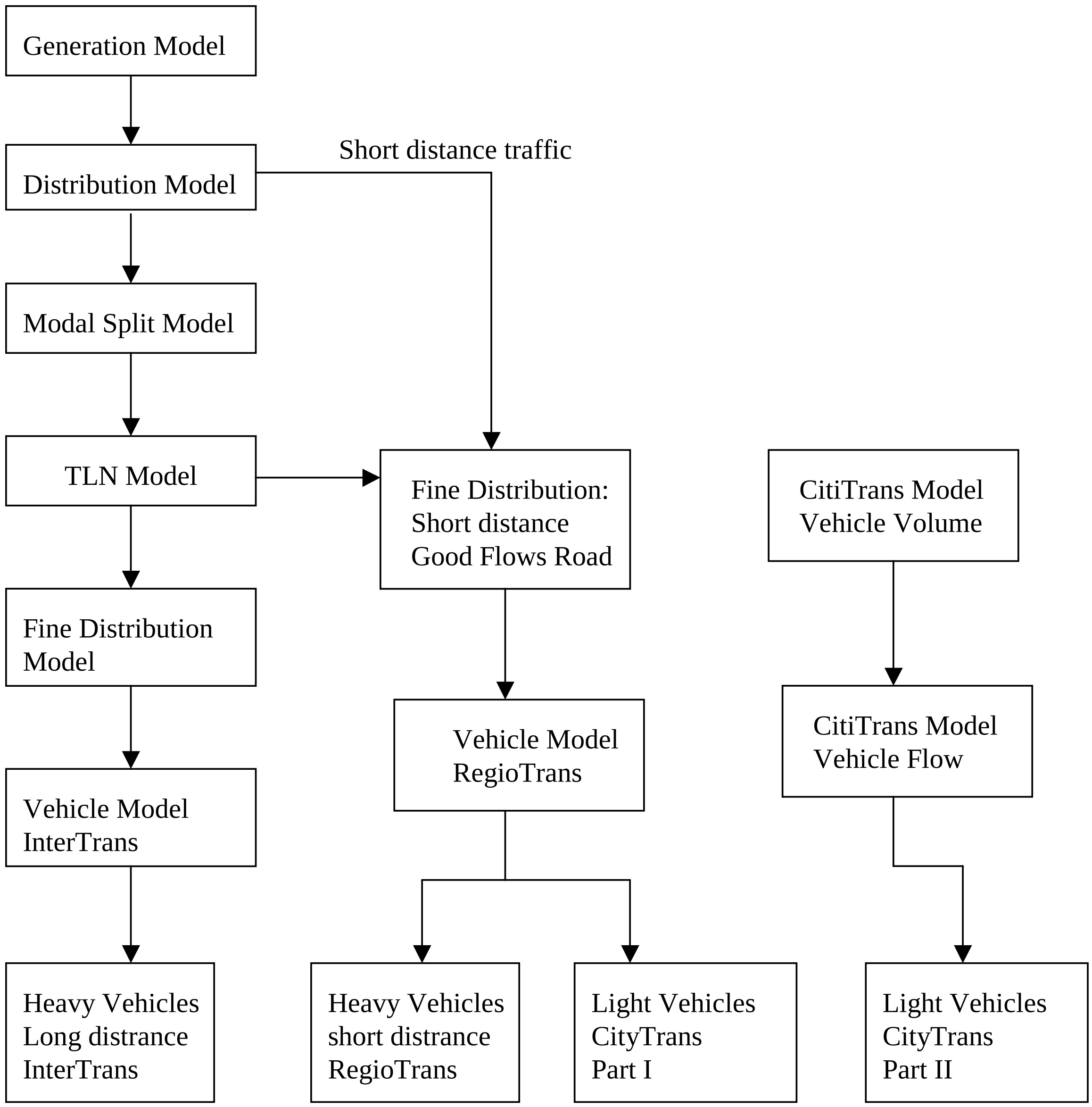

Figure 2-11 Flow chart of Cube Cargo

3. LOCATIONS OF INTERMODAL FACILITIES

Freight intermodal facilities are places where freight is transferred from one mode of transportation to another. Highways, rail, water, air transportation, and pipelines form the basic modes of freight transportation. Any transportation facilities or terminals that are utilized to facilitate freight movement from one mode to another will be considered as intermodal facilities. For practical reasons, basic transportation modes may need to be further divided into various sub-modes. This is particularly true in the case of railways and waterways. Because railway companies own their own tracks or have the usage rights on specific tracks, freight movement between networks of different companies must take place with a special arrangement between companies. Similarly, for water transportation, deep draft and shallow draft vessels usually do not share the same navigation routes. Therefore, freight transfer is necessary when both deep draft and shallow draft vessels have to be utilized to carry the commodity from its origin to its destination. For these reasons, rail terminals or rail yards that facilitate freight transfer between rail companies and seaports that facilitate freight transfer between deep draft and shallow draft vessels will also need to be included in the intermodal database. The GIS data have been created for all of the facilities, which have been geocoded in geographic coordinates of longitude and latitude. The procedure to create the GIS data for each intermodal facility is described in the following subsections.

3.1 Airports

Airports are where freight cargo is transferred between cargo planes and trucks. According to the Florida Airport Council, there are currently a total of 19 commercial service airports and 53 aviation airports in Florida. Most airports are considered intermodal terminals between highway and air transportation. However, airports that are not used for freight transportation should be excluded from further analysis. The 19 commercial service airports are listed below:

1. Daytona Beach International Airport
2. Fort Lauderdale-Hollywood International Airport
3. Gainesville Regional Airport
4. Jacksonville International Airport
5. Key West International Airport
6. Melbourne International Airport
7. Miami International Airport
8. Naples Municipal Airport
9. Okaloosa Regional Airport/Fort Walton Beach
10. Orlando International Airport
11. Orlando Sanford International Airport
12. Palm Beach International Airport
13. Panama City/Bay County International Airport
14. Pensacola Regional Airport
15. Sarasota Bradenton International Airport
16. Southwest Florida International Airport
17. St. Petersburg-Clearwater International Airport
18. Tallahassee Regional Airport

19. Tampa International Airport

The geographical information on the locations of the commercial airports in Florida was obtained from the Florida Geographic Data Library (FGDL). FGDL is a Florida GIS data-clearing house for distributing satellite imagery, aerial photographs, and spatial data by county, state, and coastal areas throughout the State of Florida. Figure 3-1 shows the locations of the commercial airports in Florida.

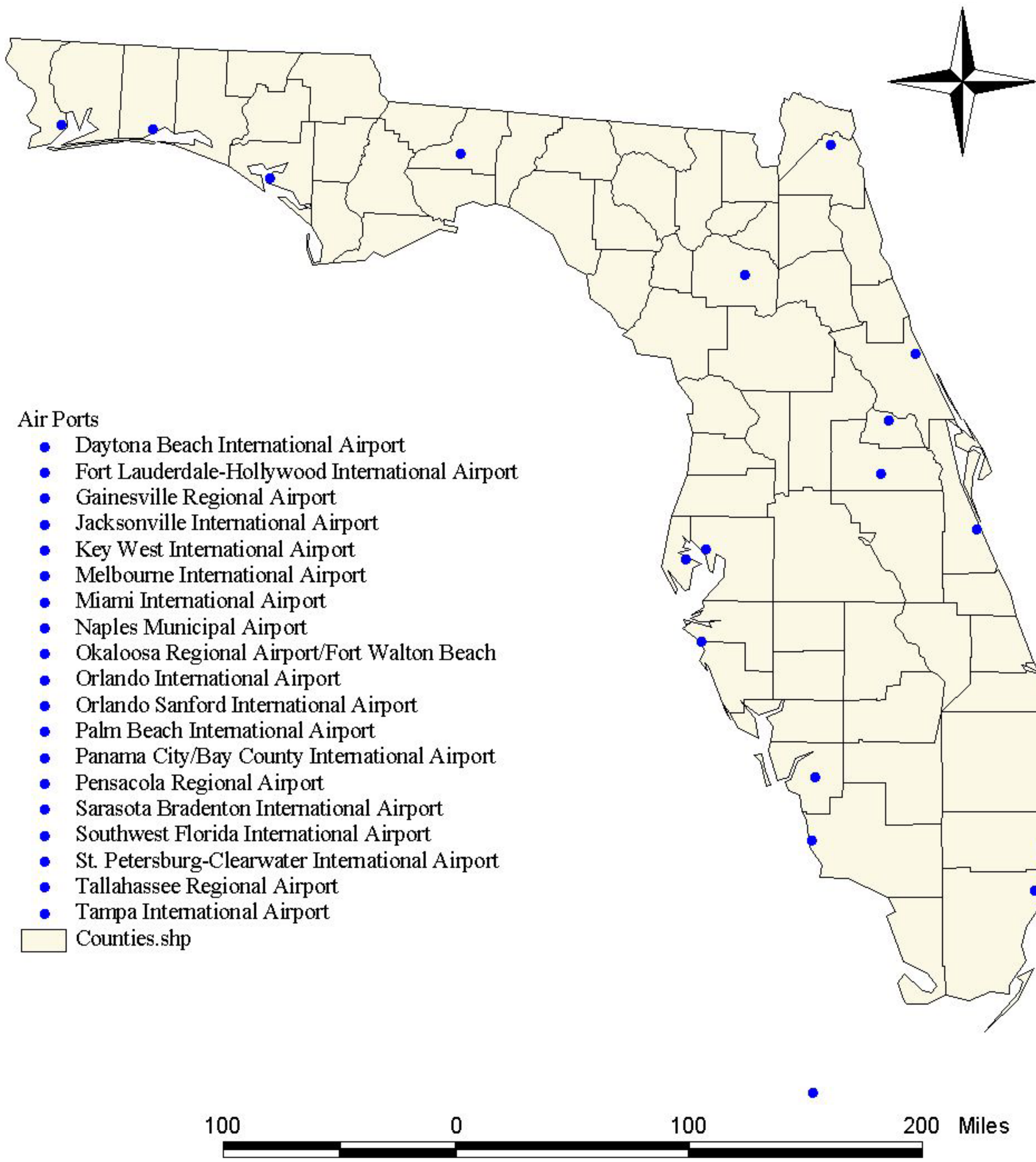

Figure 3-1 Commercial airports in Florida

3.2 Seaports

Seaports are used for freight transloading for different destinations and/or transferring between shallow and deep draft vessels. They also serve as intermodal facilities to connect freight traffic between seaways and highways and railways. Seaports usually consist of a number of docks. Each dock may have specialized equipment and handle a specific type of freight transloading. Based on the information from the Florida Port Council, the following 14 public deepwater seaports throughout Florida were identified:

1. Port Canaveral
2. Port Everglades
3. Port Fernandina
4. Port Jacksonville
5. Port of Fort Pierce
6. Port of Key West
7. Port of Manatee
8. Port of Miami
9. Port of Palm Beach
10. Port of Panama City
11. Port of Pensacola
12. Port of St. Joe
13. Port of St. Petersburg
14. Port of Tampa

The GIS data for the aforementioned seaports were obtained from the U.S. Army Corps of Engineers (USACE). These data include information on commercial facilities at the principal U.S. coastal, Great Lakes, and inland ports. The addresses of all seaports were obtained from the USACE's websites and were geocoded. The geocoded locations were then verified with the GIS data from USACE. Figure 3-2 shows the locations of the seaports in Florida.

Because it is important to include ports that handle both shallow and deep draft vessels, efforts were made to identify the locations of additional ports or docks along waterways. Six waterway systems in Florida, as shown in Figure 3-3, have been identified based on the information obtained from the Florida Intracoastal and Inland Waterway Study conducted by the FDOT. They are:

1. The Atlantic Intracoastal Waterway Inshore System
2. The Gulf Intracoastal Waterway Inshore and Offshore System
3. The Apalachicola-Chattahoochee-Flint River System
4. The Okeechobee Waterway System
5. The Miami River
6. The St. Johns River System

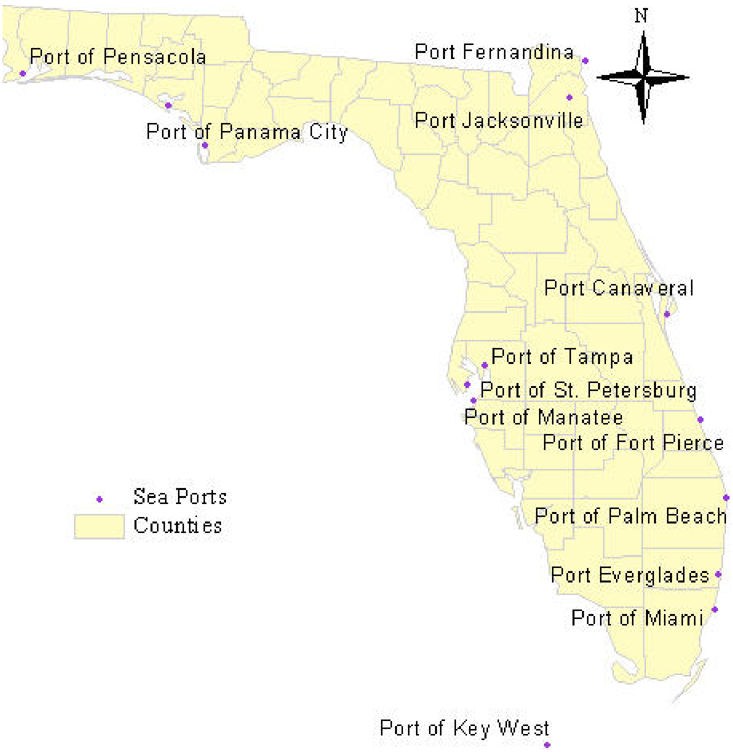

Figure 3-2 Public seaports in Florida

According to the TRANSEARCH database (described in the following section), eight Florida counties that have no seaport facilities within the county boundary had commodity inland water tonnages. Because the eight counties are located in the aforementioned waterway systems, the 2005 employment data from InfoUSA were used to identify possible locations for docks for transloading freight, based on the Standard Industrial Classification (SIC) codes. The 4-digit SIC code "4449 – Water Transportation of Freight" was used to identify entities along the intracoastal waterways on the Atlantic and Gulf Coasts. These entities were established primarily for the transportation of freight on all inland waterways. All companies in the six waterway systems with SIC Code 4449 were checked by employment size and company names. One location for each county was selected to represent the port for transloading freight through inland waterways.

Figure 3-3 Florida intracoastal and inland waterway system map (FDOT 2003a)

3.3 Rail Terminals

The Florida Rail System, as depicted in Figure 3-4, comprises 14 line-haul railroads and four terminal or switching companies. According to the FDOT's *2002 Florida Rail System Plan: Rail Connectivity Needs Assessment*, the line-haul carriers differed in sizes from fairly small intrastate railroads to large rail systems that extended from Florida to Canada. Among the line-haul railroad carriers, two were Class I carriers, one was Class II, and the remainders were Class III carriers. As shown in Table 3-1, the state railroad system comprised a total of 2,871 route miles in 2002. CSX Transportation's (CSXT) 1,616 Florida route miles represented 56 percent of the rail system in the state. The Florida East Coast Railway (FEC) was the second largest carrier, with a total of 386 route miles, which accounted for 13.5 percent of the state rail system.

