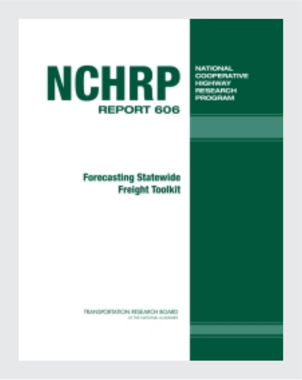

Forecasting Statewide Freight Toolkit

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 606

Forecasting Statewide Freight Toolkit

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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Kimberly M. Fisher
Staff Officer
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Federal planning legislation and regulations now mandate that state departments of transportation and metropolitan planning organizations consider the needs of freight when planning and programming transportation investments. While there are standard techniques used to forecast the movement of people, less attention has been paid to forecasting freight movements, and there are consequently fewer standardized techniques that state and local agencies can adapt to their local situation. This Toolkit is designed to provide transportation planners with the information they need to prepare forecasts of freight transportation by highlighting techniques successfully developed by state agencies across the country.

According to the U.S. Department of Transportation, the volume of freight moved within the United States has nearly doubled the rate of population increase over the past three decades. In those years, this volume has also outstripped the annualized rates of growth in disposable income and gross national product. The 2002 Commodity Flow Survey, by the Bureau of the Census, found that more than 19 billion tons of freight, valued at almost $13 trillion, moves annually over the nation's transportation system. In calendar year 2002, an average of 12 billion ton-miles of goods moved in the United States each day. All of this activity places growing pressure on each state's transportation infrastructure, leading to many costly traffic congestion problems—notably around major airports, seaports, and truck-rail transfer terminals. Significant changes have also been taking place in the spatial patterns and commodity mix of both domestic and international trade. Modern logistic practices and the rapid growth in e-commerce are now also influencing these patterns.

Analytic methods are needed to help states to (a) determine where and how much current freight activity is taking place within and across their borders, (b) forecast future mode- and commodity-specific freight movement patterns, and (c) establish and apply suitable performance measures to evaluate their effectiveness in accommodating freight demand. These tools and methodologies for individual states need to be upwardly compatible so that they can be assembled to form multistate, sub-state, and regional data and information snapshots. Currently, there exist numerous gaps in the data needed to estimate the necessary origin-to-destination (O-D) freight movements. This gap is especially apparent in the case of truck-only, as well as truck-inclusive, freight movements. Collection and analysis methods are needed to fill these data gaps, to use the resulting O-D volumes to estimate freight flows on specific sections of a state's multimodal transportation network, and to forecast O-D freight movement patterns. These patterns include freight movements both within and between metropolitan areas and crossing state borders.

The objective of this Toolkit is to provide an analytical framework for forecasting freight movements at the state level. This framework includes (1) a Toolkit of data collection techniques, analytical procedures, and computer models; (2) management approaches and decision-making procedures; and (3) performance evaluation methods that can guide states in establishing priorities for improving their transportation systems to best accommodate increased freight demand. The Toolkit provides options, along with strengths and weaknesses of techniques for addressing freight-forecasting applications that states face, such as:

- Demand for statewide multimodal freight movement,
- Regional or multijurisdictional freight movement,
- Specific single-mode or multimode corridor analyses, and
- Analyses of projected demand at specific facilities (e.g., ports, hubs, or terminals).

Transportation planners, project programmers, and the leadership in state and local transportation agencies will find this report of significant use. The Toolkit will guide the transportation professionals through defining the problem, collecting data, forecasting freight, and developing freight performance measures for their agency. Ten case studies illustrate the techniques in a variety of local settings.

CONTENTS

CHAPTER 1

Introduction

The Federal Highway Administration estimates that more than 15 billion tons of goods, worth more than $9 trillion, were transported in the United States in 1998. This translates into 310 pounds of freight moved daily for each U.S. resident.[1] Much of this freight moves on facilities that state and local governments are charged with constructing, maintaining, operating, funding, or regulating. Indeed, since deregulation in the 1980s, the efficient, safe, and secure transport of freight has become as much a state and local concern as a national concern.

Prior to the 1970s, nearly all interstate transportation was subject to Federal government economic regulation. Tariffs, routes, frequencies, and other characteristics were decided in Washington, D.C., and consequently there was little need to plan for or forecast changes in the interstate transportation of freight. With the passage of the Aviation Deregulation Act of 1978, the Motor Carrier Act of 1980, the Staggers Rail Act of 1980, and the Ocean Shipping Act of 1984, the industry was deregulated. Today, supply and demand for freight transportation is determined by the carriers themselves and by market forces; consequently, forecasts of freight movements have became both necessary and more difficult to prepare.

Recognizing this changing situation, Federal planning legislation and regulations now mandate that state departments of transportation and metropolitan planning organizations give due consideration to the needs of freight when planning and programming transportation investments. However, while state and local agencies have developed considerable capabilities for forecasting the movement of people, many have not devoted the same attention to the movement of goods.

Purpose

This Toolkit is designed to provide transportation planners with the information they need to prepare forecasts of freight transportation by highlighting techniques successfully developed by state agencies across the country. Deregulation of the freight transportation industry is not the only reason for creating this Toolkit; because long-distance, intercity, freight transportation differs from local movement of goods, the Toolkit distinguishes between the techniques and factors appropriate for use in statewide freight forecasting and those appropriate for short-distance intracity, transport.

In 2001, nearly 11% of the $10 trillion U.S. gross domestic product was devoted to transportation-related goods and services.[2] In order to make investments in transportation that help control these costs, governments at all levels must understand how their decisions affect the performance of the freight transportation system. This Toolkit is intended to present the freight forecasting techniques as part of a framework of different components that can be organized into different classes of models. In order to illustrate and explain those techniques, it presents case studies that show the application of the classes of freight models and their components.

This report contains eight sections. Following this introduction, Section 2.0 provides background and basic definitions relating to freight and freight forecasting. Section 3.0 describes state needs, as identified through a telephone and Internet survey of nearly two dozen state departments of transportation. Among the more commonly cited needs were project prioritization, modal diversion analysis, and statewide transportation planning, including preparation of state multimodal transportation plans and freight plans.

Section 4.0 introduces six basic freight model components: direct factoring, trip generation, trip distribution, mode split, traffic assignment, and economic/land use modeling. Section 5.0 identifies data sources needed to develop and validate the freight models. Since it is assumed that readers are already familiar with general data sources used in transportation forecasting, this section focuses on sources that are either unique to freight forecasting or applied to freight forecasting in unique ways.

Section 6.0 introduces the models themselves. This Toolkit focuses on five model classes: the flow factoring method, the

Table 1.1. Freight tool case studies.

State	Tool	Description
California	Southern California Association of Governments (SCAG) Heavy-Duty Truck Model	A model for forecasting the movement of heavy freight trucks as part of the comprehensive SCAG travel demand model. Created principally to more accurately model the emissions from heavy trucks.
Florida	Heavy Truck Freight Model for Florida Ports	A model developed to forecast the movement of trucks on roads near major seaports in Florida and to be used to support more detailed planning and analysis.
Florida	Intermodal Statewide Highway Freight Model	A model developed to model the generation, distribution of all freight shipments and to use mode split to estimate truck trips and to then assign the freight truck trips to the highway system. Developed for inclusion as part of the Statewide Highway Model.
Indiana	Commodity Transport Model	A research model developed to explore the feasibility of forecasting the generation distribution, mode split, and assignment of freight shipments.
Minnesota	Trunk Highway 10 Truck Trip Forecasting Model	A simplified modeling process to develop truck volumes based on economic development forecasts as part of a corridor planning study.
New Jersey	Statewide Model Truck Trip Table Update Project	A model for forecasting the movement of heavy freight trucks as part the comprehensive New Jersey statewide travel demand model. Developed as an improvement to an existing truck model.
Ohio	Interim Freight Model	A study to develop freight truck forecasts based on an existing commodity flow table. Used to determine investment needs in Ohio.
Oregon	Statewide Passenger and Freight Forecasting Model	An integrated economic/land use and transportation model that forecast the economic output of industries and the resulting flows on the transportation system. Developed to guide transportation investment and economic development in Oregon.
Washington	Cross-Cascades Corridor Analysis Project	An integrated economic/land use and transportation model that forecast the economic output of industries and the resulting flows on the transportation system. Developed to guide transportation investment and economic development in the Cross-Cascades Corridor.
National	Federal Highway Administration Freight Analysis Framework	A modeling framework that factored flows from an existing commodity flow table and used those tables to determine current and future freight flows on the nation's modal networks. Used to consider policy options to address the impacts of those freight flows.

origin-destination factoring method, the truck model, the four-step commodity model, and the economic activity model. These model classes share many of the same components, differing from each other primarily in their organization and use of these components.

Section 7.0 presents a comprehensive list of performance measures and tools needed to address the freight transportation needs identified in the telephone and Internet survey. A total of 15 primary analytical and policy areas relating to freight are presented in this section, screened for forecastability and then further screened and matched according to appropriate tool components for calculating the measures. The performance measures were assembled from numerous current sources, then matched to the 15 analytical and policy areas.