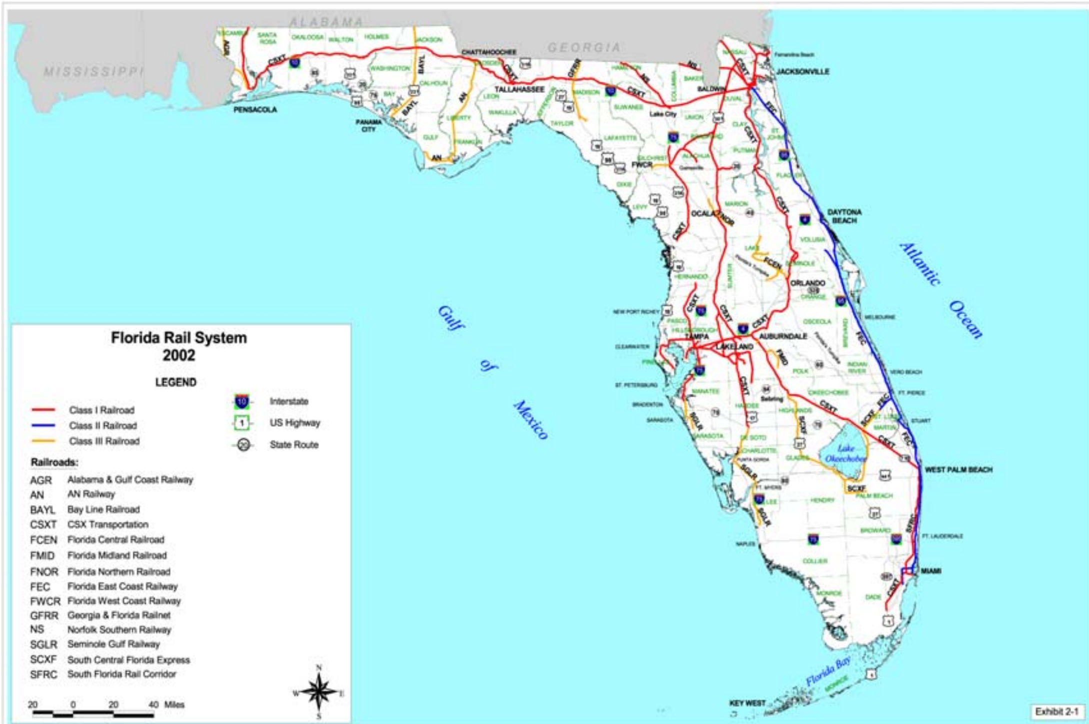

Figure 3-4 Florida 2002 rail system map (FDOT 2002a)

Table 3-1 2002 Florida freight railroad

Railroad Company	Miles of Railroad Operated in Florida	% of Florida Rail System
Alabama and Gulf Coast	44	1.5
AN Railway	96	3.4
Bay Line	63	2.2
CSX Transportation	1,616	56.3
Florida Central	66	2.3
Florida East Coast	386	13.5
Florida Midland	27	0.9
Florida Northern	27	0.9
Florida West Coast	14	0.5
Georgia and Florida RailNet	48	1.7
Norfolk Southern	96	3.3
Seminole Gulf	119	4.2
South Central Florida Express	158	5.5
South Florida Rail Corridor	81	2.8
Switching & Terminal Companies	30	1.0
Total	2,871	100.0

There are four railroads in the category of terminal companies that serve three local areas: Jacksonville (Talleyrand Terminal Railroad and St. Johns River Terminal Company); Port Manatee, (Manatee County Port Authority); and Palm Beach (Port of Palm Beach District Railway). In total, these carriers operate approximately 30 miles of track.

Rail terminals may facilitate commodity loading, unloading, and transferring for freight movement within the same rail company or between different rail companies. Some of the rail terminals may also be used as connectors between railways and highways and between railways and waterways. For the purposes of this project, terminals that only serve as transfer points for a single rail company are excluded. However, the database includes terminals that serve as connectors between different railway companies or between different modes.

Rail intermodal service is associated with the movement of semi-trailers (referred to as trailer on flatcar, or TOFC) and containers (referred to as containers on flatcar or COFC) on railway freight cars. The movement of highway trailers on railway flat cars (often called piggyback) is the oldest form of rail-highway intermodalism. Another form of "piggyback" is the transport of containers on flat cars. The movement of containers occurs in both international and domestic traffic. The lack of wheels on containers leads to the need for lift equipment to load and unload containers from/to railway cars and the eventual demise of railway ramp facilities.

There are eight rail intermodal facilities in Florida that handle conventional trailers and containers. They are located in the major metropolitan areas of Ft. Lauderdale, Jacksonville, Miami, Orlando, and Tampa. As shown in Table 3-2, three out of the eight facilities are located in Jacksonville. Four metropolitan areas – Ft. Lauderdale, Jacksonville, West Palm Beach, and Miami – are also the home to major Atlantic coast seaports. Tampa is the site of a major Gulf coast seaport.

Table 3-2   TOFC/COFC intermodal facilities in Florida

Location	Owner
Ft. Lauderdale	FEC
Jacksonville	CSXT
Jacksonville	FEC
Jacksonville	NS
Miami	FEC
Orlando	CSXT
Tampa	CSXT
West Palm Beach	CSXT

Although less commonly thought of when intermodal movement is mentioned, the transfer of bulk materials, both dry and liquid, between modes accounts for significant freight volumes. Transfers of commodities shipped in bulk, such as food products and chemicals, occur at private and railway facilities that are designed and equipped for that purpose. The bulk transfer facilities possess the necessary equipment to transfer a variety of products, including hazardous materials, efficiently and safely. Measures are taken to assure that products will be properly handled without contamination. They allow industries that are not directly served by rail to have the benefits of bulk shipment. At the same time, the facilities provide the railroads with markets they would not otherwise be able to reach. Some Florida bulk transfer terminals are owned by the railroads, although an outside party usually operates them under contract. Others are privately owned and operated, many associated with trucking companies. Table 3-3 shows the bulk transfer facilities in Florida. Figure 3-5 shows the locations for these railway intermodal terminals.

Table 3-3 Bulk transfer facilities in Florida

Location	Serving RR	Operator	Dry	Liquid
Ft. Lauderdale	CSXT	TRANSFLO, Inc	Yes	Yes
Jacksonville	NS	Bulkmatic Transport	Yes	Yes
Jacksonville	CSXT	C&C Bulk Liquid	No	Yes
Jacksonville	NS	ITAPCO	No	Yes
Jacksonville	CSXT	Petroleum Fuel & Terminal Co.	Yes	Yes
Jacksonville	CSXT	TRANSFLO, Inc.	Yes	Yes
Jacksonville	TTR	Westway Terminal Co., Inc.	No	Yes
Lakeland	CSXT	Carry Transit	Yes	Yes
Miami	FEC	Florida Bulk Transfer	Yes	Yes
Sandford	CSXT	TRANSFLO, Inc.	Yes	Yes
Tampa	CSXT	Central Florida Pipeline	No	Yes
Tampa	CSXT	TRANSFLO Inc.	Yes	Yes

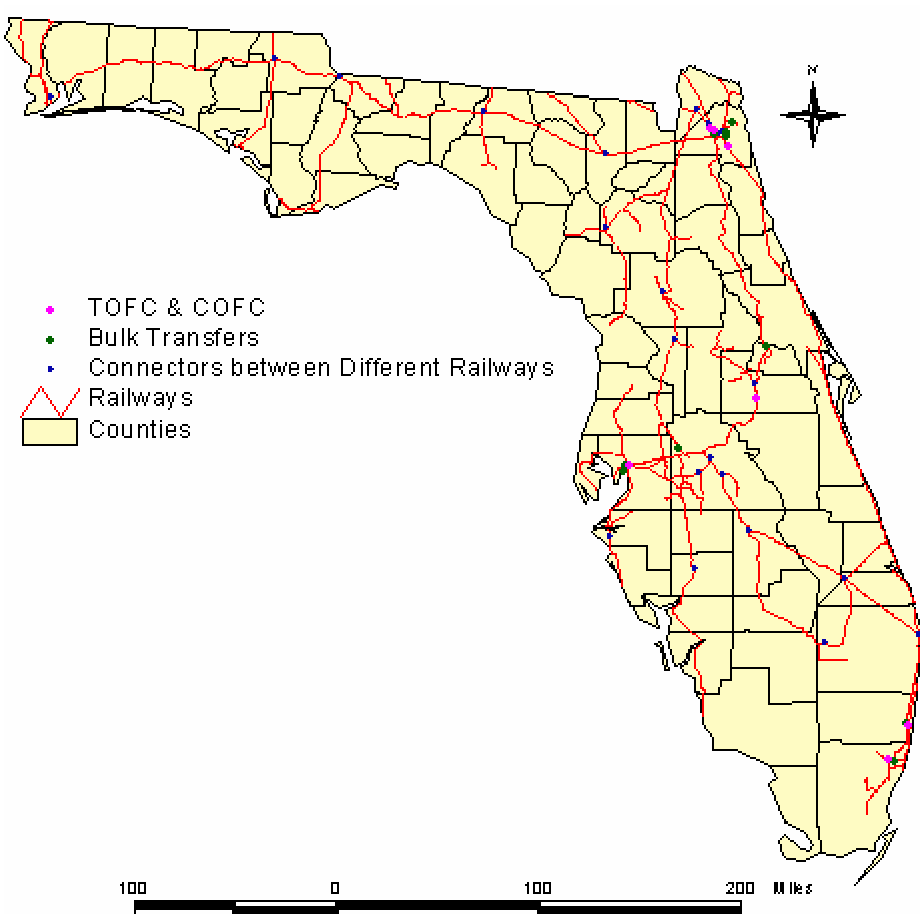

Figure 3-5 Florida railway intermodal terminals

3.4 Warehouses

Although the TRANSEARCH reports provide a broad picture of freight traffic movements in the United States, understanding the nature of TRANSEARCH data is important to interpreting the information correctly. In this database, a large portion of the commodities fall into the SIC classification of "secondary traffic," which refers to freight re-handled by trucks from warehouses and distribution centers. Distinguished from primary shipments, secondary shipments usually occur after the major shipments have taken place and then enter the distribution chains. In the TRANSEARCH database, primary movements may be thought of as shipments originating from locations where goods are produced or assembled and receive their SIC number. The destinations of these shipments are where the products or commodities come to rest, either to be consumed or subject to further processing. If a product is reshipped instead to a staging point, it is a secondary movement. Examples of secondary traffic include shipments from warehouses and distribution centers. Many of these types of facilities handle a wide range of different types of commodities, and outbound shipments may include mixed contents. For example, shipments from a supermarket chain distribution center are likely to contain a broad range of packaged food products and other consumer items.

To locate the warehouses in Florida, the InfoUSA employment database was used by extracting the companies with the SIC major group of "422"- Public Warehousing and Storage. These companies are engaged in the storage of farm products, furniture and other household goods, or commercial goods of any nature. There are 2,579 companies that fall into this category statewide. Table 3-4 shows their distribution by employment size. Only the warehouses with an employment size over 20 were selected. Figure 3-6 shows the locations for 101 such warehouses.

Table 3-4 Bulk transfer facilities in Florida

Employee Size	Number of Warehouses
<20	2,478
20-50	71
50-100	14
100-150	9
150-300	6
675	1
Total	2,579

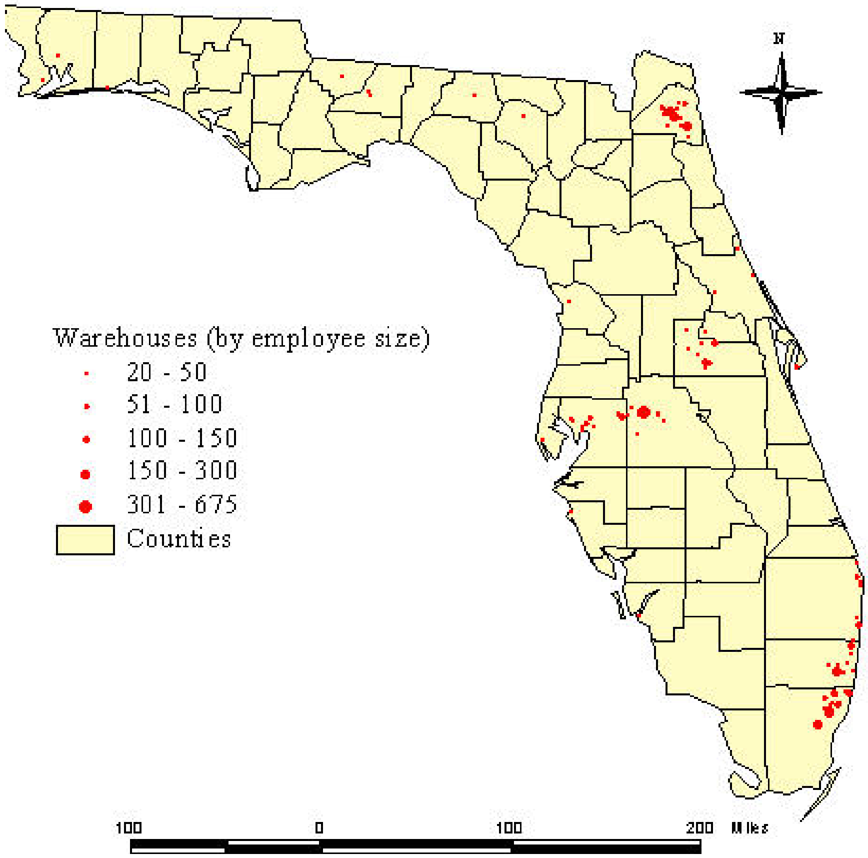

Figure 3-6 Florida warehouses

4. DEVELOPMENT OF THE FLORIDA MULTIMODAL NETWORK

To lay a foundation for multimodal freight flow analysis, the Florida Multimodal Network (FMN) was conceptualized and developed. Initially, the FMN only included nodes and links for highways, railways, waterways, and intermodal facilities. On the recommendations of SPO, air terminals and air linkages were also added to the multimodal network. Therefore, the newly constructed FMN is capable of supporting multimodal and intermodal freight flow analysis for all major transportation modes throughout Florida.

4.1 The Initial Florida Multimodal Network

For transportation analysis, especially flow analysis, an analytical network that forms an explicit representation of the navigational topology for the transportation system is required. The Florida Multimodal Network was developed for this purpose. Today, many of the transportation networks are digitally represented and can be displayed graphically in GIS. Nevertheless, a digital representation of a transportation network may not be directly useful for freight analysis. Frequently, digital networks focus more on the geometric representation of the physical transportation links and nodes, including geometric topology.

For flow analysis, in addition to the representation of network geometry, functional relationships or navigational topology of the transportation network need to be explicitly established. In some cases, a single physical link needs to be split into multiple links (e.g., multiple owners or multiple trackage right holders for the same railroad track). Similarly, some of the nodes in a cartographic database need to be decomposed into multiple nodes so that freight activities can be separated into multiple sub-mode networks. In other cases, navigational topology must be explicitly represented (e.g., traffic movement or channelization in intersections). In still other cases, notional links must be created to connect different modes of transportation networks.

The initial development effort for the analytical multimodal network for freight analysis in Florida included network links and nodes for highways, railways, waterways, and intermodal facilities. Single modal analytical networks were first constructed separately, and then merged through intermodal connections into an interconnected analytical network. The highway network is a critical component of the multimodal network, not only because highways play an important role in the freight movements, but also because when other modes are involved, highways usually serve as starting and ending connections. The highway network that was built into the FMN consists of two separate networks: the highway network inside Florida and the highway network outside Florida. The network inside Florida was developed by FDOT, through its collaborations with Cambridge Systematics, Inc., the Corradino Group, and the Caliber Corporation. The network outside Florida was developed by the ORNL, which, in addition to major highways in the U.S., includes major roadways in Canada and Mexico.

To develop the rail network component of the FMN, the railway network database developed at the ORNL was utilized. This network has a moderate generalization on the link-node structure, which is particularly useful for routing and for freight movement analysis. A special data file of intra-modal transfers provided interlining company-specific sub-networks. An essential aspect in the development of the analytical rail network is to recognize that railways are owned and operated by individual companies. To allow an accurate representation of the operational characteristics of the railway network, rail links operated by different companies were split into different sub-networks, and then inter-sub-network connections were constructed with the interlining file.

The waterway network represents another critical component in the multimodal transportation systems in Florida. This network includes waterways that connect Florida ports with not only those in other parts of the country, but also those that connect to the rest of the world. For the construction of the FMN, the NORTAD water network forms the basis for North America waterways. Trans-oceanic links are also incorporated to provide global water connections. Functionally, Florida ports handle two types of freight vessels: shallow draft barges and deep ocean vessels. For analysis and routing purposes, waterways for these two types of vessels are separated into two sub-networks: the shallow draft and deep draft sub-network. As specialized ships are used in the Great Lakes, the waterway links in the Great Lakes form the third sub-network: the Great Lake sub-network. The first step to construct the analytical waterway network is to split multiple functional waterway links into single functional links, with each single functional link only representing one type of the three possible waterway connections: deep draft links, shallow draft links, and Great Lake links. The next step is to interconnect the waterway sub-networks, so that waterway routes between origins and destinations that go through different types of waterway links can be established. The NORTAD port database was utilized as a base to establish connectivity for the deep draft, shallow draft, and Great Lake waterway sub-networks.

To establish connectivity among different modal networks (e.g., of highways, waterways, and railways), the intermodal terminals database that was developed at ORNL was utilized. The database provides the location of the intermodal facilities and allows the reconfiguration of the relationships between these terminals and different modal networks. To incorporate the intermodal terminals into the FMN, notional links were created to represent the connections between different modal networks. Specifically, access links between terminals and modal networks were searched for and established. In some cases, multiple access links were identified and compared, and decisions were made to choose the most likely connectivity. After intermodal transfer links and access links between intermodal facilities and modal networks were created, merging modal networks and the intermodal connections formed a unified analytical network.

4.2 Incorporating Airports and Air Interconnections into the FMN

On the completion of the initial FMN, the inclusion of airway terminals in the multimodal network was recommended by SPO. For this purpose, nineteen airports that were most likely to be used for cargo shipments were selected. To incorporate these airports into the FMN, two separate steps were involved. One was to establish access links from the airports to the multimodal network. The second was to establish airway linkages among these airports and regional centroids outside Florida.

As for the construction of the access links from airports to the multimodal network, highway nodes were selected as the connecting points between the airports and the multimodal network.

With the 19 airports, 38 bi-directional linkages were established to connect highway nodes and the airports. This means that each airport was allowed to have two bi-directional connections to the FMN. Note also that when the two bi-directional connection links were selected, four alternative links, each in a different direction, were first identified, and then the two with the shortest distance connectivity were selected.

As for the airport interconnections, because only the 19 airports in Florida were provided, it was necessary to establish some notional origins and destinations for those air shipments that go beyond Florida. For representational purpose, the regional centroids that represent the multimodal flow origins and destinations outside Florida were chosen as the notional origins and destinations for air cargo, while inside Florida, the 19 airports were utilized as the starting and ending points of air shipments. With the selection of the actual and national air shipment origins and destinations, interconnection links between these origins and destinations were constructed to represent airway routes. With the access links to the FMN, air transportation became part of the FMN.

The incorporation of the airports and air linkages into the FMN and the inclusion of the initial modal networks (e.g., highways, waterways, railways, and the intermodal interconnections) provide an important infrastructure for freight analysis on all of the major modes in Florida. This newly updated FMN was utilized as the basis for establishing commodity flow patterns.

5. PREPARATION OF THE COMMODITY FLOW O-D DATA

Major efforts have been made by the FDOT Systems Planning Office (SPO) to develop strategies, procedures, and computer models to address the needs for intermodal transportation analysis and planning in Florida. These efforts already resulted in extensive data and various models and tools to facilitate freight analysis. To take advantage of the existing resources, the current project directly adopted the Florida highway network for the construction of the Florida multimodal network. At the same time, the TRANSEARCH database that was utilized for its highway freight flow analysis project was also selected to support intermodal commodity flow analysis on the multimodal transportation network. To provide a broader perspective, this section contains a review of some of the alternatives on the commodity O-D databases, followed by a detailed description of the TRANSEARCH database tables. Finally, some of the additional efforts involved in preparing the database to support the flow loading task are described.

5.1 Commodity Flow Databases

It is well-understood that flow O-D tables are the most critical data elements required to support freight flow analysis. To provide these O-D tables, government agencies, private sectors, and non-profit organizations have spent millions of dollars each year on data collection and data development. However, many of the existing data sources are piecemeal, putting emphasis on a specific transportation mode or focus on selected industrial sectors. For multimodal freight analysis, there are very few alternatives available. The most referenced data sources include the CFS data and the Freight Analysis Framework (FAF) data. Both are in the public domain and have the potential to address some of the needs for state DOTs.

The CFS data represent an important data source for estimating commodity movements in the U.S. The data were generated as a product by the U.S. Census Bureau in collaboration with the Bureau of Transportation Statistics in the U.S. DOT. The data cover major domestic and export freight activities in the U.S. associated with manufacturing, mining, and wholesale trade. The most useful part of the data is the O-D flow table, which provides freight movement by tonnage, by value, by mode, by commodity category, and by geographic origins and destinations. Nevertheless, because of the national focus of the CFS, these data may not be directly useful for regional governments or for state DOTs. In particular, the data do not provide a complete picture of all of the freight movements. Therefore, complementary data sources would be necessary to fill in the gaps existing in the CFS data.

To address the commodity data needs and to support freight transportation planning and policy decisions at the national level, the Federal Highway Administration established the FAF program. A major product of the program is the FAF commodity O-D database, which provides estimates of tonnage and the value of goods shipped by commodity type, transportation mode, and by geographic regions at the national and international level (FHWA 2006). This database was developed by integrating data from a variety of sources, including the CFS data and other components of the Economic Census. Additionally, forecasts are provided for 2010 to 2035 in five-year increments. From a coverage point of view, the FAF can be an ideal source for freight analysis at the national level. However, the use of large geographic regions, e.g., 114 regions for the U.S. and seven regions at the international level, makes it difficult for state and regional governments to directly apply the data for regional freight analysis or transportation decision making. Efforts have been underway to adapt the data for state and regional applications, but it may take time before the data can be readily utilized by state DOTs.

There are many other alternative data sources [e.g., Rail Carload Waybill sample data by the Federal Railroad Administration (FRA), waterborne commerce flow data by the U.S. Army Corp of Engineers, Highway Performance Monitoring Systems by the Federal Highway Administration, and many others]. Nevertheless, enormous efforts are required to put these different data sources together, especially when multiple major transportation modes are involved. To a great extent, it is not practical for an individual project, or even for an individual government agency, to piece all of these data together. Therefore, an alternative to acquire data from commercial sources may represent a cost effective way to address the data needed for multimodal commodity flow analysis.

5.2 The TRANSEARCH Database

FDOT has been working with several other private and public institutions on intermodal freight analysis with a focus on highways. In these efforts, decisions have been made to use the TRANSEARCH database as the primary data source for commodity flow origins and destinations. The database that has been acquired by FDOT provides the multimodal commodity O-D tables for 2003. The database provides not only the O-D tables, but also descriptions about the origin and destination regions used in the O-D tables. Information about the routes used to assign the O-D flows is also provided.

There are several important data tables in the database. The most important one is the TRANSEARCH 2003 O-D table. In this table, each entry provides the flow origin, destination, and tonnage by mode, by truckload, and by value. Particularly, when multiple transportation modes are involved, tonnage for each mode is defined in detail. For truck flows, tonnages and truck loads are separated into more detailed categories (e.g., truck tonnage, less than truck load tonnage, private truck tonnage) and are separated.   It is the same for truck loads. The TRANSEARCH 2003 O-D includes O-D flows for highways, waterways, air transportation, and the other category. The other category was interpreted as intermodal.

The second important table is the 2003 rail O-D table. In this table, flow tonnage and value are defined for each O-D entry, plus the rail carloads. The table also provides tonnages and values for intermodal flows, which are interpreted as flows that have a rail mode preference, but the use of other modes are not excluded (e.g., the use of highways and waterways).

The TRANSEARCH 2003 with rail O-D table provides combined entries for the TRANSEARCH 2003 O-D table and the rail 2003 O-D table. However, each O-D entry in the TRANSEARCH 2003 with rail O-D table only includes the tonnage by mode (e.g., truck, less than truckload truck, private truck, rail, water, air, and intermodal). No information on truck loads, rail carloads, or intermodal units is provided. The table is useful only where the tonnage by mode and by origin and destination is concerned.

The remaining tables in the database are for information purposes. The Highway Routes and the Rail Routes tables are useful for referencing the transportation links that are included in selected O-D entries. The regions table provides a list of origin and destination regions used by the O-D tables. The regions by county table is particularly useful when regions are aggregated. This table is utilized in this study to establish the regional centroids.

The TRANSEARCH database is in Microsoft Access format, which makes it easy to use and to customize. One of the shortcomings of the database is that no geospatial data are provided with the data tables, which makes it difficult to use the information contained in the routes tables. The user may have to find his/her own data sources for regional boundaries and regional centroids.

5.3 Commodity O-D Table Preparation

The TRANSEARCH O-D information by mode, by tonnage, and by car- or truckload is of particular importance to this study. The O-D entries by modes are essential because this information directly determines the mode preference when the flows are assigned to the network. The tonnage information, when loaded on the network, provides flow volumes on the system. The carload or truckload information can be utilized to provide traffic counts, which can be compared with observations from selected locations [e.g., the Highway Performance Monitoring System (HPMS)]. For these considerations, two TRANSEARCH database tables were utilized: the TRANSEARCH 2003 table and the rail 2003 table.

The TRANSEARCH 2003 table contains information on regions where commodity flows originate from and end up, commodity category codes, truck tons, less than truckload tons, private truck tons, air tons, water tons, other tons, truck loads, less than truckload loads, private truck loads, values, and entry road, exit road, etc. For simplicity, columns of flow origin, destination, commodity category code, truck tons, air tons, water tons, other tons, and truck loads were selected from the TRANSEARCH 2003 table for subsequent processing. From the rail 2003 table, the columns of flow origin, destination, commodity category code, carload tons, carload cars, intermodal tons, and intermodal units were selected. With these selections, these two tables were then used to construct five tables, each for different mode category:

1) There is a table for air tons where the column of air tons > 0,
2) There is a table for truck tons where the column of truck tons > 0,
3) There is a table for intermodal tons and other tons where the intermodal tons or other tons > 0,
4) There is a table for rail tons where carload tons > 0, and
5) There is a table for water tons where water tons > 0.

Note that, for those table entries where multimodal flows were involved, several modes of transportation would be utilized. In these cases, the table separation procedure was intended to simplify the flow loading process by choosing each of the involved transportation modes separately. However, when the multimodal flows were loaded to the network, the aggregated flows from individual modes would produce the effect of multimodal loading. In fact, the intermodal table was directly utilized to load intermodal flows to the multimodal network.

The O-D tables from the TRANSEARCH database were based on regional origins and destinations. The TRANSEARCH database itself does not include the regional boundaries for the defined origins and destinations. To solve this problem, the ORNL county and state boundary database was utilized as a starting point. Given the different levels of aggregation involved, some of the counties or states were merged to establish regional boundaries that correspond to the TRANSEARCH database regions. O-D regions inside Florida or immediately neighboring Florida correspond to the county boundaries. Regions far from Florida are much larger, for example, comprising several states or provinces for the northern or western U.S. and Canada, or the entire country for Mexico.

To associate regional origins and destinations to the multimodal network, point centroids were created for each origin and destination region. Four access links were then created between these centroids and the highways for each of the centroids. These four access links each were chosen from the shortest distance links that were identified in four different directions, e.g., northeast, northwest, southwest, and southeast. However, in a particular direction, access links may not be available within a given distance, which is particularly true in places such as Hawaii. In these cases, the access links were omitted for the given direction.

6. MULTIMODAL COMMODITY FLOW ASSIGNMENT

Once the origin and destination of a given commodity flow entry are provided, the major task is to identify the routes in the multimodal network that the flows are most likely to follow. For this research effort, two possibilities for the flow route choices are considered. One is when the mode or modes that are to be utilized are not explicitly defined by the O-D table. In this case, the routing procedure directly makes the decision regarding the flow routes, while the choice of the mode or modes is determined automatically after the routes are selected. The second case is that the O-D table already provides preference on the choice of the mode or modes before the routes are to be determined. In this case, the routing procedure goes with the mode or modes that are provided by the O-D table. In either case, the routing procedure needs to evaluate the routing decisions carefully because a large number of alternatives are available on the multimodal network.

6.1 Impedance Factors for Mulitmodal Routing

To support the routing decisions on the multimodal network, several basic impedance factors were examined: transportation distance, cost, and time. From a computational point of view, transportation distance can be easily obtained with any of the length calculation functions. This is true for most of the transportation links that connect flow origins and destinations. There are special links in the multimodal network; their lengths need special attention, that is, the access links and transfer links between different modes. In general, computed lengths can be utilized for those links, but those lengths do not represent the actual impedances from an analysis point of view. For this reason, notional lengths were assigned to those special links. In fact, when the notional lengths were determined, reference was made to the waiting time on these links, which, in any case, is a rough guess and not from empirical data.

The per-ton-mile transportation cost is perhaps one of the most important factors when routing decisions are made. The transportation literature provides a broad range of statistics on the cost per ton-mile for different transportation modes. Air transportation is considered the most expensive mode, followed by trucks, rail, and barges. Even with the same mode, because of the differences in the equipment used, commodity compatibility, or requirements for special handling, the cost per ton-mile can differ several-fold when different commodities are involved. From an application point of view, it would be useful to identify, for different commodities, how much they actually cost when different transportation modes are utilized.

As to this research, a more general cost profile was adapted for multimodal commodity routing. This cost profile was based on the average freight revenue per ton-mile from the Bureau of Transportation Statistics. Note that transportation costs are also time dependent. That is, due to the cost changes in operations, fuels, and other elements, costs per ton-mile change from year to year. It would be most useful if the time given for the cost profile were to match the time for the origin and destination flow tables. However, this is not the case. This project utilized the average freight revenue per ton-mile for the year 2001, when the cost statistics were made available for all the major modes (e.g., $0.804 per ton-mile for air transportation, $0.266 for truck, $0.0224 for rail, and $0.0072 for barge). Note that the cost for trucks is for general freight common carriers, and those carriers are generally less than truck load carriers.