So that the users of the Toolkit may have the benefit of the experiences of other planners and may see actual applications of techniques, Section 8.0 presents 10 case studies. Two case studies have been chosen for each of the model classes defined in Section 6.0. As shown in Table 1.1, the case studies draw widely from the various model components, and represent a variety of data source applications.

CHAPTER 2

Background and Definitions

2.1 Definition of Freight

The term "freight," in its most basic sense, refers to goods transported from an origin to a destination. Freight movement is not an end in itself, but serves an economic purpose: to ensure that products reach a location where they can be consumed. For this reason, demand for freight is considered a derived demand rather than a primary demand. In other words, the demand for freight stems from the economic requirement to move goods from a production site to a market.

In transportation planning, goods transported incidental to the primary purpose of a trip, such as luggage accompanying an airline passenger on a business trip or tools accompanying a workman on a service call, are generally not considered freight. Other definitions of freight exclude certain types of goods movement due to the difficulty in identifying and forecasting those freight shipments. For example, the Bureau of Transportation Statistics' Commodity Flow Survey (CFS), an important source of freight data, excludes shipments from farms, government facilities, and most retail establishments (catalog and mail-order houses excepted). The CFS does not cover shipments of agricultural products from a farm to a processing center or terminal elevator (most likely short-distance, local movements), but does cover the shipments of these products from the initial processing center or terminal elevator onward.

These exceptions notwithstanding, goods moved over long distances and between cities constitute freight movements. Local shipments at the initial stage of a long-distance movement also are part of freight movements, and all other shipments including local delivery are called goods movements.

Other definitions of freight focus on the modes that are used. Goods carried by rail, water, and air are generally considered freight, while goods transported by truck may be considered freight only if the truck in question carries goods that are also likely to be carried by other modes or is not limited to local delivery.

Freight also can be labeled primary and secondary. Primary freight is defined in the Toolkit as goods moved over long distances and between cities, significant for statewide planning applications. Depending on the sources of data and the techniques that can be supported, this definition of primary freight also includes goods moved by local truck that are at the initial stage of a long-distance movement, such as agricultural products traveling from farms to grain elevators. Secondary freight moves to and from distribution centers or through intermodal facilities. Forecasting techniques for secondary freight movements have been developed elsewhere and practitioners should seek other resources for this information, such as the Federal Highway Administration's *Quick Response Freight Manual*.[3] For the travel forecasting processes, the *Quick Response Freight Manual* classifies commercial vehicles into a) four-tire commercial vehicles, including delivery and service vehicles, b) single unit trucks with six or more tires, and c) combined trucks consisting of a power unit (truck or tractor) and one or more trailing units.

2.2 Statewide Freight Forecasting

This Toolkit focuses on three types of long-distance, intercity freight movements:

1. Shipments with an origin and destination in a single state;
2. Shipments with an origin and destination in two different states; and
3. Shipments with an origin and destination in two different states that pass through one or more intermediate states.

In order to properly identify and forecast these three types of movements, the boundaries of the freight forecasting study area may extend well beyond a single metropolitan region or state. In many cases, a study area may include the entire continental United States or even all of North America.

While freight forecasting often is used to estimate future demand, it also may provide information on freight movements in the current transportation system. This could include evaluating changes in performance in response to changes in the current transportation system, such as increases in the price of travel on a specific facility, or developing information on existing flows that could not be easily observed, such as freight flows by commodity using a specific roadway that could not be obtained by counting the number of trucks.

2.3 Freight Terminology

In order to identify and forecast freight shipments, it is important to define key attributes of those shipments. The Transportation Research Board Committee on Freight Transportation Data refers to the desirable elements of a freight database using the mnemonic CODMRT, which stands for:

- **C**ommodity – The type of freight being moved.
- **O**rigin – The geographic start of the freight trip.
- **D**estination – The geographic end of the freight trip.
- **M**ode – The mode or modes being used to carry the freight.
- **R**oute – The route on the modal network used to carry the freight.
- **T**ime – The time period for which the freight data was collected.[4]

An implicit data element is also the flow unit, such as tons, dollar value, or vehicles, that is being recorded. The CODMRT mnemonic also is useful to describe the elements that will be produced by freight forecasts. The terms are defined as:

- **Commodity –** A way of classifying the type of freight being shipped. Commodities are assumed to be indistinguishable based on the characteristics important in shipping. Commodities of the same class are assumed to have the same value per ton, the same density (weight per volume), and the same handling characteristics. There are several classification schemes for freight, most notably the Standard Transportation Commodity Classification (STCC) codes of the American Association of Railroads, and the Standard Classification of Transported Goods (SCTG) a system developed jointly by U. S. and Canadian government agencies based on the Harmonized System to address statistical needs in regard to products transported.
- **Origins and Destinations –** The geographic starting and ending points of a freight shipment. Origins and destinations generally do not refer to a specific street address, but to a larger identifiable geographic unit in which the address is located, such as a county, a state, or a census tract.
- **Mode –** The vehicles and infrastructure used to transport goods. The most common modes defined in freight are truck, rail, water, air, and pipeline. Subcategories and combinations of these basic modes may themselves be defined as modes.
- **Route –** The sequence of specific individual facilities (such as, sections of roads, railroad tracks, etc.) that are used to transport freight between the origin and destination on a specific mode.
- **Time –** The time of day, as defined by the Committee on Freight Transportation Data. For purposes of this Toolkit, it is assumed that time refers to the freight forecast time period as reflected in the flow data, such as tons per year or vehicles per day.
- **Flow Units –** The way the freight flow is being reported and forecast as defined by all of the above attributes. If the freight flow is expressed for all modes, the flow unit must be expressed in a unit common to all modes, such as tons per year.

Knowing all of the above characteristics for given shipments of freight makes it possible to sum those shipments to identify the total of all freight using a specific route or originating from a specific location.

CHAPTER 3

State Needs

As part of the development of the Toolkit, a survey of state transportation departments was conducted in March 2003 to identify the need for freight forecasting tools. The objectives of the survey were to:

- Identify policy and planning needs for freight analysis and forecasting; and
- Review current applications of the freight forecasting tools.

This section examines the survey responses through discussion of the policy and analytical needs identified by the states, current application of freight tools, the needs not being addressed by these tools, and individual state responses. Table 3.1 shows the state departments of transportation (DOT) that were interviewed as part of the survey.

3.1 Freight Policy Needs

As shown in Table 3.2, the survey responses revealed a wide range of state needs for analytical freight tools. These needs are discussed in greater detail below.

State Transportation Planning

State transportation planning, including preparation of state multimodal transportation plans and freight plans, is a basic function common to most states. Most see the need for improved freight elements within their multimodal statewide transportation plans. Some have initiated state freight plans to more specifically address freight issues within their overall state multimodal planning processes.

Project Prioritization, Statewide Transportation Improvement Program Development

Many states identified the need for tools to help set priorities among freight projects and to develop specific inputs to the statewide transportation improvement program. Some states mentioned the desire to identify short-term freight improvement priorities in cooperation with freight stakeholders to demonstrate short-term benefits and keep freight stakeholders engaged in longer-term capital plans and project prioritization for freight.

Modal Diversion Analysis

A few states have conducted modal diversion analysis between truck and rail and more see the need to do so. Some states feel that major highway corridors will be unable to handle the forecast truck travel and wish to analyze the potential for the rail system to accommodate a greater share of the growth.

Pavement, Bridge, and Safety Management

A few states mentioned the need for truck data and tools to support pavement, bridge, and safety management systems.

Policy and Economic Development Studies

Many ad hoc freight policy requests as well as more extensive policy studies are often required from departmental officials, the governor's office, or the legislature. These special analyses often are tied to economic development issues and sometimes to state economic models maintained by the state economic development agency.

Needs and Economic Analysis

A few states mentioned the use of freight forecasting tools for needs and economic analysis. Economic needs outputs have been fed into economic models to determine state or regional economic development effects in various industries.

Table 3.1. State departments of transportation participating in the survey.

Survey	State	Location in United States	Population Size[a]	Ports	International Land Borders
Phone	California	Southwest	Large	Pacific	Southern
	Colorado	Mountain	Medium	None	
	Florida	Southeast	Large	Atlantic; Gulf	
	Maine	Northeast	Small	Atlantic	Northern
	Maryland	Northeast	Medium	Atlantic	
	New Jersey	Northeast	Medium	Atlantic	
	Texas	Southwest	Large	Gulf	Southern
	Washington	Northwest	Medium	Pacific, River	Northern
	Wisconsin	Midwest	Medium	Great Lakes; River	
E-mail/Internet	Arkansas	South	Small	River	
	Iowa	Midwest	Small	River	
	Idaho	Mountain	Small	None	Northern
	Kansas	Midwest	Small	River	
	Minnesota	Midwest	Medium	Great Lakes; River	Northern
	Montana	Mountain	Small	None	Northern
	North Dakota	Midwest	Small	River	Northern
	Oklahoma	Southwest	Small	None	
	Pennsylvania	Northeast	Medium	Great Lakes; River	
	South Carolina	Southeast	Medium	Atlantic	
	South Dakota	Midwest	Small	River	
	Tennessee	South	Medium	River	
	Virginia	Southeast	Medium	Atlantic	
	Vermont	Northeast	Small	None	Northern

[a] Population size is defined here as follows: Small state = under 4 million; Medium state = between 4 million and 15 million; Large state = over 15 million.