In many cases, cost itself is not a determining factor for multimodal route choices. Transportation time is another important factor. To understand the time spent in the transportation system, it is essential to understand the speed of the commodity movement in the system. Take highways as an example. Travel speeds differ from link to link, from one type of road to another type of road, with different levels of congestion. This is the same with railways and with waterways. Movement speeds in intermodal facilities are more complex, and there is little information regarding them.

For simplicity, a general speed profile was adapted for routing flows on the multimodal network. For highways, links from the FDOT network already carry speed information, which was directly taken as the link attribute in the multimodal network. For the portion of highway network that is outside Florida (e.g., the ONRL highway network), the link function classes were utilized as the basis to establish the link travel speeds. Traffic congestion was not considered as a factor when the highway travel speeds were determined. This is one area that can be further improved in the future.

For railways, there is little information available to determine the freight movement speeds on specific railway links. Instead, a national average speed of 22 miles per hour was assigned to the entire railway network. This average speed is based on statistics of the Association of American Railroads. One positive aspect with the use of this national average speed for railways is that, from a mode choice point of view, one would certainly choose highways rather than railways if the speed were the only concern.

For waterways, more information is available regarding barge movement speeds. These speeds vary from one river to another river or from one waterway to another waterway. Generally speaking, downstream barges move faster than upstream barges; deeper water allows higher speed; and, in some places, barge movement speeds are regulated for safety reasons. For simplicity, a single speed was applied to all of the waterway links, which is eight miles per hour. This speed falls between the range of 6 to 11 miles per hour for many of the waterways in or near the U.S. Like railways, this speed gives a distinctive characteristic to waterways when transportation time is evaluated.

For air transportation, a single notional speed of 300 miles per hour was used for all of the air transportation links.

6.2 A Combined Impedance Indicator

Of the three impedance factors that were examined for routing commodities though the multimodal network, distance or length is simply a multiplier. That means that when the per mile transportation cost or per mile transportation time is determined, distance or length can be directly used as a multiplier for per mile cost or time to get the total cost or time. Therefore, the true determining factors are either per mile cost or time, or a combination of both. If a customer were only concerned with cost, he or she would choose waterways when waterways are available, then railways, highways, and finally air transportation. In contrast, if a customer is only concerned with time, air transportation would be the first choice, then highways, railways, and waterways. If both the transportation cost and transportation time are being considered, the question is then how he or she would make the decision on the choice of a mode or modes. To solve this problem, an integrated cost and time impedance function was developed to derive combined impedance indicators for each of the network links.

To develop the integrated cost and time impedance function, the first consideration is to bring cost and time onto the same footing. For travel time, transportation speeds range from eight miles per hour for waterways to 300 miles per hour for airways. As for transportation costs, cost per ton mile ranges from $0.0072 for waterways to $0.804 for airways. To make them comparable, two scaling functions were introduced, one for cost, and one for time:

cost_scaling_factor = k_cost × cost_per_ton_mile + cost_constant,
time_scaling_factor = k_time × (1.0/speed_miles_per_hour) + time_constant.

For the cost scaling function, the objective is to derive the cost scaling factor with a value ranging from 0.01 to 1.0 when the distance or the length of a link is set as one mile. That is, if a one-mile link were most costly in the transportation system, its cost scaling factor would be set to 1.0. In contrast, if a one-mile link were most inexpensive, its cost scaling factor would be set to 0.01. Similarly, for the time scaling function, the objective is to derive the time scaling factor with a value ranging from 0.01 to 1.0 when the distance or the length of a link is set as one mile. That is, if a one-mile link took the longest time to traversal in the transportation system, its time scaling factor would be set to 1.0. In contrast, if a one-mile link took the least time to traverse, its time scaling factor would be set to 0.01. Because both the time scaling and the cost scaling factor have the values ranging from 0.01 to 1.0, they are directly comparable when both factors are combined together.

Next, a combined cost and time impedance function was introduced to integrate both the cost and time factors for all of the multimodal network links. This function makes use of the link length as a multiplier, one cost preference factor, one time preference factor, and the cost and time scaling factors. The two preference factors are constrained with a summation of 1.0. That is:

combined_impedance_indicator = link_length × [(cost_preference_factor ×
cost_scaling_factor) + (time_preference_factor × time_scaling_factor)],

with the constraint

(cost_preference_factor + time_preference_factor) = 1.0.

If a customer has a 50% to 50% preference regarding the cost and time for his or her shipment, the combined impedance indicator would be:

combined_impedance_indicator = link_length × [(0.5 × cost_scaling_factor) +
(0.5 × time_scaling_factor)].

When different cost and time preference factors are utilized, different combined impedance indicators can be generated. By adjusting the cost and time preference factors, the combined impedance indicator can be geared toward choosing a specific transportation mode. With some experiments, it was determined that a 0.7 speed preference factor and a 0.3 cost preference factor were used to give preference to highways. Based on the impedance function, the combination of a 0.7 speed preference factor and a 0.3 cost preference factor will provide the following impedance indicators for one mile traveling distance: 0.307 for airway, 0.182 for highway, 0.256 for railway, and 0.703 for waterway. When the impedance indicators are compared, it is clear that highway impedance is the lowest for the same traveling distance. This means that if multimodal paths that have the same travel distance are available from an origin to a destination, the highway path will be selected.

Similarly, the combination of a 0.05 speed preference factor and a 0.95 cost preference factor will provide the following impedance indicators for one mile traveling distance: 0.951 for airway, 0.321 for highway, 0.045 for railway, and 0.060 for waterway. When the impedance indicators are compared, railway impedance is the lowest for the same traveling distance. This means that if multimodal paths that have the same travel distance are available from an origin to a destination, the railway path will be selected.

Once the impedance indicators were determined for the links of the multimodal network, flow assignment was simply a shortest path calculation with the given origins and destinations, followed by cumulating link flows through tracking the links for any of the origin and destination pairs provided in the O-D data table. In this way, the preference for the choice of the transportation modes would be implicitly determined through the commodity flow routing process.

6.3 Multimodal Flow Assignment Results

After the Florida Multimodal Network, the origin and destination flow tables, and the distance, cost, and time, as well as the cost-time impedance indicators were prepared, the follow-up task was to load the O-D tables to the multimodal network. As described in Section 5.3, for computational efficiency, five O-D tables were separately constructed. Four of the five tables have predetermined mode preferences. That is, the truck O-D table gives mode preference to highways. The rail O-D table gives mode preference to railways, but the routing procedure always assumes that the flows start from and end with highways. That is, the rail O-D table would generate the routes that have a mode sequence of starting from highways, switching to railways, and then coming back to highways again. This is the same for waterways and air transportation. As for intermodal preferences, because the intermodal O-D table was initially derived from the rail O-D table and the general TRANSEARCH O-D table, it was assumed that for the intermodal O-D table, the mode preference would be mainly geared toward railways and waterways. However, highways were always included as part of the route choice.

When the truck O-D table was loaded to the multimodal network, the flow assignment procedure selected a predetermined cost-time impedance indicator that provided preference for highways. Then the procedure went through each O-D pair and assigned the O-D flow to the shortest path for the given O-D pair. Because of the use of the cost-time impedance indicator, which gave preference to highways, the procedure chose highway connections as the primary mode for the truck O-D table. Figure 6-1 provides the map for the loaded highway flows on the multimodal network.

When the waterway O-D table was loaded onto the multimodal network, the flow assignment procedure simply selected cost as the impedance, which provided preference to waterways. Then the procedure went through with each O-D pair, and assigned the O-D flow to the shortest path for the given O-D pair. Because transportation cost provided preference for waterways, the procedure chose the waterway links as the primary mode. Figure 6-2 provides a map for the loaded waterway flows on the multimodal network. Note that even though preference was given to waterways, highways always served as the starting and ending linkages when the waterway O-D table was loaded to the multimodal network. Because highway flows were already counted in the truck O-D table, flows loaded on the highways through the waterway O-D table were subtracted out to eliminate double counting.

When the rail O-D table was loaded to the multimodal network, the flow assignment procedure selected a predetermined cost-time impedance indicator that provided preference for railways. Then the procedure went through with each O-D pair and assigned the O-D flow to the shortest path for the given O-D pair. Because the cost-time impedance indicator provided preference for railways this time, the procedure chose railway links as the primary mode. Figure 6-3 provides a map for the loaded railway flows on the multimodal network. Like waterways, even though preference was given to railways, highways always served as the starting and ending linkages when the rail O-D table was loaded to the multimodal network. Hence, flows loaded on the highways through the railway O-D table were subtracted out to eliminate double counting.

When the air O-D table was loaded to the multimodal network, the flow assignment procedure simply selected time as the impedance for the multimodal network because travel time provided a natural preference for air transportation. Then the procedure went through with each O-D pair and assigned the O-D flow to the shortest path for the given O-D pair. Figure 6-4 provides a map for the loaded air flows, which are merely symbolic because the actual flight routes may be different from the straight lines generated for the flow loading purpose.

When the intermodal O-D table was loaded to the multimodal network, the flow assignment procedure selected the pre-determined impedance indicator that provided preference for railways, waterway, and highways. Then the procedure went through with each O-D pair and assigned the O-D flow to the shortest path for the given O-D pair. As shown in Figure 6-5, the loaded flow map indicates that the intermodal flows are truly intermodal, and include links for railways, waterways, and highways.

After the five O-D tables were loaded on the multimodal network, link flows generated with each separate O-D table were aggregated. This provided an overall flow picture for the entire multimodal transportation network, as shown in Figure 6-6.