Commodity Flow Analysis

Some states identified the need for commodity flow analysis to better understand the types, values, and economic importance of freight movement to, from, and within the state. This applies to general policy and planning efforts to improve freight knowledge, support state economic development, support specialized freight analyses, and prepare briefings and presentations to DOT management, the legislature, and the governor's office.

Rail Planning

Many states see a growing need for rail planning. States are concerned that, without adequate rail capacity, more freight will shift to trucks, thus overburdening already congested highway corridors. States believe that short-line railroads should play a greater role in reducing wear on highways and improving access to service provided by major railroads.

Trade Corridor and Border Planning

Implementation of the North American Free Trade Agreement (NAFTA) and the Transportation Equity Act for the 21st Century (TEA-21) in the 1990s has generated considerable interest in multistate border and corridors planning. Several states have already developed state strategic corridor efforts.

Operational Needs

Operational needs include a broad array of operational issues. Topics mentioned were the importance of focusing on short-term operational improvements for freight, the possibility of special truck lanes, rest area truck parking needs, hazmat and other truck routings, security issues related to goods movement, the need for improved truck accident data and analysis, truck size and weight, and motor carrier hours-of-service changes.

Project Development or Design Needs

Many states mentioned needs for freight forecast to support project-level detail for development or design.

Terminal Access Planning

States with major ports such as New Jersey and South Carolina identified port access planning as a major priority for freight models and analysis. New Jersey specifically is using a refined version of its statewide freight model for the purposes of access planning at the Port of New York/New Jersey. More detailed network, zone, and truck data were required for the subregion around the port. Some Midwestern states identified grain movement and grain elevator access as an issue for potential application of freight tools.

Table 3.2. States' primary freight policy and analytical needs.

Need	Response Frequency
State transportation planning, including preparation of state multimodal transportation plans and/or freight plans	High
Project prioritization, statewide transportation improvement program (STIP) development	High
Modal diversion analysis	High
Pavement, bridge, and safety management	Medium
Policy and economic studies for governor, legislature, commission, etc.	Medium
Needs analysis	Medium
Commodity flow analysis to understand types, values, and economic importance of freight movement to, from, and within the state	Medium
Rail planning	Medium
Trade corridor and border planning	Medium
Operational needs	Medium
Project development or design needs; e.g., forecasts and loadings	Medium
Terminal access planning; forecasting truck loadings for highway access facilities to ports, other intermodal terminals, and grain or other heavy commodity terminals	Medium
Truck flow analysis and forecasting	Medium
Performance measurement/program evaluation	Medium
Bottleneck analysis	Medium

Note: States listed multiple primary freight policy and analytical needs.

Truck Flow Analysis and Forecasting

Truck flow models are used for basic highway planning, for special generator analysis, corridor analysis, project development, and as input to air quality model analysis. Florida, Texas, and Vermont have developed statewide truck models and Washington is in the process of doing so. Statewide models are virtually nonexistent for the other modes and few states have them under development, although several states mentioned a future need.

Performance Measurement/Program Evaluation

According to the survey, freight performance measurement is a relatively new area for state DOTs. Minnesota is one of the few states that has developed any freight-specific performance measures. Current models provide very little output useful to performance measurement. Measures such as freight vehicle travel time and delay, reliability, cost, freight corridor condition and performance, intermodal connector condition and performance, and customer satisfaction have been suggested as measures but are relatively undeveloped as compared to passenger systems. One interesting FHWA project involves testing measures of freight travel time, delay, and reliability in freight-significant corridors using satellite tracking devices on trucks. This is an example of public/private cooperation to collect freight performance data while respecting important privacy issues.

Bottleneck Analysis

A few states mentioned the potential use of tools for freight bottleneck analysis, although there has been little

Table 3.3. State needs versus model classes.

Policy and Analytical Needs	Type of Tool[a]				
	Facility Flow Factor	O-D Factor Models	Truck Models	Commodity Models	Economic-Based Models
1 State transportation planning	–	P	P	P	P
2 Project prioritization, STIP development	P	S	P	P	P
3 Modal diversion analysis	–	S	–	P	P
4 Pavement, bridge, and safety management	P	S	P	P	P
5 Policy studies	–	–	–	–	–
6 Needs analysis	P	S	P	P	P
7 Commodity flow analyses	–	P	–	P	P
8 Rail planning	–	S	–	P	P
9 Trade corridor and border planning	–	–	–	–	–
10 Operations, safety, security, truck size and weight issues, etc.	–	–	–	–	–
11 Project development or design needs; e.g., forecasts and loadings	P	S	S	S	S
12 Terminal access planning	–	S	–	S	P
13 Truck flow analysis and forecasting	–	S	P	P	P
14 Performance measurement/ program evaluation	–	–	–	–	–
15 Bottleneck analysis	–	–	S	S	S

[a] P, primary; S, secondary.

such application to date. Oregon recently completed a study of the Interstate 5 corridor that identified and analyzed a bottleneck at the Columbia River crossing. Ohio plans to conduct a freight bottleneck analysis in the future.

3.2 Available Methods

The survey revealed that existing methods, which primarily produce facility-level forecasts of freight flows, are generally able to respond to changes in the transportation system and meet the state needs identified in Table 3.2. The degree to which the five classes of freight models described in Section 5.0 meet these needs shown as a primary or secondary output or function based on professional judgment, is shown in Table 3.3. Four policy needs were identified as currently unmet by existing freight methods:

- **Policy Studies –** Owing to the difficulty of relating transportation investments to quality of life or economic development policy goals;
- **Trade Corridor and Border Planning –** Owing to the simplified treatment within the models of freight flows beyond a state's border, or more commonly the U.S. border;
- **Operations, Safety, Security, Truck Size, and Weight Issues –** Owing to the absence of connections of the freight models to microsimulation tools (a shortcoming shared with traditional passenger travel demand forecasting models); and
- **Performance Measurement/Program Evaluation –** Owing both to a lack of information on appropriate freight performance measures (which will be addressed in Section 7.0) and to the absence of techniques to directly utilize the outputs of freight models to calculate these measures.

CHAPTER 4

Forecasting Components

This Toolkit is organized on the basis of five basic model classes and six modeling components. The model classes share many basic components, as shown in Table 4.1. All of the classes, except the direct facility flow factoring model class, assign one or more modal tables to modal networks. The origin-destination (O-D) factoring, four-step commodity, and economic activity models all have mode split components. The truck, four-step commodity, and economic activity model classes all have trip generation and trip distribution components. The truck and four-step models use exogenously supplied zonal employment or economic activity in the trip generation component, while the economic activity model forecasts the employment or economic activity based on economic and land use data.

Section 4.6 discusses economic activity/land use models, which, depending on the model class, can be integrated into the freight forecasting process, run separately to provide socioeconomic data forecasts, or used to obtain growth factors.

4.1 Direct Factoring

As shown in Figure 4.1, the direct factoring model component produces forecasts of link volumes, such as those on roads, railroad tracks, or ports, using basic information about existing flows and forecasts of economic data or trends that would affect the facility.

This method uses existing freight flow for a facility, modal network link, or terminal. Factors are developed and applied to estimate changes in this facility flow due to growth or changes in transportation service on that facility or on a competing facility regardless of mode.

Direct factoring is used in many states. Usually intended for short-term forecasts, the model component involves simple methods intended for rapid application of existing data to determine one or more forecasted items. Successful direct factoring requires many assumptions and the model's range of applicability is limited. The Federal Highway Administration's *Guidebook on Statewide Travel Forecasting* discusses time series methods for direct forecasts of vehicular volumes on highway and for forecasting the inputs to four-step models.[5] The *Guidebook* emphasizes autoregressive integrated moving average (ARIMA) models and growth factor methods, while describing a linear regression model to forecast truck volumes on Interstate 40 in New Mexico. The Federal Highway Administration's *Quick Response Freight Manual* describes two methods of applying factors to traffic volumes applicable to rural highways as well as urban highways.[3] The first method involves estimating a growth factor from current and past truck count data and applying the resulting factor to future years using a conventional compound interest formula. The second method determines separate growth factors for various "economic indicator variables," usually employment in local industrial sectors. The future growth in economic indicator variables, as calculated by a compound interest formula, is used to forecast growth in commodity groups.

NCHRP Report 260: Application of Statewide Freight Demand Forecasting Techniques, describes a generalized procedure of O-D table factoring and assignment.[6] The report assumes that commodity production is directly related to employment in industries that produce the commodity. For estimating consumption, it recommends the use of an input-output table. Commodity consumption calculations follow a three-step process:

1. Obtain an input-output table;
2. Convert dollar amounts to tons and sum the columns of the table to find consumption by industry; and
3. Allocate tons to counties (the assumed size of the Traffic Analysis Zone, or TAZ) according to the employment by consuming industries and population (for final demand) in each county.

These steps assume that the production and consumption estimates can be applied to an existing commodity

Table 4.1. Freight model classes by component.

	Model Component					
Model Class	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Split**	**Traffic Assignment**	**Economic/Land Use Modeling**
Direct Facility Flow Factoring Method	Of facility flows					
O-D Factoring Method	Of O-D tables			Included	Included	
Truck Model		Based on exogenously supplied zonal activity	Included	Not Applicable	Included	
Four-Step Commodity Model		Based on exogenously supplied zonal activity	Included	Included	Included	
Economic Activity Model		Based on outputs of economic model	Included	Included	Included	Included

flow matrix or (in the absence of a matrix) incorporated into a gravity model of shipment distribution.

4.2 Trip Generation

As shown in Figure 4.2, the trip generation model component forecasts the productions and attractions of freight movements that begin or end in a geographic zone based on the characteristics of that zone. The most common characteristic used in trip generation is the employment by industry that produces and consumes various goods. The output of trip generation, a production and attraction file for all geographic zones, customarily serves as input to other model components used in freight forecasting. However, the production and attraction file can be useful on its own, showing freight trips that end in zones.

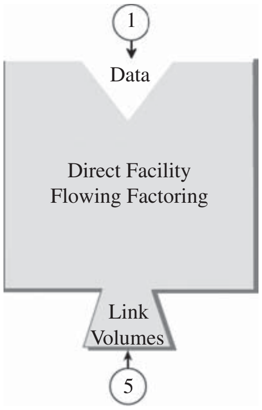


Figure 4.1. Direct factoring.

The trip generation models used in statewide freight forecasting include a set of annual or daily trip generation rates or equations by commodity, providing annual or daily flows originating or terminating in geographic zones as functions of TAZ or county population and disaggregated employment data. Production and consumption tonnages for special generators like seaports, airports, and other intermodal transfer terminals are directly obtained from the port or terminal for the base year. The commodity flow tonnages for external zones are obtained from the commodity flow database and are disaggregated at the TAZ or county level based on the distribution of employment within each TAZ or county.

For the truck model class of freight models, trip generation is usually calculated separately for internal trips between zones (I-I) and external trips between internal and external zones (E-I, I-E, and E-E). Trip rates are derived from national sources such as the *Quick Response Freight Manual* and/or regional sources, if available. These are applied to households and employment data to obtain truck trips internal to the state. Different trip rates by truck type are used for truck trip productions and attractions. The socioeconomic data used in a typical truck model are consistent with those data used in

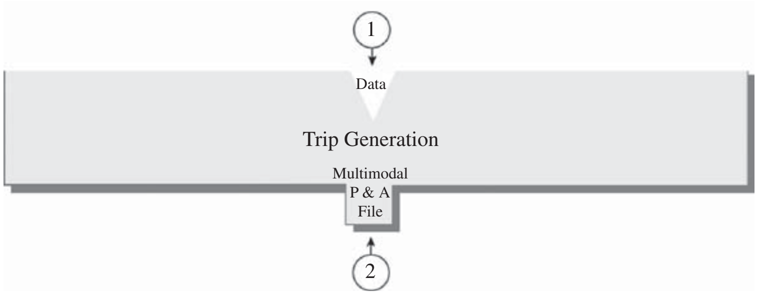


Figure 4.2. Trip generation.

passenger models, except that the employment data are stratified into more employment categories. This process provides more accuracy for truck travel, allows for a direct relationship between the commodities being estimated in the external trip model that captures truck flows in and out of the state, and helps allocate these commodities to traffic analysis zones within the state. The stratification of employment data is usually by Standard Industrial Classification (SIC) codes at the two-digit level. The trip rates are usually adjusted during model calibration based on local or regional knowledge of truck trip ends. Section 5.6 includes a detailed discussion of SIC codes, and Table A.2 in Appendix A shows the correspondence between STCC codes and the Standard Classification of Transported Goods SCTG.

The external truck trips (E-I and I-E) entering and leaving the state are derived from observed data at external stations and truck survey data. These data are disaggregated to the TAZ level based on percent distribution of various employments by industry within each internal TAZ. Some truck models also use commodity flows that have either their origin or destination within the state boundary. This process involves the conversion of commodity flow tonnage to truck trips. The through trips (E-E) that pass through the state with both origin and destination outside the state are added to the external truck trips as well.

Trip rates are applied to socioeconomic data and also are used for truck terminals and intermodal facilities in conjunction with observed truck trips at airports, seaports, and rail terminals.

The commodity-based trip generation model includes a set of annual or daily trip generation rates or equations by commodity, providing annual or daily flows as functions of TAZ or county population and disaggregated employment data. The Florida Intermodal Statewide Highway Freight Model, described in Section 8.9, uses Reebie Associates' TRANSEARCH freight database to derive linear production and consumption equations for 14 commodity groups. The independent variables are primarily population and employment by SIC at the county level for the State of Florida. The employment categories are based on the U.S. Department of Commerce's Bureau of Economic Analysis 1996 input-output tables and tailored to the commodity group being estimated.

Production and consumption tonnages for special generators like seaports, airports, and other intermodal transfer terminals are obtained directly from the port or terminal for the base year. The commodity flow tonnages for external zones are obtained from the commodity flow database and are disaggregated at the TAZ or county level based on the distribution of employment within each TAZ or county.

As shown in the Section 8.8 case study, the Indiana Commodity Transport Model includes 21 commodity groups considered important to the state. The trip generation equations were developed based on a regression of data available from the Bureau of Transportation Statistics' 1993 Commodity Flow Survey (CFS). The Nebraska Statewide Freight Forecasting Model also uses the 1993 CFS data to develop a trip production model. However, IMPLAN software provided input-output coefficients that were used to derive trip attraction equations. The Vermont Statewide Freight Study uses O-D data from the TRANSEARCH database, organized at the two-digit STCC level to build the trip tables. In addition to commodity flows, the Vermont study uses roadside surveys, motor carrier surveys, and data from interviews with key shippers to develop the trip tables. The Iowa Statewide Freight Transportation Model also uses the Reebie TRANSEARCH commodity data, organized by Bureau of Economic Analysis zones at the two-digit STCC level. The Nebraska, Vermont, and Iowa models are not the subject of case studies in Section 8.0, but are cited in the References section of the Toolkit. Section 5.6 describes STCC codes in greater detail.

4.3 Trip Distribution

As shown in Figure 4.3, the trip distribution model component produces the production and attraction file for zones to forecast a table of freight flows between all geographic zones. The trip distribution model also requires some information about the degree of difficulty for freight to travel between all zones. With the exception of single mode models

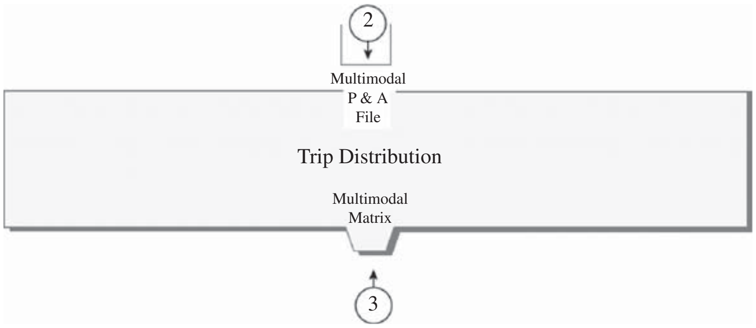


Figure 4.3. Trip distribution.

such as the freight truck model, the flow in the trip table is expressed in units that are common to all modes. When the freight trip table is a multimodal commodity table, it customarily serves as input to the mode split model component. When the table is for a single mode it customarily serves as input to the assignment model component. However, the trip tables themselves are useful in analyzing the markets for freight flow between geographic zones.

The trip distribution models are used in statewide models to forecast the volume of freight shipped between an origin and a destination. All the state freight models surveyed use gravity models for distribution. Gravity models distribute trips by purpose between origins and destinations, based on the total tons produced at an origin, attracted to a destination, and the relative impedance, in the form of friction factors, of traveling between these zones. Gravity models calculate this distribution for each O-D pair by purposes and adjust the calculations iteratively based on the calculations of all other pairs of the same trip purpose.

Truck models use truck types as trip purposes. For the New Jersey Statewide Truck Model described in Section 8.6, the trip purposes were light, medium, and heavy trucks. These were distributed from origins to destinations using the gravity model technique, the same method used in any typical automobile passenger model. The friction factor curves are first derived from the *Quick Response Freight Manual* and later adjusted to provide the best fit with average trip lengths derived from observed truck survey data. The friction factors were developed using the following equations from the manual:

Light = exp (–0.08 * congested travel time)
Medium = exp (–0.10 * congested travel time)
Heavy = exp (–0.03 * congested travel time)

The New Jersey model employs different gravity models for internal, external, and through-trips for both medium and heavy truck types. These models are calibrated to match target distributions based on a combination of observed data for trips in New Jersey where data are available, and data from other cities where local data are unavailable.