Figure 6-1 Highway flow map

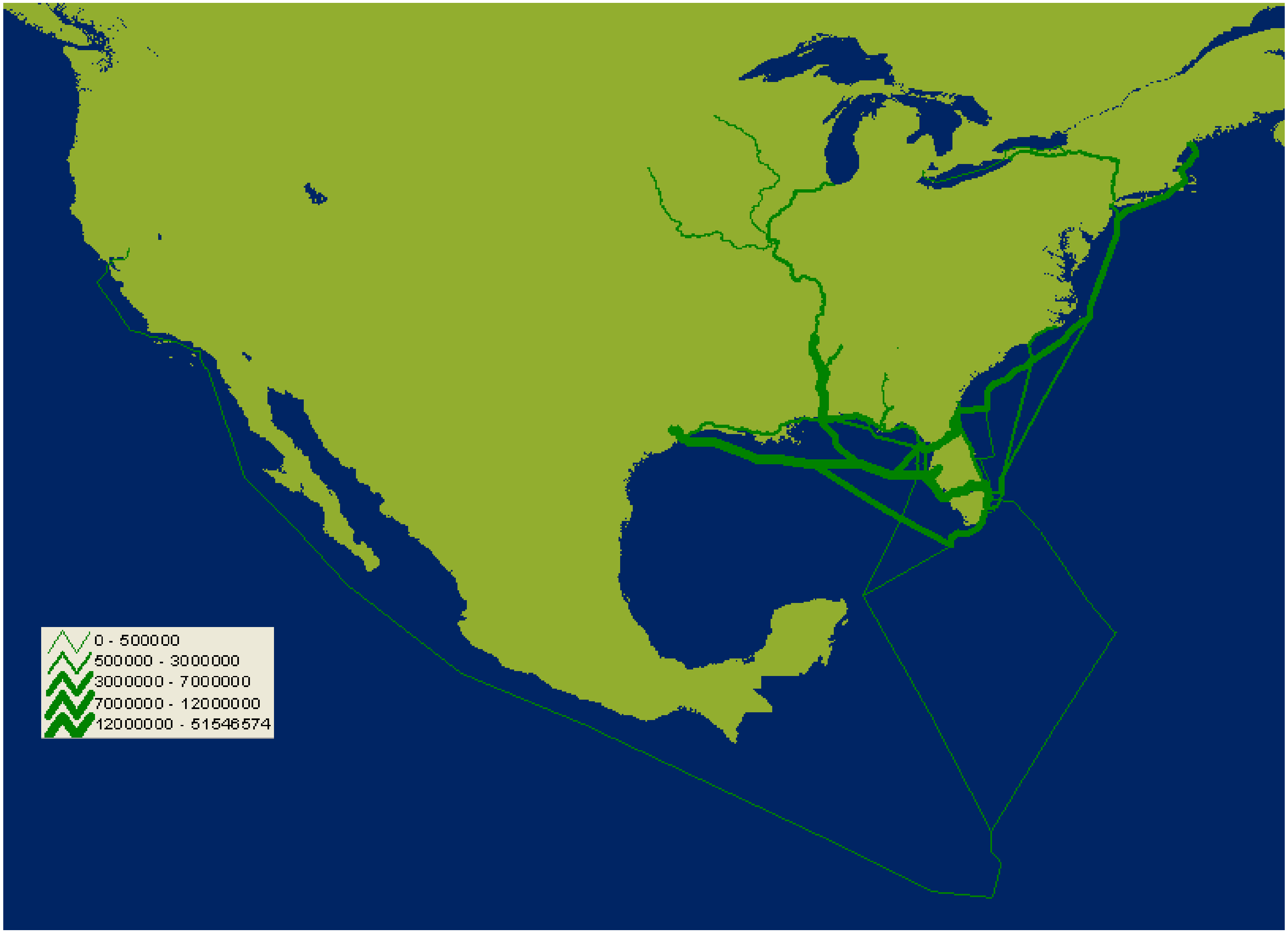

Figure 6-2 Waterway flow map

Figure 6-3 Railway flow map

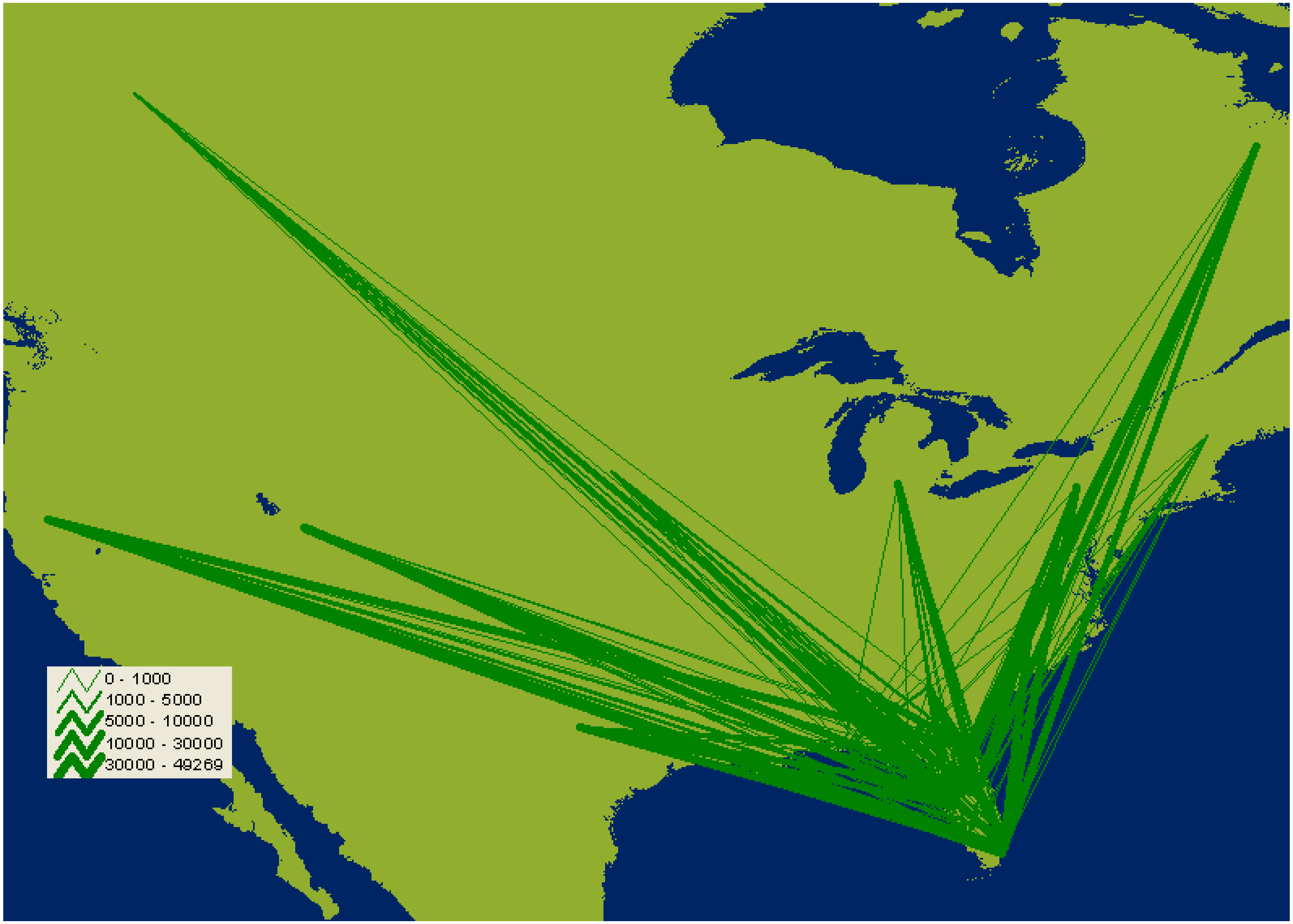

Figure 6-4 Airway flow map

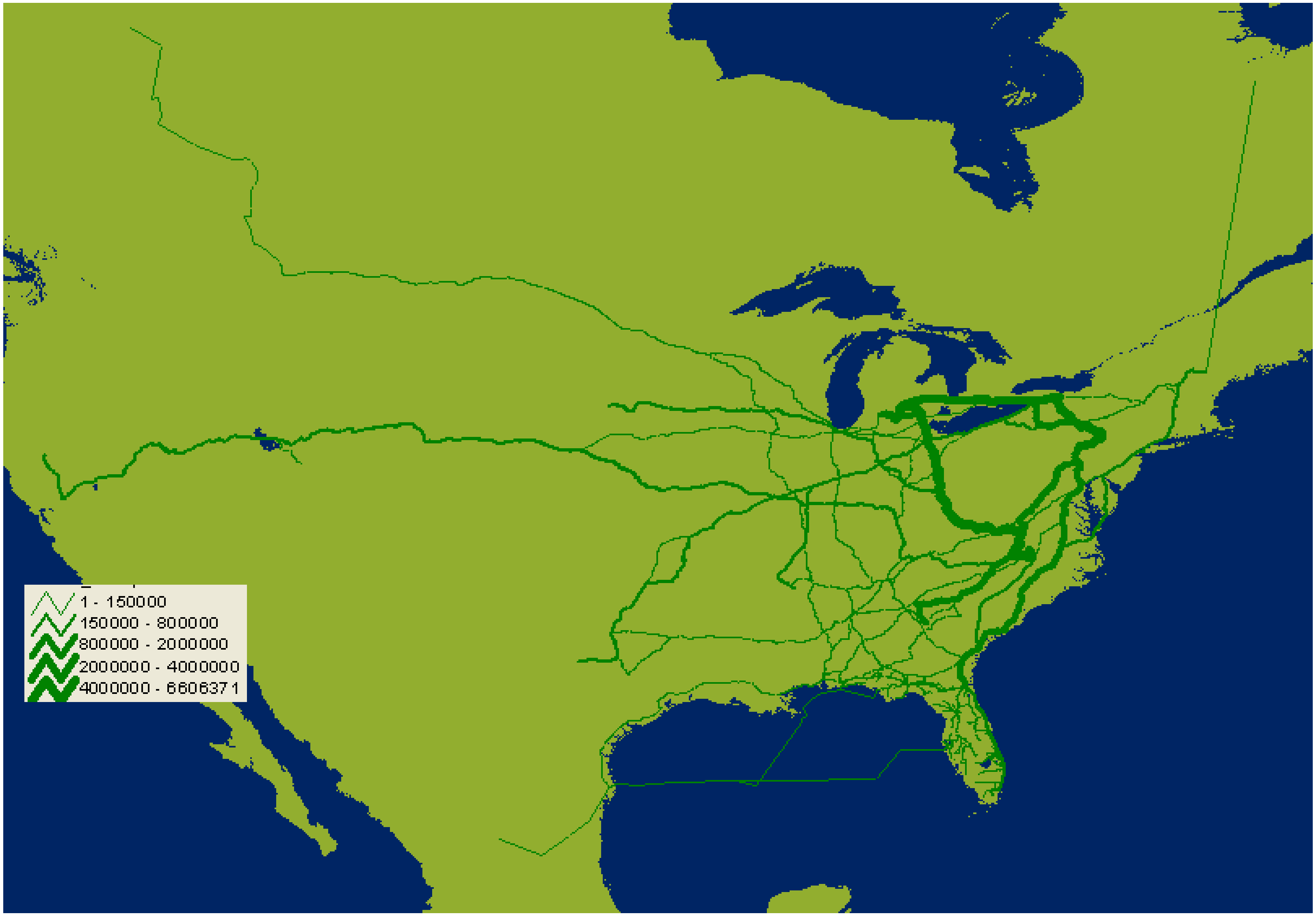

Figure 6-5 Intermodal flow map

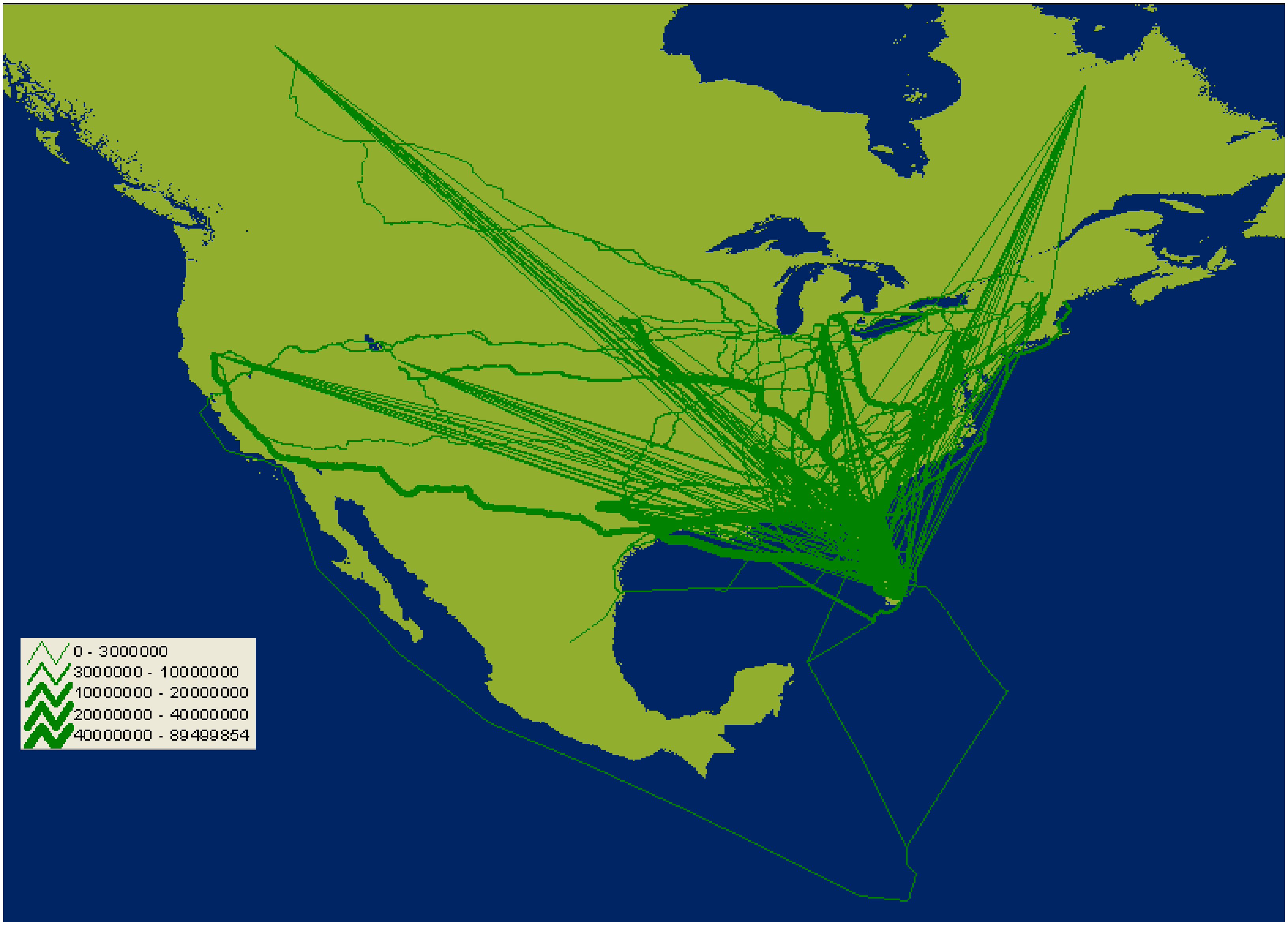

Figure 6-6 Multimodal commodity flow map

7. MODEL EVALUATION

The loading of the O-D tables on the multimodal network was described in Chapter 6. The link flows generated from each O-D table were aggregated to provide an overall flow for the entire multimodal transportation network. The resulting truck volumes on highway sections in the multimodal network were validated with the observed truck volumes, which were obtained from Florida Traffic Information (FTI) CD. This chapter describes the model evaluation process and results.

7.1 Tonnage to Truck Conversion Factor in the Statewide Freight Model

In the modal split model developed by Cambridge Systematics, Inc., the tonnage to trucks conversion was carried out by applying the payload factors derived from the U.S. Census Vehicle Inventory and Use Survey (VIUS) (FDOT 2002b) (see Section 2.1.4). These factors convert the annual tonnage into annual trucks based on distance and commodity type. The VIUS data contain complete information of each sampled record. The Florida records were extracted for the analysis, and the average payloads were calculated by five distance groups:

- Less than 50 miles;
- At least 50, but less than 100 miles;
- At least 100, but less than 200 miles;
- At least 200, but less than 500 miles; and
- At least 500 miles.

The VIUS survey records include the percentage of the total mileage traveled by a truck carrying certain products, equipment, materials, etc. In the *Commodity Origin-Destination Database User Guide* (FDOT 2002b), correspondence between the VIUS product classes (shown in Table 7-1) and the STFM Commodity Groups was established. In Table 7-1, “No Load” (Index 47), which indicates an empty truck, is treated by VIUS as a separate product category.

Table 7-1 VIUS product classes

Index	VIUS Product Classes
1	Live animals and fish
2	Animal feed or products of animal origin
3	Cereal grains
4	All other agricultural products
5	Basic chemicals
6	Fertilizers and fertilizer materials
7	Pharmaceutical products
8	All other chemical products and preparations
9	Alcoholic beverages
10	Bakery and milled grain products
11	Meat, seafood, and their preparations
12	Tobacco products
13	All other prepared foodstuffs
14	Logs and other wood in the rough

15	Paper or paperboard articles
16	Printed products
17	Pulp, newsprint, paper, or paperboard
18	Wood products
19	Articles of base metal
20	Base metal in primary or semi-finished forms
21	Nonmetallic mineral products
22	Non-powered tools
23	Powered tools
24	Electronic and other electrical equipment
25	Furniture, mattresses, lamps, etc.
26	Machinery
27	Miscellaneous manufactured products
28	Precision instruments and apparatus
29	Textile, leather, and related articles
30	Vehicles, including parts
31	All other transportation equipment
32	Coal
33	Crude petroleum
34	Gravel or crushed stone
35	Metallic ores and concentrates
36	Monumental or building stone
37	Natural sands
38	All other nonmetallic minerals
39	Fuel oils
40	Gasoline and aviation turbine fuel
41	Plastics and rubber
42	All other coal and refined petroleum products
43	Hazardous waste
44	All other waste and scrap
45	Recyclable products
46	Mail and courier parcels
47	Empty shipping containers
48	Passengers
49	Mixed freight (for-hire carriers only)
50	Multiple categories

The weighted annual mileage was calculated for each record in the Florida VIUS database by each VIUS product and each distance class. The weighted annual pound mileage by product class and by distance class for each record was obtained by multiplying the weighted annual mileage with the average payload for the surveyed truck. The weighted annual miles and the weighted annual pound miles were summed for all records. The average annual pound mile was divided by the average annual miles to obtain the average payload for each commodity by distance class. Table 7-2 gives the average payload.

Table 7-2 Average payload by commodity group and distance class used in STFM

Commodity Group	Average Payload in Pounds				
	<50 miles	50 – 100 miles	100 – 200 miles	200 – 500 miles	500+ miles
Agricultural	18,408	36,286	43,901	38,956	35,572
Minerals	41,237	35,000	42,138	-	46,000
Food Products	17,283	37,194	44,574	42,209	42,465
Non-Durable Manufacturing	7,155	10,105	36,208	12,441	29,579
Lumber	9,405	50,378	44,780	56,639	48,314
Paper	22,630	19,924	39,723	34,003	36,960
Chemicals	23,215	41,506	39,240	46,916	37,329
Petroleum Products	39,091	51,042	54,648	43,708	34,653
Durable Manufacturing	10,237	13,944	37,440	38,416	34,464
Concrete, Clay, Glass, Stone	31,647	40,617	39,934	45,413	44,802
Non-municipal Waste	20,565	34,060	32,295	46,132	42,066
Miscellaneous Freight	13,796	14,416	41,777	38,575	36,853
Warehousing	18,039	13,068	47,820	6,685	23,125

Note that the payloads shown in Table 7-2 do not include the percentage of mileage traveled by an empty truck. The factor used to convert annual tonnage to annual trucks should account for both the average payload and the percentage of empty trucks in each commodity group. This percentage of "no load" mileages by commodity group may be calculated from the VIUS "No Load" product class. Table 7-3 lists the empty truck percentages by commodity type and distance traveled used in STFM. Table 7-4 gives the annual tons to annual truck conversion factors by commodity and the distance between TAZs, taking into account the effect of empty trucks.