The commodity-based freight models use gravity models for trip distribution. However, rather than being trip-specific, the models are developed and applied for commodity groups serving as the purposes for individual tables. Freight flows in tonnage and by commodity group are distributed on an O-D basis for an entire state, either at a district, county, or TAZ level. The primary impedance variables are average travel distance, average travel time, or composite modal travel time.

The trip distribution component for the Florida Intermodal Statewide Highway Freight Model described in Section 8.9 uses a standard gravity model and distributes tons produced in one zone to tons consumed in another zone using friction factors calibrated based on the average trip lengths identified from TRANSEARCH. In the Indiana Commodity Transport Model described in Section 8.8, freight shipments are distributed by a gravity model calibrated using the CFS data. Special care is taken to match the average shipping distance per ton for each commodity group. This prevents any inappropriate weighting for many short-distance lightweight deliveries versus a few long-distance heavyweight shipments that might be included in the same commodity group.

4.4 Mode Split

As shown in Figure 4.4, the mode split model component uses a freight trip table, obtained either from the trip distribution or the commodity flow model components, to forecast tables of freight flows between all geographic zones for individual freight modes. The mode split component also requires some information about the relative benefits of the utility of using each freight mode between all geographic zones. The modal trip tables of freight flow customarily serve as inputs to the assignment model component. If the flow is not expressed as vehicles, but in flow units common for all modes such as tons, a conversion to vehicles may be made prior to using the tables in assignment. However, the trip tables themselves are useful in analyzing the markets for freight flow between geographic zones by mode.

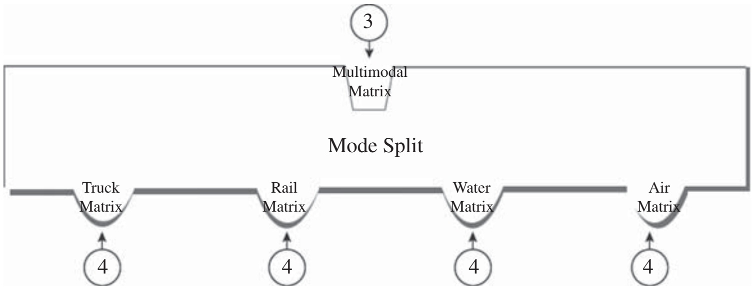


Figure 4.4. Mode split.

Mode split models, as they are used in statewide freight forecasting, convert future flows by all modes into flows by specific modes. (By definition the truck model class involves only a single mode.) A mode split model may use modal shares from the base year commodity data by origin, destination, and commodity group to determine the mode split in the forecast year. These are usually not sensitive to factors like travel times, travel costs, safety, and reliability. By identifying specific markets that may have the option to switch modes based on the distance traveled, the type of commodity, and the size of the shipment, it may be possible to qualitatively adjust mode shares. If modal utility data is available, that information can be used together with the base commodity flow data to develop freight mode split models.

Commodity flow tonnage is converted to vehicles based on commodity-specific factors (tons per truck or railcar) so that loaded truck and/or railcar trips can be assigned to the corresponding networks. In most of the models, conversion to air and waterborne vehicles is not undertaken since assignment to air and water networks is typically not performed. However, the Texas statewide model does convert barge traffic to waterborne tons.

For the O-D factoring class of models, in the process of factoring existing O-D commodity tables by modes, each existing modal table is often factored separately. Implicitly, this assumes that existing mode shares for each commodity will continue in the future. This is not the only option for treating the split into modes within the O-D factoring class of models. How modal allocation is treated depends on the modal-specific network information that is available.

If no information is available on the travel times and costs for the competing modes, the traditional assumption that existing mode shares will continue in the future is appropriate. If qualitative but not quantitative information is available, it is possible to use that qualitative information to change specific mode shares. Market segments of particular commodities, O-D pairs by shipping distances, and shipment size may be identified and expert opinion used to change the modal share.

A typical commodity-based mode split model uses modal shares from the base year commodity data by origin, destination, and commodity group to determine the mode split in the forecast year. These base shares are usually not sensitive to factors like travel times, travel costs, safety, and reliability. However, in some instances mode-specific information from the commodity data is used to develop freight mode split models. A detailed explanation of these methods is provided in the mode split section of the O-D factoring method (Section 6.2).

The Indiana Commodity Transport Model uses the 1993 CFS data to project observed national modal shares into the future. The mode split model in the Florida model is based on an incremental logit choice model and historical mode split percentages. The base year water and air mode splits for each commodity group are assumed to remain unchanged in the future. The choice model is applied to the splits between truck, intermodal, and carload rail, which pivot about the base year percentages:

$$S_i' = \frac{S_i \ \exp(\Delta U_i)}{\sum_{I=1}^{J} S_j \ \exp(\Delta U_j)}$$

where

S_i' = new share of mode i;
S_i = original share of mode i; and
ΔU_i = utility of mode i in the choice set J (j = 1,2,3,. . .,J).

The coefficients of the utility function were adopted from a study in New York and calibrated to the TRANSEARCH database for Florida.

At the national level, the Vehicle Inventory and Use Survey (VIUS) data set provides a large sample that can be used to determine average payloads by commodity, operating radius, vehicle size, and type of truck usage. This information is applicable to long trips (greater than 200 miles), since these are typically interstate movements. For shorter trips beginning and ending within the state, average payloads should be estimated from only those vehicles based in-state. This method has been used widely in many statewide and regionwide freight models. However, there are some exceptions where the freight tonnage is divided into an equivalent number of vehicles, with ton-per-vehicle rates determined separately for each commodity group. These rates are based on values (by commodity group) from the Surface Transportation Board Rail Waybill sample and the assumption that each truckload carries 40% of the load carried by a railcar.

4.5 Traffic Assignment

As shown in Figure 4.5, the assignment model component uses the table or matrix of freight flows by mode between all zones produced by the mode split model component to forecast freight volumes on individual links of the modal networks. The assignment model component customarily processes each mode separately using a network for that mode with attributes important to freight in order to find the optimum path or sequence of links between all geographic zones. For truck freight flows, the travel times on the highway network may account for the congestion caused by passenger autos and other vehicles. In that case the freight truck trip tables will be assigned together with those auto tables to find the total link travel times and volumes. For the economic activity model class, the link volumes are used to adjust the original economic forecast in an iterative process until an equilibrium is reached.

Network assignment models, as used in statewide freight forecasting, apply the modal freight trips to paths identified from the modal network. Essentially three types of assignment models are used: rules-based assignment, freight truck only network assignment, and multiclass network assignment. Rail networks are typically rules-based assignment models, given the difficulties of including rail business practices in an assignment model. Freight truck only mode and multiclass assignments typically apply only to trucks on highways.

Rules-based assignment techniques may be developed by the analysts or purchased as part of the existing O-D survey. The distinguishing feature of a rules-based assignment is that the analyst does not have the ability to change the paths to be used in response to changes in performance on the system or the introduction of new facilities. As part of its TRANSEARCH commodity flow database, Reebie Associates provides the option to map truck freight flows on a highway network. This routing is accomplished through the use of special files that contain:

- A highway network with unique highway identifiers for each highway segment;
- A set of paths between origin and destination zones consisting of the highway links used to travel from origins to destinations; and
- An O-D table of truck flows by commodity with the identifier of the path used by those flows.

The TRANSEARCH Highway Network is available as a Microsoft Access table and an ArcView shapefile. By initiating queries within Access and exporting those results to ArcView, it is possible to develop maps of the flows of some or all commodities on the highway system.

In freight truck only assignments, the freight truck trip table is assigned to the highway network using an all-or-nothing assignment process. Since a straight all-or-nothing assignment typically loads too many trips onto the interstate highways, a procedure to adjust the link speeds for noninterstate highway segments is often applied. This serves to draw more trips from the interstate roads to the competing U.S. and state highways that run parallel to them. The unfortunate part of the assignment step is the failure to address the possibility of congestion due to the presence of a large number of passenger vehicles sharing the road.

The Freight Analysis Framework (FAF) uses a methodology to estimate trade flows on the nation's highway infrastructure, seeking to understand the geographic relationships between local flows and overall transportation. Truck assignment in the FAF is accomplished using TransCAD's Stochastic User Equilibrium and with other vehicles, such as automobiles, preloaded on the network. FAF is an improvement over the all-or-nothing assignment because it accounts for congestion.