Table 7-3 Empty truck percentage used in STFM

Commodity Group	< 50 miles	50 – 100 miles	100 – 200 miles	200 – 500 miles	500+ miles
Agricultural	24%	25%	9%	9%	8%
Minerals	34%	14%	22%	24%	22%
Food Products	1%	1%	3%	6%	9%
Non-Durable Manufacturing	6%	6%	6%	10%	6%
Lumber	9%	9%	17%	15%	9%
Paper	9%	31%	11%	9%	5%
Chemicals	3%	9%	24%	8%	5%
Petroleum Products	8%	27%	10%	4%	3%
Durable Manufacturing	13%	9%	8%	12%	11%
Concrete, Clay, Glass, Stone	1%	5%	8%	13%	15%
Non-Municipal Waste	12%	33%	17%	6%	5%
Miscellaneous Freight	2%	2%	8%	12%	6%
Warehousing	15%	3%	49%	33%	1%

Table 7-4 Annual tons to annual trucks conversion factors used in STFM

Commodity Group	<50 miles	50 – 100 miles	100 – 200 miles	200 – 500 miles	500+ miles
Agricultural	0.1001	0.0494	0.0376	0.0461	0.0542
Minerals	0.0421	0.0564	0.0451	0.0443	0.0435
Food Products	0.1109	0.0516	0.0431	0.0453	0.0458
Non-Durable Manufacturing	0.2706	0.1960	0.0535	0.1583	0.0647
Lumber	0.1856	0.0373	0.0423	0.0340	0.0397
Paper	0.0816	0.0920	0.0496	0.0569	0.0518
Chemicals	0.0815	0.0439	0.0459	0.0331	0.0504
Petroleum Products	0.0440	0.0336	0.0360	0.0436	0.0535
Durable Manufacturing	0.1831	0.1315	0.0509	0.0481	0.0532
Concrete, Clay, Glass, Stone	0.0507	0.0428	0.0456	0.0414	0.0430
Non-Municipal Waste	0.0897	0.0537	0.0619	0.0409	0.0473
Miscellaneous Freight	0.1398	0.1193	0.0454	0.0455	0.0523
Warehousing	0.1097	0.1328	0.0342	0.1613	0.0859

After the conversion of annual tons to annual trucks, Cambridge Systematics, Inc. then converted the annual truck trip table to a daily truck trip table by applying a factor of 306 working days per year.

7.2 Truck Conversion Factors Used in This Study

For this study, to convert tonnage to truck by commodity classification used in TRANSEARCH, a relationship between these commodity types and the VIUS commodity classification is required. Jack Faucett Associates provided the correspondence between these two classifications in one of their final report prepared for the U.S. DOT (Jack Faucett Associates 1999), which is summarized in Table 7-5.

Table 7-5 Correspondence between TRANSEARCH classification and VIUS classification

STCC	Description	VIUS	Description
1	Farm Products	01	Farm Products
10	Metallic Ores	04	Mining Products
11	Coal	04	Mining Products
13	Crude Petroleum or Natural Gas	10	Petroleum Products
14	Nonmetallic Minerals	05	Building Materials
20	Food or Kindred Products	03	Processed Foods
22	Textile Mill Products	17	Textiles and Apparel
23	Apparel or Related Products	17	Textiles and Apparel
24	Lumber or Wood Products	06 07	Logs and Other Forest Products Lumber and Fabricated Wood Products

25	Furniture or Fixtures	16	Furniture or Hardware
26	Pulp, Paper, or Allied Products	08	Paper Products
27	Printed Matter	08	Paper Products
28	Chemicals or Allied Products	09	Chemicals and/or Drugs
29	Petroleum or Coal Products	10	Petroleum Products
30	Rubber or Misc. Plastics	11	Plastics and/or Rubber Products
31	Leather or Leather Products	17	Textiles and Apparel
32	Clay, Concrete, Glass, or Stone	05 26	Building Materials Glass Products
33	Primary Metal Products	12	Primary Metal Products
34	Fabricated Metal Products	13	Fabricated Metal Products
35	Machinery	14	Machinery
36	Electrical Equipment	14	Machinery
37	Transportation Equipment	15	Transportation Equipment
39	Misc. Manufacturing Products	27	Miscellaneous Products of Manufacturing
40	Waste or Scrap Materials	21	Scrap, Garbage, etc.
41	Misc. Freight Shipments	20	Mixed Cargo
48	Waste Hazardous Materials	29	Hazardous Waste (EPA Manifest)

The methodology used by Cambridge Systematics, Inc. (described in Section 9.1) to calculate the conversion factor was adopted. Table 7-6 shows the average payload, in pounds, of each commodity type for each distance group.

Table 7-6 Average payload by commodity group and distance class

STCC	Average Payload in Pounds					
	On Road Average	<50 miles	50-100 miles	100-200 miles	200-500 miles	500+ miles
1	30,142	19,256	28,287	34,948	36,256	33,749
10	40,852	41,237	40,838	35,000	–	46,000
11	40,852	41,237	40,838	35,000	–	46,000
13	42,161	39,091	42,990	51,042	43,708	34,653
14	36,148	31,604	35,332	39,930	45,845	48,565
20	33,420	17,283	23,492	37,194	42,209	42,465
22	14,121	11,476	15,188	7,604	10,759	28,802
23	14,121	11,476	15,188	7,604	10,759	28,802
24	24,700	10,025	22,128	46,624	47,907	44,192
25	19,027	4,741	21,160	19,778	13,850	30,607
26	29,522	22,630	35,053	19,924	34,003	36,960
27	29,522	22,630	35,053	19,924	34,003	36,960
28	31,606	23,215	27,962	41,506	46,916	37,329
29	40,852	41,237	40,838	35,000	–	46,000
30	14,552	7,380	6,523	10,152	33,972	38,327
31	14,121	11,476	15,188	7,604	10,759	28,802
32	79,220	65,332	87,418	86,992	88,628	84,013

33	27,560	15,472	19,299	15,406	44,818	47,199
34	20,425	9,757	25,521	12,622	28,469	41,674
35	24,500	11,684	26,803	29,231	33,253	31,019
36	24,500	11,684	26,803	29,231	33,253	31,019
37	21,441	7,858	20,524	14,443	44,960	32,061
39	18,271	13,435	16,714	10,607	45,022	33,163
40	26,073	23,094	17,409	36,427	–	43,000
41	22,836	13,796	25,219	14,416	38,575	36,974
48	11,972	2,000	9,771	9,771	–	25,000

The percentage of empty trucks was estimated from the VIUS for each commodity type. Table 7-7 summarizes the empty truck percentages. Table 7-8 shows the annual tonnages to annual trucks conversion factors by commodity type and the distance group. This takes empty trucks into account.

Table 7-7 Empty truck percentages

STCC	On Road Average	Distance (miles)				
		< 50	50-100	100-200	200-500	500+
1	8	8	3	18	9	4
10	6	13	1	5	0	0
11	6	13	1	5	0	0
13	12	14	14	2	5	7
14	14	20	13	9	8	2
20	4	4	4	4	4	3
22	1	3	1	0	2	4
23	1	3	1	0	2	4
24	15	13	21	24	12	3
25	5	3	1	13	1	4
26	4	8	8	1	3	4
27	4	8	8	1	3	4
28	10	5	9	10	22	6
29	12	14	14	2	5	7
30	2	3	1	1	3	7
31	1	3	1	0	2	4
32	14	20	13	9	7	4
33	9	17	8	6	5	4
34	5	2	19	1	2	5
35	13	5	14	17	18	14
36	13	5	14	17	18	14
37	6	6	5	10	4	5
39	3	5	5	1	9	4
40	8	11	12	0	0	0
41	8	4	14	5	12	4
48	0	0	0	0	0	0

Table 7-8 Annual tons to annual trucks conversion factors

STCC	Average Payload in Pounds					
	On Road Average	<50 miles	50-100 miles	100-200 miles	200-500 miles	500+ miles
1	0.0717	0.1122	0.0728	0.0675	0.0601	0.0616
10	0.0519	0.0548	0.0495	0.0600	0.0517	0.0435
11	0.0519	0.0548	0.0495	0.0600	0.0517	0.0435
13	0.0531	0.0583	0.0530	0.0400	0.0480	0.0618
14	0.0631	0.0759	0.0640	0.0546	0.0471	0.0420
20	0.0622	0.1203	0.0885	0.0559	0.0493	0.0485
22	0.1430	0.1795	0.1330	0.2630	0.1896	0.0722
23	0.1430	0.1795	0.1330	0.2630	0.1896	0.0722
24	0.0931	0.2254	0.1094	0.0532	0.0468	0.0466
25	0.1104	0.4346	0.0955	0.1143	0.1459	0.0680
26	0.0705	0.0954	0.0616	0.1014	0.0606	0.0563
27	0.0705	0.0954	0.0616	0.1014	0.0606	0.0563
28	0.0696	0.0905	0.0780	0.0530	0.0520	0.0568
29	0.0548	0.0553	0.0558	0.0583	0.0524	0.0465
30	0.1402	0.2791	0.3097	0.1990	0.0606	0.0558
31	0.1430	0.1795	0.1330	0.2630	0.1896	0.0722
32	0.0288	0.0367	0.0259	0.0251	0.0243	0.0245
33	0.0791	0.1512	0.1119	0.1376	0.0469	0.0441
34	0.1028	0.2091	0.0933	0.1600	0.0717	0.0504
35	0.0922	0.1797	0.0851	0.0801	0.0710	0.0735
36	0.0922	0.1797	0.0851	0.0801	0.0710	0.0735
37	0.0989	0.2698	0.1023	0.1523	0.0463	0.0655
39	0.1127	0.1563	0.1256	0.1904	0.0484	0.0627
40	0.0828	0.0961	0.1287	0.0549	0.0507	0.0465
41	0.0946	0.1508	0.0904	0.1457	0.0581	0.0563
48	0.1671	1.0000	0.2047	0.2047	0.14235	0.0800

7.3 Observed Freight Data

The source for observed truck volume data is the 2003 FTI CD developed by FDOT. Data from 2003 are used because the O-D data used in the multimodal transportation model are based on the 2003 TRANSEARCH Database. The CD contains traffic count data for the year 2003 for thousands of highway segments statewide. It also contains an ACEESS table, "Annual_Vehicle_Classification," which is published by the Traffic Data Section of the Transportation Statistics Office for selected stations. For these stations, the vehicle classification information was collected for the district and statewide Traffic Characteristics Inventory (TCI). The stations were selected by location, based on district first and then county, as well as the length of the highway, function classification, traffic volume, and land use around the count stations. The "Annual_Vehicle_Classification" table includes percentages for each of the 15 vehicle categories, shown in Table 7-9, based on the FHWA's Traffic Monitoring Guide (FHWA 2001).

Table 7-9 FHWA vehicle classification description

Category	Description
1	Motorcycles
2	Passenger Cars
3	Pick-Ups and Vans
4	Buses
5	Two-Axle, Six-Tire Single-Unit Trucks
6	Three-Axle Single-Unit Trucks
7	Four- or More-Axle Single-Unit Trucks
8	Three- or Four-Axle Single-Trailer Trucks
9	Five-Axle Single-Trailer Trucks
10	Six- or More-Axle Single-Trailer Trucks
11	Five- or Less-Axle Multi-Trailer Trucks
12	Six-Axle Multi-Trailer Trucks
13	Seven- or More-Axle Multi-Trailer Trucks
14	Not Used
15	Other

The truck percentage was calculated by adding the percentages of vehicle category 5 as a medium truck and categories 6-13 as heavy trucks. There are 7,643 records statewide in the Annual Vehicle Classification ACCESS table. The count database was refined and data for some of the count stations were removed for various reasons. First, among the 7,643 records, 2,458 records have vehicle classification data. The remaining records have either a zero truck count due to missing data or do not have vehicle classification data. There are 27 records that could not be found in the GIS file, and nine count stations cannot be displayed on the network map. A total of 2,422 highway segments are included in the final truck count database.

7.4 Validation Results

During the assignment, the O-D tables were not separated by commodity type because it would demand considerable computing resources. This does not mean that assigning commodity flows by commodity types is computationally prohibiting. However, because there are more than 260,000 links and 180,000 nodes in the multimodal network, it will be necessary to develop a computational strategy to effectively deal with the constraints imposed by the computational time and memory. If bi-directional flows are considered, an additional 100 million memory space is required simply to trace flows on each of the network links. With regard to computational time, when two-digit STCC commodity types are considered, 49 commodity categories need to be handled simultaneously, which implies a significant increase in computational time. Therefore, the link volumes on the multimodal network were annual tonnages for all commodities. Because the tonnage-to-truck conversion factors are based on commodity types, the percentage for each commodity was obtained first by proportioning tonnages of each STCC category to the total truck tonnages of the 245,596 records in TRANSEARCH. Table 7-10 gives these percentages.

Table 7-10   Percentage of truck tonnages by STCC for TRANSEARCH data

STCC	Total Tonnage	Percentage
1	23,628,007	7.96
10	5,798	0.00
11	578	0.00
13	0	0.00
14	99,329,698	33.45
20	36,963,638	12.45
22	912,591	0.31
23	3,007,034	1.01
24	14,756,914	4.97
25	1,477,042	0.50
26	11,375,326	3.83
27	1,672,458	0.56
28	27,833,422	9.37
29	21,653,472	7.29
30	3,135,948	1.06
31	376,013	0.13
32	23,027,650	7.76
33	9,416,278	3.17
34	5,862,842	1.97
35	2,826,839	0.95
36	2,478,295	0.83
37	5,935,898	2.00
39	1,259,584	0.42
40	0	0.00
41	0	0.00
48	0	0.00
Total	296,935,324	100.00

The total assigned tonnages on each highway link in the multimodal network were split based on the percentages given in Table 7-10 for different commodities. To obtain the annual truck volumes, the annual tonnages for each commodity type were then multiplied with the conversion factors listed in column “On Road Average” in Table 7-8. Similar to the STFMM, the converted annual truck loads were converted to daily truck volumes by applying a factor of 306 working days per year.

The assigned versus observed traffic data were compared for truck miles traveled by truck type and highway function classification. Figure 7-1 shows the highway function classification and the TTMSs with observed truck data in the South Florida area. Table 7-11 compares the total assigned truck VMT and observed VMT by function class. Note that the total assigned VMT for the 2,422 links is already 13.4% less than the observed VMT. One reason for this is that the O-D tables only include the county to county flows but not flows within counties. Therefore, intra-county freight was not accounted for. It is also observed that the total assigned VMT on the rural interstate highways is 31.83% more than observed VMT. In general, for these 2,422 links, volumes on the urban roads are under-assigned (by 62.06%) and volumes on the rural roads are over-assigned (by 19.53%). Similarly, links of a higher function class also tend to be more over-assigned than those of a lower function class. There may be several causes for these errors. One may be the use of all-or-nothing assignment without considering the congestion effect. Moreover, as mentioned before, the missing intra-county flows in the O-D tables also aggravate the under-assignment of flows to urban network links. Another possible cause may be the large zones and detailed network. The differences between the assigned and observed VMTs are plotted in Figure 7-2. It may be seen that these differences vary by location, and many links on I-10 were particularly over-assigned.