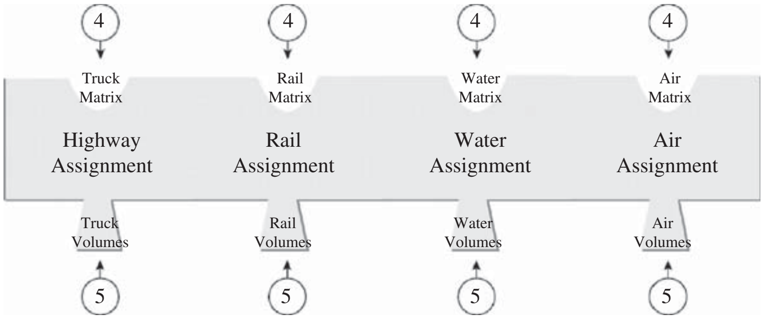


Figure 4.5. Traffic assignment.

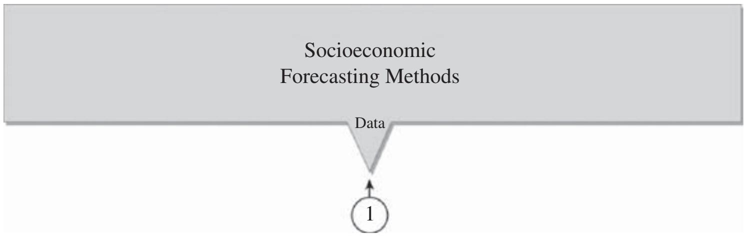


Figure 4.6. Economic/land use modeling.

Multiclass network assignment of the truck trips can be based on an equilibrium highway assignment, and truck trips are usually assigned together with the passenger vehicle model because congestion has a significant impact on truck travel times. Truck trips may also be assigned separately by vehicle size using the multiclass assignment technique. Many truck models are developed using a conversion of truck volumes to passenger car equivalents (PCE) for assignment purposes. This factor provides a means of accounting for the fact that larger trucks take up more space on the roads than passenger cars, and behave differently during acceleration and braking. This is important to determine the effects on capacity and congestion for assignment of both trucks and passenger cars. The Transportation Research Board's *Highway Capacity Manual* recommends PCE values of 1.5 and 2.0 for single unit trucks with six or more tires and combination units respectively. The truck model developed by the Baltimore Metropolitan Council indicated that the PCE value for heavy truck varies from 2.0 to 4.0. This value depends on roadway grades, acceleration, and braking times. If observed data on passenger car equivalents are collected, then these assumptions by truck type should be modified.

4.6 Economic/Land Use Modeling

The economic/land use modeling component shown in Figure 4.6 may be used to prepare the basic socioeconomic forecasts by geographic area used in freight forecasting. If the economic forecasts are prepared independently of the freight transportation forecasts they will serve as inputs to factor facility flow or standalone commodity trip tables or as inputs to the trip generation model component. The forecasts depend on the relative accessibility between geographic zones and the forecast is revised based on the resulting forecast of link volumes. These iterative adjustments may be made as part of a formal model process.

Economic/land use modeling components in statewide freight forecasting include modeling techniques known as a spatial input-output (I-O) or econometric models. The land use considerations in these models that consider state and national economic activity are generally far less developed than in metropolitan land use models and typically only forecast household and economic activity across county-level zones based on basic supply, demand, and cost relationships for the state and national economy. These models may be used to develop the forecast socioeconomic variables that will be used by the freight model.

Econometric models are seldom maintained and operated by state departments of transportation. Most often they are operated by other state agencies, by state universities (such as, University of Florida Bureau of Economic and Business Research, University of Kansas Econometric Model) or by private firms (for example, Global Insights as WEFA for the FAF and Ohio Interim Model and as DRI for the Nebraska Model, REMI, Woods & Poole for Indiana). When operated by others, the state departments of transportation may receive and use only economic activity outputs, such as employment by industry and population, to use directly in statewide freight forecasting. Alternatively, they may receive growth rates to apply to existing freight flows, or a complete forecast of future freight flows.

When included as a component within the economic activity class of models, the economic/land use model components may be operated by the state DOT in cooperation with economic development agencies.

CHAPTER 5

Data Sources

In order to forecast statewide freight flows, data are needed to develop and validate the models and methods used as inputs. Quality and precision are the keys to freight modeling, with the accuracy of the freight flow forecast dependent on the accuracy of the database. If the underlying database is not complete and correct, then the estimated freight flow will be inaccurate. This section of the Toolkit identifies data sources unique to freight forecasting or applied to freight forecasting in a unique way. General data sources used in transportation forecasting should be familiar to users of the Toolkit and will be mentioned briefly. Freight-specific data sources for important databases also will be briefly summarized, while sources used in the case studies will be described in more detail.

5.1 Model Development

As described in Sections 4.0 and 6.0, statewide freight forecasting methods employ a variety of techniques, models, and formulas for processing data. The nature and form of the equations and the values for their coefficients and parameters are determined through a model development process familiar to those that have developed passenger forecasting models. The sources of this data for freight are described below.

Local Surveys

The construction of a passenger transportation forecasting model often begins with a travel survey. A travel survey gathers information about the number of trips, the purpose of these trips, the time the trips were taken, the cost, the distance traveled, the mode choice, and information about the traveler. A travel survey thus provides the behavioral data needed to establish the trip generation, trip distribution, mode split, and assignment relationships specific to a study area. The survey size must be designed to provide a statistically valid sample of all potential travelers.

When conducting a survey of freight movements, one encounters a basic problem: determining the size of the market that should be surveyed. Conducting a cordon survey around an entire state boundary is generally impractical, and matching vehicles passing through a statewide cordon can be extremely difficult. Cordon surveys do not usually provide information about the contents of vehicles, such as, commodity information, which makes it impossible to tie the freight flows back to economic development data.

Generally, shipper and carrier surveys prove more manageable. In a shipper survey, a major shipper is asked to fill out a form detailing each shipment dispatched in a given time period. The information collected might include the type of commodity, the place of origin, the destination, the transport mode or modes, the dollar value and physical volume of the shipment, and other general information. In a carrier survey, a major carrier is asked to detail all the shipments carried and possibly also the route chosen. With the consent of the carrier's management and staff, electronic driver information systems may be used to collect similar data. Determining a statistically valid sample of shippers and carriers for a specific statewide survey and the appropriate expansion factors is extremely difficult and expensive. However a shipper diary survey is regularly conducted by the U.S. Census Bureau for the CFS.

Compilations

Developers of freight forecasting models may wish to avoid the expense of conducting a behavioral survey and instead use the rates, coefficients, and relationships developed by others. While not as well developed as those for passenger planning, several publications provide values that can be used in truck generation and distribution models. These publications include the Institute of Transportation Engineers' *Trip Generation Handbook*[7], the National Cooperative Highway Research Program's *Truck Trip Generation Data*[8], and the

Federal Highway Administration's *Quick Response Freight Manual*[3], and *Accounting for Commercial Vehicles in Urban Transportation Models.*[9]

National Surveys

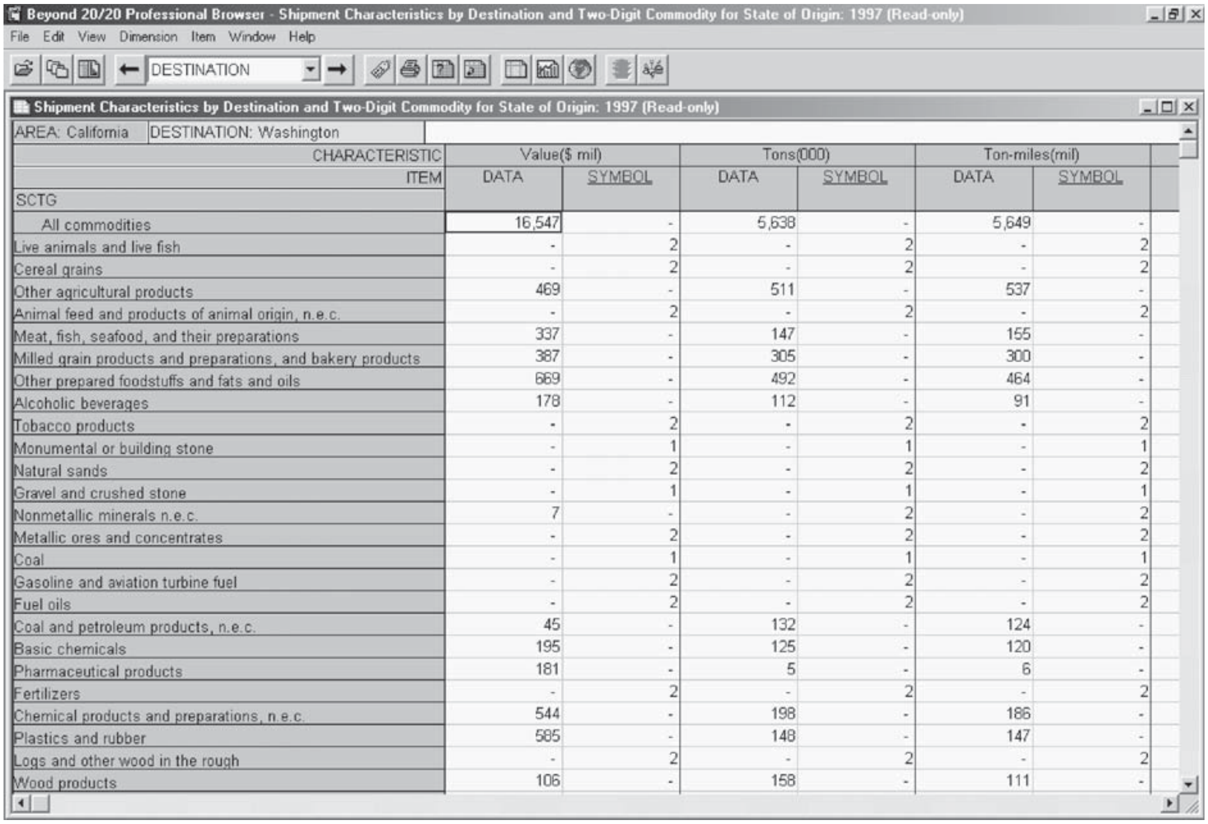
Shipper surveys typically require a nationwide sample. While a survey of shippers within the target market area will provide a sound picture of outbound shipments, this limited coverage will otherwise miss inbound activity. To avoid the size and complexity of conducting such a study for an individual freight forecasting project, existing surveys may be obtained. The two most common surveys, the CFS and TRANSEARCH, are described in detail as part of this Toolkit. Also described is the FAF's Commodity Database, a publicly available database created from TRANSEARCH.