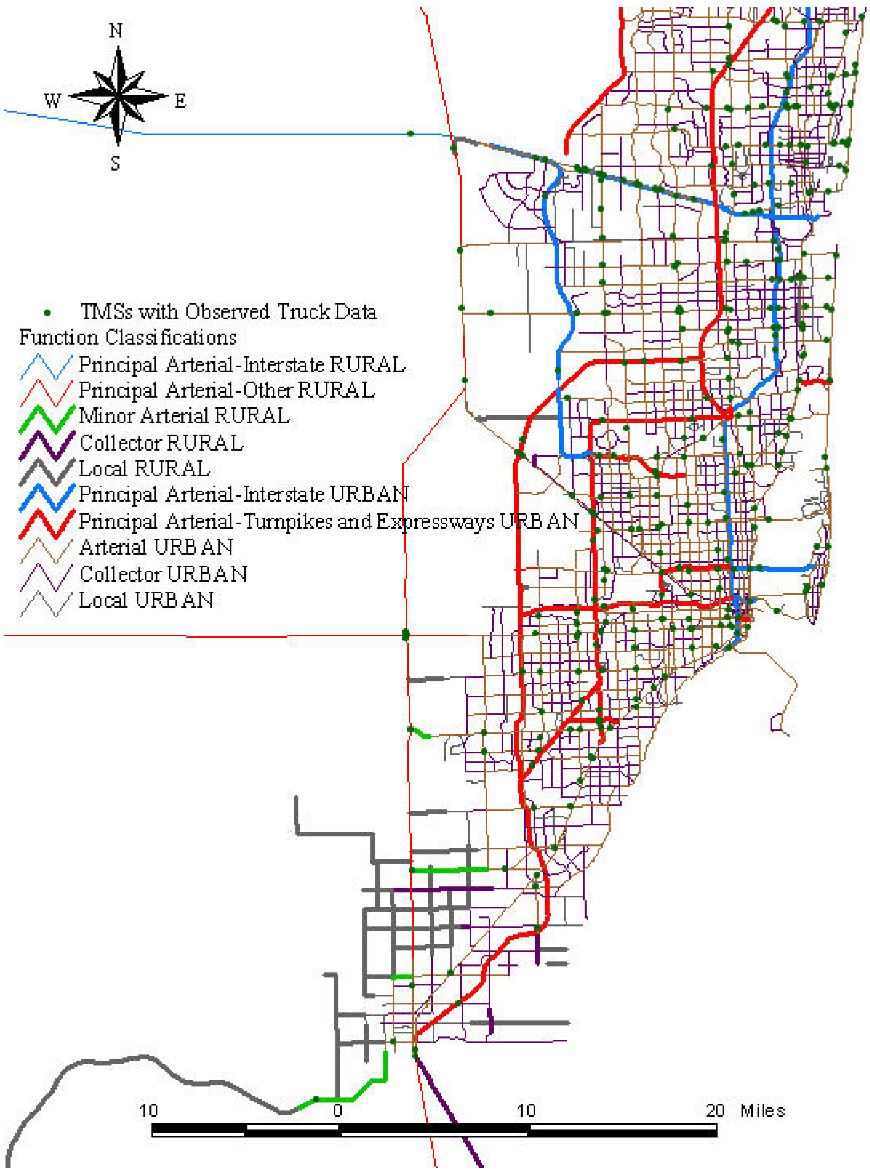

Figure 7-1 Highway function classification and TTMSs with observed truck data

Table 7-11 Comparison of total observed and assigned VMTs (2,422 Links)

Function Classification	# of Links	Mileage	Total Truck VMTs		Diff %
			Observed	Assigned	
Principal Arterial-Interstate Rural	55	302	1,594,670	2,102,161	31.82
Principal Arterial-Other Rural	386	543	724,979	820,971	13.24
Minor Arterial Rural	262	390	170,354	94,738	-44.39
Collector Rural	90	145	44,506	11,558	-74.03
Rural Subtotal	*893*	*1,380*	*2,534,509*	*3,029,428*	*19.53*
Principal Arterial-Interstate Urban	94	104	810,791	361,598	-55.40
Principal Arterial-Turnpikes and Expressways Urban	50	47	129,896	160,735	23.74
Arterial Urban	1,409	544	756,027	126,521	-83.27
Collector Urban	73	31	17,884	1,622	-90.93
Urban Subtotal	*1,626*	*626*	*1,714,598*	*650,476*	*-62.06*
Total	**2,422**	**2,006**	**4,249,107**	**3,679,905**	**-13.40**

Unlike the STFM, in which the O-D tables were estimated by models and were separated by truck types, the O-D tables in this research were directly obtained from the TRANSEARCH database and were recorded in total truck tonnages. To divide the total VMTs into heavy and medium truck VMTs, the percentages of heavy and medium trucks are first estimated based on the vehicle classification data from the 2,422 links for each function class of roadways. Table 7- provides these percentages. Note that there are generally more heavy trucks on rural roads than on urban roads, and that roads of a higher function class carry more heavy trucks.

Table 7-12 Medium and heavy truck percentages by function class

Function Classification	# of Links	Medium Truck	Heavy Truck
Principal Arterial-Interstate Rural	55	0.1734	0.8266
Principal Arterial-Other Rural	386	0.2942	0.7058
Minor Arterial Rural	262	0.3453	0.6547
Collector Rural	90	0.3431	0.6569
Principal Arterial-Interstate Urban	94	0.2853	0.7147
Principal Arterial-Turnpikes and Expressways Urban	50	0.3861	0.6139
Arterial Urban	1,409	0.4395	0.5605
Collector Urban	73	0.4299	0.5701
Total	2,422	0.1734	0.8266

Using the above percentages, the heavy and medium truck VMTs were computed for each group of roads. The results are compared with the observed VMTs in Table 7-13. The differences between the assigned and observed VMTs are plotted in Figure 7-3 Locations of the percent differences in heavy truck VMT and Figure 7-4 for heavy trucks and medium trucks, respectively.

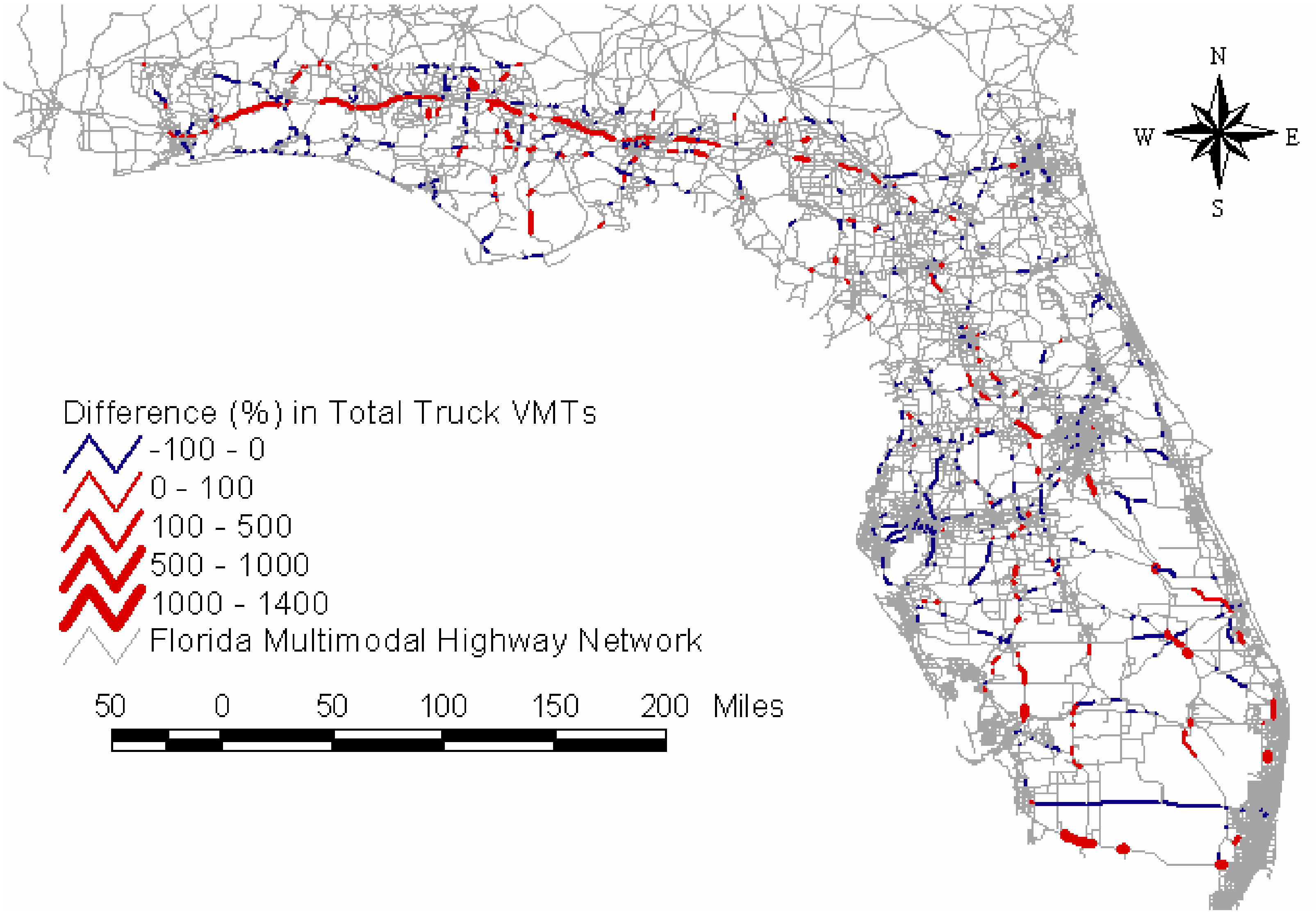

Figure 7-2 Locations of the percent differences in truck VMT

Table 7-13 Percentage difference between assigned and observed VMT by function class

Function Classification	# of Links	Heavy Truck			Medium Truck			Total		
		Observed	Assigned	% Diff.	Observed	Assigned	% Diff.	Observed	Assigned	% Diff.
Principal Arterial-Interstate Rural	55	1,343,636	1,738,073	29.36	251035	364,088	45.03	1,594,670	2,102,161	31.82
Principal Arterial-Other Rural	386	541,511	579,724	7.06	183468	241,247	31.49	724,979	820,971	13.24
Minor Arterial Rural	262	113,825	62,063	-45.47	56529	32,675	-42.20	170,354	94,738	-44.39
Collector Rural	90	30,395	7,597	-75.01	14111	3,961	-71.93	44,506	11,558	-74.03
Principal Arterial-Interstate Urban	94	606,260	258,555	-57.35	204531	103,043	-49.62	810,791	361,598	-55.40
Principal Arterial-Turnpikes and Expressways Urban	50	80,932	98,748	22.01	48964	61,987	26.60	129,896	160,735	23.74
Arterial Urban	1,409	422,631	70,980	-83.21	333396	55,541	-83.34	756,027	126,521	-83.27
Collector Urban	73	11,043	926	-91.62	6840	696	-89.82	17,884	1,622	-90.93
Total	2,422	3,150,233	2,816,666	-10.59	1,098,874	863,238	-21.44	4,249,107	3,679,905	-13.40