Commodity Flow Survey

CFS is conducted every five years as part of the U.S. Census Bureau's Economic Census and is designed to provide data on the flow of goods and materials by commodity, origin, destination, and mode of transport. Prior to 1997 the CFS reported commodity information using the STCC code. Beginning with the 1997 CFS, the SCTG codes were used, providing a more modern focus and a better link to industry classification and output measures.

Due to variations in methodology, sample size, and other changes, the CFS is not particularly consistent from year to year, making it hard to build time-series data. Nonetheless, the CFS remains the only shipper survey to which a response is mandatory. As such, it is less likely to be biased than other shipper surveys.

In terms of statewide forecasting, the CFS presents difficulties. Since the survey is predominantly designed to map national-level traffic, the small sample size within each state means that data must be aggregated to preserve shipper confidentiality. Consequently, origin and destination data are publicly released on CD-ROM at two aggregation levels: state-to-state and between 86 of the largest metropolitan areas (portions within the primary state boundary only). Furthermore, the 1997 data are available only as predefined data files through a browser, as shown in Figure 5.1. While commodity, origin, destination, and mode information is available, only three of the four characteristics are reported in any one table. Individual tables by origin, destination, and commodity must be transformed and aggregated to produce a national database. Additional processing is necessary to estimate data that is aggregated or suppressed to preserve confidentiality.



AREA: California DESTINATION: Washington

CHARACTERISTIC	Value($ mil)		Tons(000)		Ton-miles(mil)	
ITEM	DATA	SYMBOL	DATA	SYMBOL	DATA	SYMBOL
SCTG						
All commodities	16,547	-	5,638	-	5,649	-
Live animals and live fish	-	2	-	2	-	2
Cereal grains	-	2	-	2	-	2
Other agricultural products	469	-	511	-	537	-
Animal feed and products of animal origin, n.e.c.	-	2	-	2	-	2
Meat, fish, seafood, and their preparations	337	-	147	-	155	-
Milled grain products and preparations, and bakery products	387	-	305	-	300	-
Other prepared foodstuffs and fats and oils	669	-	492	-	464	-
Alcoholic beverages	178	-	112	-	91	-
Tobacco products	-	2	-	2	-	2
Monumental or building stone	-	1	-	1	-	1
Natural sands	-	2	-	2	-	2
Gravel and crushed stone	-	1	-	1	-	1
Nonmetallic minerals n.e.c.	7	-	-	2	-	2
Metallic ores and concentrates	-	2	-	2	-	2
Coal	-	1	-	1	-	1
Gasoline and aviation turbine fuel	-	2	-	2	-	2
Fuel oils	-	2	-	2	-	2
Coal and petroleum products, n.e.c.	45	-	132	-	124	-
Basic chemicals	195	-	125	-	120	-
Pharmaceutical products	181	-	5	-	6	-
Fertilizers	-	2	-	2	-	2
Chemical products and preparations, n.e.c.	544	-	198	-	186	-
Plastics and rubber	585	-	148	-	147	-
Logs and other wood in the rough	-	2	-	2	-	2
Wood products	106	-	158	-	111	-

Figure 5.1. Commodity flow survey.

The 2002 data has been collected and partial releases began to be made available in 2004. The 2002 survey excluded shipments by establishments classified in the North American Industry Classification System (NAICS) as farms, forestry, fishing, government agencies, construction, transportation, and most retail and service industries. The 2002 survey also excluded shipments from logging establishments, because under NAICS the classification of this industry moved from manufacturing (included in the scope of the CFS) to agriculture (out-of-scope for the CFS). The CFS is a survey of domestic establishments and measures shipments leaving an establishment's facility, and it includes exports but not imports (unless the imported goods are received by an included domestic business at the port of entry and reshipped by that business). The 2002 CFS also excludes shipments of crude petroleum by the oil and gas extraction industries because of issues with how these companies record and report shipment information.

The 1997 CFS is available on CD-ROM from the U.S. Census Bureau at http://www.census.gov/econ/www/cfsmain.html. The 2002 CFS will be available in February 2005.

TRANSEARCH

TRANSEARCH is a database of freight traffic flows available from Reebie Associates. Although proprietary, it also is the most commonly used source of freight data; four of the case studies reported in this Toolkit rely on TRANSEARCH. TRANSEARCH uses several mode-specific data sources to create a picture of the nation's freight traffic flows on an origin to destination commodity basis, refining the geographic market identification to the county level.

TRANSEARCH is updated annually using the following sources:

1. Annual Survey of Manufacturers by state and industry;
2. Surface Transportation Board (STB) Carload Rail Waybill Sample of market-to-market rail activity by industry;
3. Army Corps of Engineers waterborne commerce data describing market-to-market water activity by industry;
4. Federal Aviation Administration (FAA) enplanement statistics and airport-to-airport cargo volumes;
5. Rail, water, and air freight flow data deducted from the Bureau of Census Annual Survey of Manufacturers (ASM)-based production data; and
6. Reebie Associates' proprietary Motor Carrier Data Exchange Program, which provides information on actual market-to-market trucking industry movement activity. The truckload sample covers about 6% of the market, and Reebie Associates' less-than-truckload sample is about 40%. In total, information is received on over 75 million individual truck shipments.

TRANSEARCH's county-to-county market detail is developed through the use of Reebie Associates' Motor Carrier Data Exchange inputs and its Freight Locator database of shipping establishments, which provides information about the specific location of manufacturing facilities, measures of facility size (both in terms of employment and annual sales), and a description of the products produced.