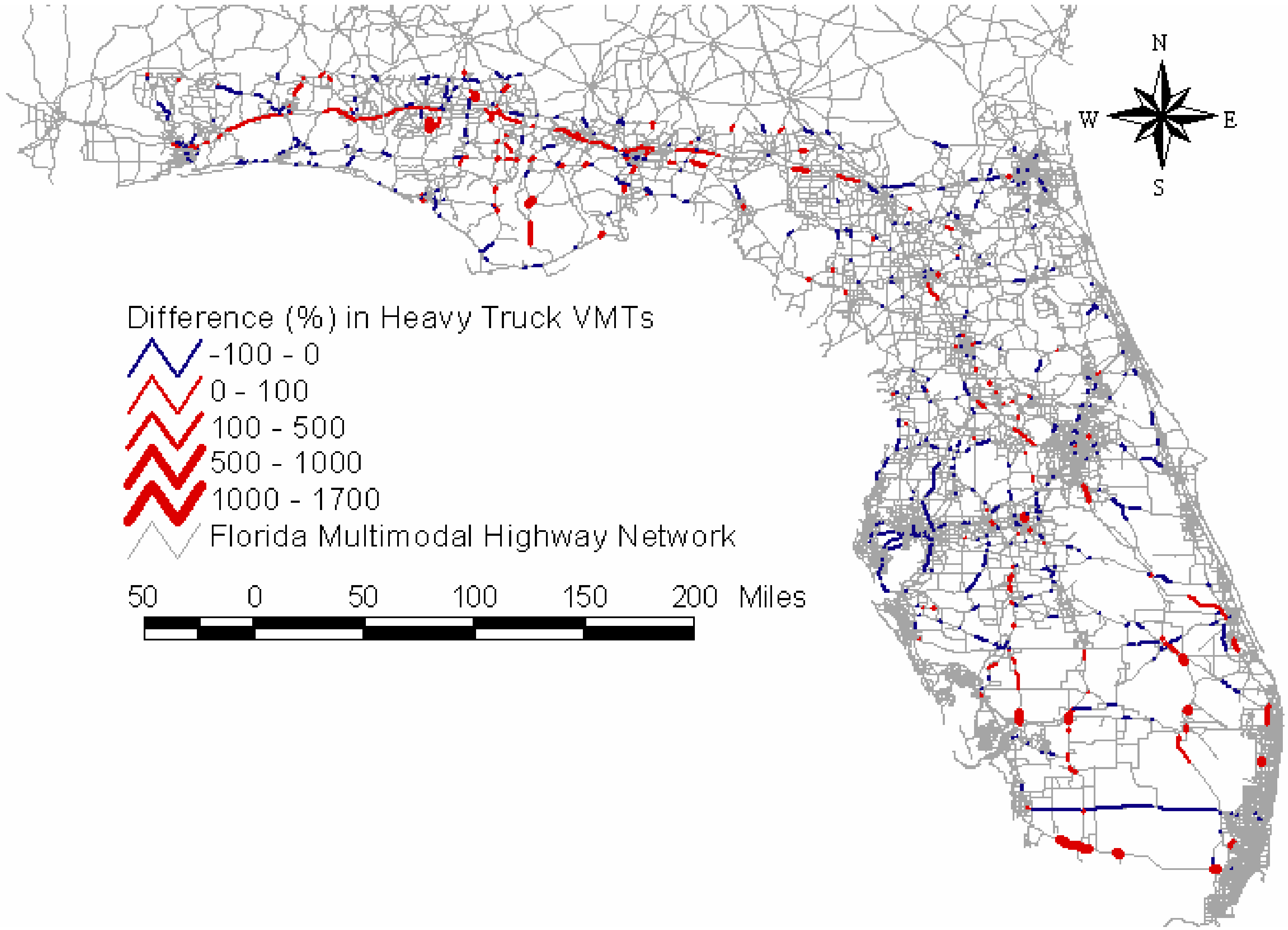

Figure 7-3 Locations of the percent differences in heavy truck VMT

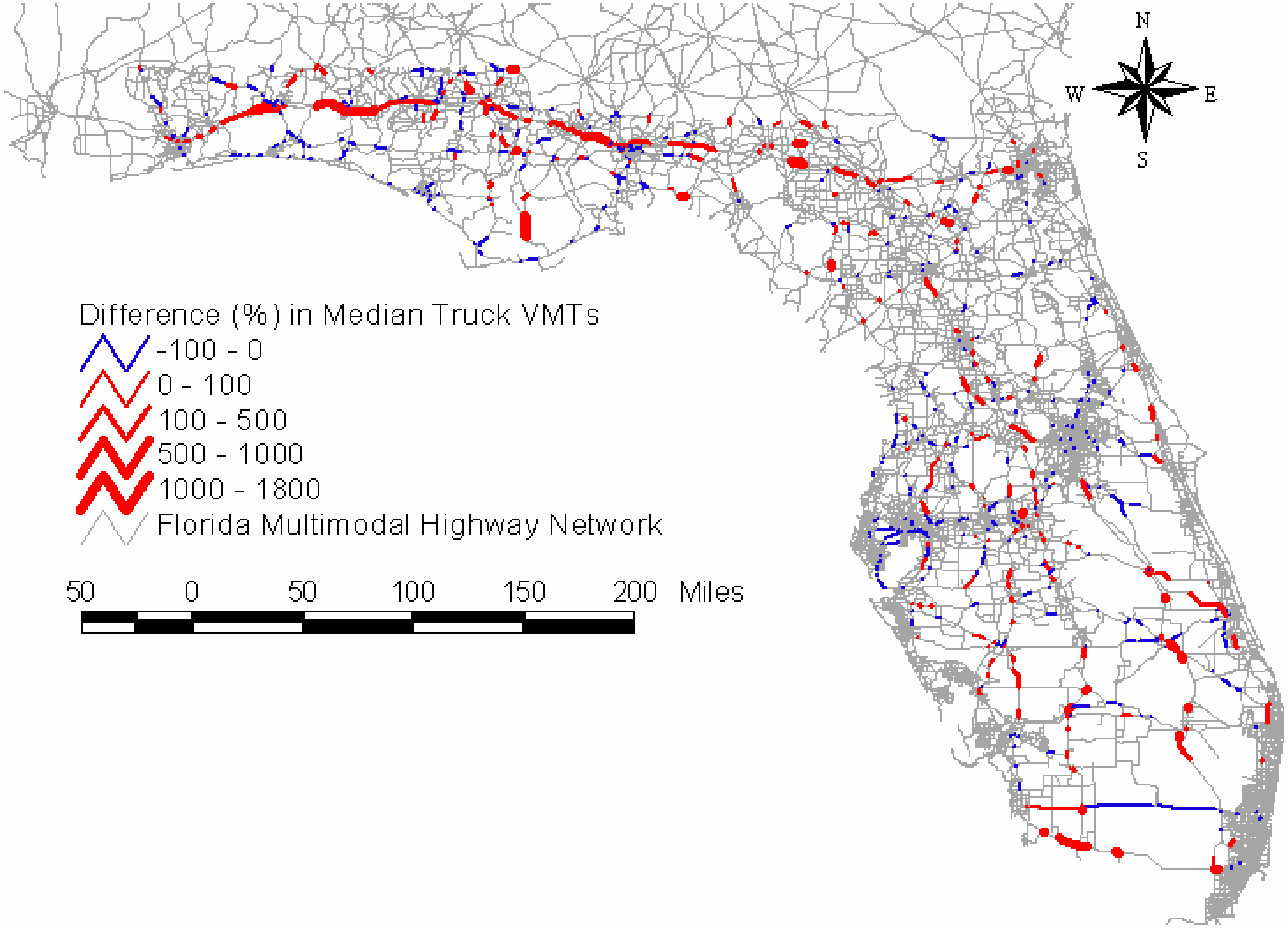

Figure 7-4 Locations of the percent differences in medium truck VMT

8. CONCLUSIONS AND DISCUSSION

Extensive efforts have been made in Florida and elsewhere in the area of commodity flow analysis. These efforts are especially valuable to the present research. In particular, this research leveraged the highway network that was developed by FDOT and its collaborators, as well as the TRANSEARCH database that was acquired by FDOT. This research led to the development of the Florida Multimodal Network, which will benefit future freight analysis activities. The generation of intermodal flow patterns on the multimodal network is another important product of this research project. Nevertheless, many challenges remain in commodity flow analysis of multimodal transportation networks. Much of the flow data acquired or modeled cannot be effectively validated. Given the scope of the problem, the methods or models developed to generate the flow patterns are still theoretical and have limited accuracy with regard to addressing application needs.

There are several areas that are perceived as valuable for future research. One is the characterization of the mode preference of the multimodal transportation system. The research has shed some light on the problem, but effort has been limited in this area. It would be good to derive preference functions through linking the mode choice decisions when O-D tables are generated. Information on congestion, intermodal bottlenecks, and some other cost or time constraints may also be helpful when the mode preference functions are determined.

The second area worth future investigation is the improvement of the flow loading process when multimodal freight flows are assigned to the network. Some of the simple improvements may include the incorporation of the information on roadway capability or observed traffic counts into the loading procedure. That is, when flows reach capacity or observed flow limits, alternative routes would be considered. This would help reduce the overloading of links. Other measures, such as added cost or time for congestion, can be used to allocate flows to less utilized links. In this way, consideration can be given to factors such as competition between different modes or system flow adjustment for congestion reduction.

The third area worthy of further study is the data. Because of the lack of data on transportation networks, O-D flows, cost, delay, and capacity of the intermodal facilities, it is difficult to drill down the model to a detailed level. The most demanding data, of course, are the commodity O-D tables. The adaptation of the FAF O-D tables for use by state DOTs is certainly possible. However, refining the county-level O-D tables to the level of Traffic Analysis Zones within counties, even if aggregated to certain degrees, will improve the model accuracy by considering the flow patterns within a county. This will also help local government develop plans for improvements of freight facilities. The challenge is that much of the existing data are still too aggregated and lacking in details, making them less useful for planning decisions. In particular, many of the intermodal transportation decisions involve pubic and private partnerships. The use of more accurate data is critical in gaining public confidence when transportation decisions are made by the government.

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APPENDIX A. RAILROAD CONVERSION FACTORS

NCHRP Synthesis 358 summarizes statewide travel forecasting models, which forecast statewide travel demand, including passenger vehicle and freight movement (Horowitz 2006). It describes the types and purposes of models being used, integration of state and urban models, data requirements, computer needs, resources (including time, funding, training, and staff), limitations, and overall benefits.

Conversion of commodity flow to vehicle movement in freight models is discussed and sources that were used to obtain conversion factors are summarized:

- VIUS (Florida, Georgia, Michigan, Montana, Ohio, Wisconsin)
- Commercial freight data vendor (Kentucky, Louisiana, Tennessee, Texas)
- Rail Carload Waybill Sample (Georgia, Indiana, Ohio)
- Data from another state or from an MPO (Kentucky, Virginia)
- Truck intercept studies (Georgia)

Black (1997) computed density factors for rail cars, which carry commodities imported to or exported from Indiana, based on the Carload Waybill Sample. The tonnages of the 19 commodities were aggregated by commodity and rail carloads. By dividing the former by the latter, commodity density, which is given as tons, by commodity, per carload, was obtained. Table A-1 presents density factors for import and export and a weighted average of these import and export density factors.

Monsere (2001) conducted a study to develop a statewide freight model of Iowa. In the model, freight tonnage was converted to a number of railcars by using the average load weight of each commodity type, the percentages of each vehicle type, and the expansion factor for the treatment of empties. The conversion was accomplished on a link-by-link basis.

The average carload weight was estimated based on the 1992 Carload Waybill Sample for the five-digit STCC commodity type and the railcar types that are commonly used to transport the commodity type. For the estimation, such information as the five-digit STCC code, the number of carloads, the car type, the billed weight, and the actual weight of the commodity was extracted from the waybill sample and summarized. Table A-2 shows the summary of the waybill sample in terms of commodity type, railcar type, weight of cargo (tons), and percent of carloads by railcar type.

Table A-1 Traffic density factors for rail cars by commodity

Commodity STCC	Import Rail Traffic	Export Rail Traffic	Weighted Rail Density
01	94.90	96.20	96.13
11	100.60	99.10	100.42
14	97.10	97.40	97.20
20	77.35	80.36	79.52
22	25.00	15.00	18.33
23	-------	-------	10.00*
24	73.88	55.50	72.27
25	-------	15.00	15.00
26	64.82	50.64	62.10
28	85.11	90.11	87.58
29	63.20	77.16	65.90
32	86.70	77.10	81.15
33	87.48	85.21	85.82
34	28.40	16.16	19.76
35	68.75	21.70	28.42
36	18.80	16.25	16.69
37	19.93	23.40	22.50
40	75.40	82.60	78.47
50**	92.85	14.88	86.56

* Estimated values
** There is no STCC 50. It is used here to represent STCC 21, 27, 30, 31, 38, and 39.

Table A-2 Average car loads for rail

STCC	Commodity Description	Car Type	Weight of Cargo (tons)	Percent of Carloads by Type
11	Field Crops	Hopper, covered	92.73	100%
112	Bituminous coal or lignite	Hopper, special modified	93.29	100%
201	Meat or poultry, fresh or chill	Tank car	82.19	77%
		Refrigerated box car	49.59	23%
202	Dairy products	Refrigerated box car	62.76	100%
204	Grain mill products	Hopper, covered	74.47	75%
		Tank car	94.77	25%
209	Misc. food preparations	Hopper, covered	76.47	65%
		Tank car	78.11	35%
262	Paper	Box car	67.73	77%
281	Industrial chemicals	Tank car	84.31	66%
		Hopper, covered	96.46	34%
287	Agricultural chemicals	Tank car	98.75	59%
		Hopper, covered	96.57	41%
291	Products of petroleum refining	Tank car	70.20	100%
324	Cement, hydraulic	Hopper, covered	89.04	100%
327	Concrete, gypsum, and plaster products	Hopper, covered	89.68	100%
331	Steel mill products	Gondola, w/ roof	86.42	65%
		Gondola	80.99	35%
352	Farm and garden machinery	Flat car, specially equipped	21.33	100%
371	Motor vehicles and equipment	Auto rack	23.07	100%

Source: Monsere 2001, which was based on Carload Waybill Sample (1992).

The expansion factors for the treatment of empties are based on the likelihood that a particular commodity is backhauled. Table A-3 summarizes the expansion factors used in the study. A factor of 2.0 indicates that all vehicles return empty. A factor of 1.0 is assigned if the returning vehicle can be used to haul another commodity. A factor of 1.5 indicates that railcars may have an opportunity for a backhaul in some instances. It was assumed that the cars return to the origin via the same path in the network.

Table A-3 Expansion factors for the treatment of empties

STCC	Commodity Description	Rail Expansion Factor
11	Field Crops	1.5
112	Bituminous coal or lignite	2
201	Meat or poultry, fresh or chill	2
202	Dairy products	2
204	Grain mill products	1.5
209	Misc. food preparations	1.5
262	Paper	1.5
281	Industrial chemicals	2
287	Agricultural chemicals	2
291	Products of petroleum refining	2
324	Cement, hydraulic	2
327	Concrete, gypsum, and plaster products	1.5
331	Steel mill products	1.5
352	Farm and garden machinery	1.5
371	Motor vehicles and equipment	2

Source: Monsere 2001.

For each link in the network, the freight tonnage was converted to number of vehicles by type for the commodity group using the following “weighted” formula:

$$N_i = \frac{W p^i_{ne}}{\alpha_i} x_i$$

where:

N_i = annual total number of all vehicles of type *i*,
W = annual weight of commodity assigned to link (tons),
p^i_{ne} = effective percentage of vehicle type *i* of mode *n*,
α_i = average weight per vehicle type *i* (tons/unit), and
x_i = vehicle expansion factor for empties of type.

$$p^i_{ne} = \frac{p^i_n}{\left(\frac{\alpha_i}{\alpha_j}\right)\left(p^i_n\right) + \left(p^j_n\right)}$$

where:

p^{i}_{ne} = the effective percentage of vehicle type i of mode n,
p^{i}_{n}, p^{j}_{n} = the actual percentage of vehicle type i and j of mode n, and
α_i, α_j = the average weight per vehicle type i and j (tons/unit).

A report prepared by Bhat and Prozzi (2004) contains a description of TransCAD embedded models, which are designed to display container flows on highways and railroads in Texas and to perform mode choice analysis. The models can deal with commodity O-D input tables complied in terms of commodity tonnages by road and rail, container commodity tonnages by road and rail, or container commodity flows by road and rail. If input tables are compiled in terms of commodity tonnages, conversion factors embedded in the models are applied to convert commodity tonnages to container tonnages and, finally, to container flows.

Table A-4 presents conversion factors converting commodity tonnages into container tonnages. The factors were estimated based on the 2001 Transborder Surface Freight Database.

Table A-4 Conversion factors for estimating containerized tonnage

Commodity	Truck	Rail
Agricultural Products	0.040	0.200
Construction Materials	0.020	0.002
Food	0.030	0.010
Hazardous Materials	0.020	0.070
Machinery & Equipment	0.010	0.020
Manufacturing Products	0.040	0.040
Mixed Freight Shipment	0.030	0.020

Source: Bhat and Prozzi (2004), estimated based on the 2001 Transborder Surface Freight Database.

Table A-5 summarizes the conversion factors converting container tonnages to container flows, which represents number of containers. The conversion factor of 15.8 tons per container from Reebie Associates, which represents an average weight per container for all commodities transported by truck, is used for the truck mode. The conversion factors for rail are estimated based on the 1996 Carload Waybill Sample.

Table A-5 Factors converting containerized tonnage into number of containers

Commodity	Truck	Rail
Agricultural Products	15.8	21.4
Construction Materials	15.8	16.8
Food	15.8	19.8
Hazardous Materials	15.8	19.4
Machinery & Equipment	15.8	11.8
Manufacturing Products	15.8	15.7
Mixed Freight Shipment	15.8	15.1

Source: Bhat and Prozzi (2004), estimated based on Reebie Data for Truck and Carload Waybill Sample for Rail.

The Rail Carload Waybill Sample contains information on commodities carried by railroads, while VIUS includes commodities only for trucks. The Carload Waybill Sample is a stratified sample of carload waybills submitted by railroads, which terminate over 4,500 cars per year, to the Surface Transportation Board (STB). This database contains rail shipment data such as origin and destination points; type of commodity; number of cars, tons, and revenue; length of haul; participating railroads; and interchange locations. Some of the information in the Carload Waybill Sample is confidential and unavailable for public use. This information is used primarily by federal and state agencies. For public use, the Sample contains aggregated non-confidential data. Movements are generally aggregated to the Bureau of Economic Analysis (BEA) region level and commodities are summarized at the five-digit Standard Transportation Commodity Code (STCC) level.

Reebie Associates compiled the TRANSEARCH database using the public-use, non-confidential Rail Carload Waybill Sample, trade statistics, and proprietary shipment information, including the Annual Motor Carrier Data Exchange. The data contain origins and destinations, type of commodity (identified by the STCC), number of carloads (or the number of cars) and intermodal units (i.e., number of trailers and containers), carload tons and intermodal tons, and railroad routes to spatially locate rail freight flows on the region's railroad map. Conversion factors to convert tonnage to number of railcars were estimated based on the TRANSEARCH database and summarized in Table A-6.

Table A-6 Annual ton to railcar conversion factor

STCC2	Carload Ton	Carload Car	Average Ton	Conversion Factor
1	2,667,785	27,290	97.76	0.0102
9	2,560	40	64.00	0.0156
10	859,140	8,552	100.46	0.0100
11	20,540,153	203,585	100.89	0.0099
14	5,753,899	57,427	100.20	0.0100
20	4,763,579	57,296	83.14	0.0120
22	5,520	80	69.00	0.0145
24	2,216,259	27,216	81.43	0.0123
26	4,991,480	72,464	68.88	0.0145
28	6,101,334	65,336	93.38	0.0107
29	1,720,846	21,585	79.72	0.0125
30	15,080	360	41.89	0.0239
32	3,133,915	33,592	93.29	0.0107
33	4,368,985	51,187	85.35	0.0117
34	3,576	60	59.60	0.0168
35	75,196	2,200	34.18	0.0293
36	155,800	8,200	19.00	0.0526
37	2,482,026	109,876	22.59	0.0443
40	3,551,526	43,332	81.96	0.0122
41	70,188	3,040	23.09	0.0433

42	120	40	3.00	0.3333
46	1,680	80	21.00	0.0476
48	53,520	640	83.63	0.0120
49	74,120	820	90.39	0.0111