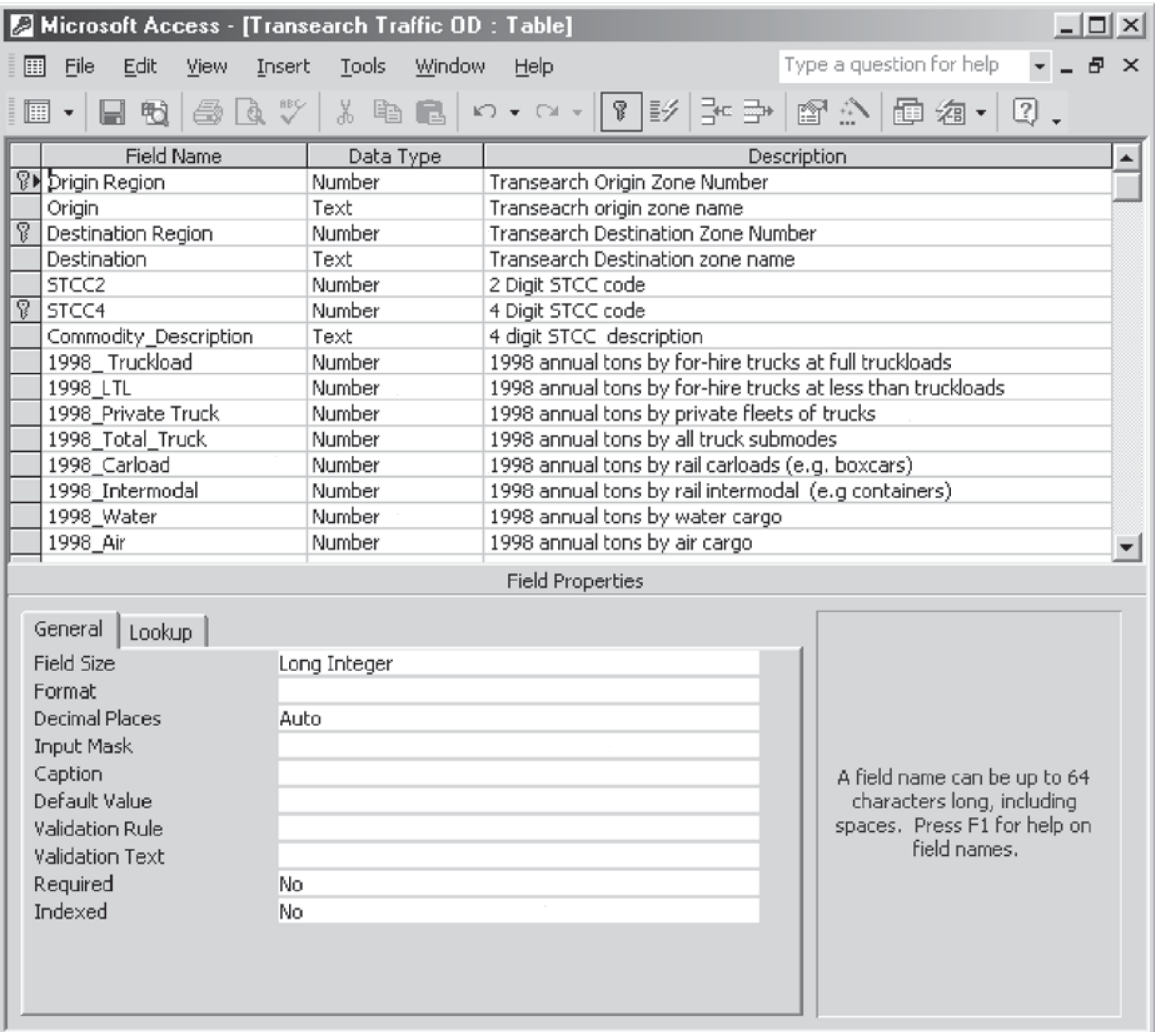
Primary coverage of truck traffic is limited for nonmanufactured products. For manufactured products information is provided using the STCC Code, which can be aggregated from a four-digit level. Supplemental material for agricultural and mining resource extraction shipments from the source to a processing plant not ordinarily covered in commodity flow surveys is available for an additional charge.

Traffic movements originating in warehouses or distribution centers or drayage movements of intermodal rail or air freight are shown as STCC 50. These are by definition truck movements. Movements to warehousing and distribution centers may be by other STCC codes and by any mode. Details on the types of items being moved in STCC 50 are not available.

The CFS defines the use of multiple modes, such as truck and rail, as a separate mode. The TRANSEARCH database, shown in Figure 5.2, is an unlinked trip table that reports the portion of a trip by each mode, and in some cases submodes, separately. This allows the volume of shipments at intermodal transfer points to be identified, but the information on the lining of the trips is lost.

As discussed, TRANSEARCH is constructed from many commercial and public sources of data, representing domestic and NAFTA trade flows. Economic modeling is used to adjust the surveys where data is lacking or confidential and to check elements such as spatial patterns and logic. Given the complexity of its sources and the additional analysis that is undertaken, the construction of TRANSEARCH cannot be easily summarized. This inability to completely document all elements and proprietary sources has led to some concerns by some users about the data's inclusiveness. Despite these concerns, TRANSEARCH is an accepted freight database widely used for planning by the FHWA, many U.S. states and metropolitan planning organizations (MPOs), as well as private freight carriers and shippers.

The inland or surface movement of import and export traffic volumes to locations outside of North America is included in the data but only to and from the location where the freight crosses the U.S. border. However, the flow patterns of this freight are based on the movement patterns of domestically sourced goods in the same market areas and are not the actual movements of the import/export freight.



Field Name	Data Type	Description
Origin Region	Number	Transearch Origin Zone Number
Origin	Text	Transeacrh origin zone name
Destination Region	Number	Transearch Destination Zone Number
Destination	Text	Transearch Destination zone name
STCC2	Number	2 Digit STCC code
STCC4	Number	4 Digit STCC code
Commodity_Description	Text	4 digit STCC description
1998_ Truckload	Number	1998 annual tons by for-hire trucks at full truckloads
1998_LTL	Number	1998 annual tons by for-hire trucks at less than truckloads
1998_Private Truck	Number	1998 annual tons by private fleets of trucks
1998_Total_Truck	Number	1998 annual tons by all truck submodes
1998_Carload	Number	1998 annual tons by rail carloads (e.g. boxcars)
1998_Intermodal	Number	1998 annual tons by rail intermodal (e.g containers)
1998_Water	Number	1998 annual tons by water cargo
1998_Air	Number	1998 annual tons by air cargo

Field Size	Long Integer
Format	
Decimal Places	Auto
Input Mask	
Caption	
Default Value	
Validation Rule	
Validation Text	
Required	No
Indexed	No

A field name can be up to 64 characters long, including spaces. Press F1 for help on field names.

Figure 5.2. TRANSEARCH database.

TRANSEARCH is available for purchase from Reebie Associates at http://www.reebie.com.

STB Carload Rail Waybill Sample

STB is the official authority of the Carload Waybill Sample. Railroads terminating over 4,500 cars per year are required to file a sample of waybills with the STB. The primary purpose of the Carload Waybill Sample is regulatory oversight. The Waybill Sample contains rail shipments data such as origin and destination points; type of commodity; number of cars, tons, revenue; length of haul; participating railroads; interchange locations; and Uniform Rail Costing System shipment variable cost estimates. It contains confidential information and is used primarily by Federal and state agencies. While the Waybill Sample is not available for public use, a public-use version contains aggregated nonconfidential data. Movements are generally aggregated to the Bureau of Economic Analysis (BEA) region to BEA region level at the five-digit Standard Transportation Commodity Code level. The STB Waybill Sample is a stratified sample of carload waybills for terminated shipments by railroad carriers.

Army Corps of Engineers Waterborne Commerce Data

Waterborne traffic movements are reported to the Army Corps of Engineers by all vessel operators. The reports are generally submitted on the basis of individual vessel movements completed. For movements with cargo, the point of loading and the point of unloading of each individual commodity must be delineated. Military cargo moved in commercial vessels is reported as ordinary commercial cargo; military cargo moved in Department of Defense vessels is not reported. In summarizing the domestic commerce certain movements Cargo carried on general ferries; coal and petroleum products loaded from shore facilities directly into bunkers of vessels for fuel; and insignificant amounts of government materials (less than 100 tons) moved on government-owned equipment in support of Corps projects. Foreign commerce data are furnished to the Corps of Engineers by the Bureau of the Census under a working arrangement sponsored by the Office of Management and Budget.

Freight Analysis Framework Commodity Database

FAF, described in Section 8.5, produced a Commodity Flow Database (CFD) that provides O-D information on commodity flows by mode for the years 1998, 2010, and 2020. These flows, given in tons, are organized by commodity and mode. The CFD is divided into domestic flows (state-to-state) and international flows. The data are available in both Microsoft Access 2000 (*.mdb) format and tab-delimited text (*.txt) format, the latter suitable for importing into a Microsoft Excel spreadsheet. A set of lookup tables of the STCC Commodity and Federal Information Processing System (FIPS) codes for states also is provided. Separate tables are provided for domestic, international, international air, and petroleum flows.

For domestic flows, the Federal Highway Administration provides a single file that contains state-to-state freight flows by commodity and mode for 1998, 2010, and 2020. Figure 5.3 illustrates the Microsoft Access data format. The first and second columns indicate a state freight flow from origin “05” to destination “06.” The FIPS reference table translates this to a flow from Arkansas to California. The next three columns indicate rail flows of 4,800 tons in 1998, 5,772 tons in 2010, and 5,930 tons in 2020. The sixth column labeled STC corresponds to the STCC reference table. In this case, “01” corresponds to farm products.

Note that the O-D pair in the database is not unique. The rail freight flow of farm products is not the only movement from Arkansas to California. Rather, many records for all commodities by modes between Arkansas and California can be found later in the table.

The International database file represents freight flows of international origin or destination, by commodity and mode for 1998, 2010, and 2020. It adds the international region of origin or destination (Mexico, Canada, Europe, Latin America, Asia, and Rest of World) to the database and indicates whether the freight is exported or imported. The actual state in which the freight enters or exits the United States is reported as the origin or destination.

The International Air dataset contains freight by air only, from international origins or destinations. The beginning records in the file contain records on foreign air shipments that do not have a U.S. destination or origin. These are labeled foreign in the Direction column. Both the origin and destination states are designated “00” since the flow is purely international. In addition, records show domestic shipments classified as international flows. These state-to-state flows are labeled starting with the point of entry or exit into the United States shown respectively as the origin or destination for reporting purposes. The international origin or destination also is given.

The STCC13-Petro file contains international pipeline flows in tons for 1998, 2010, and 2020. These flows are not usually part of statewide freight forecasting models.

A summary of the contents of the FAF Commodity Flow Databases is shown in Table 5.1. The database can be obtained from the Federal Highway Administration at http://ops.fhwa.dot.gov/freight/freight_analysis/faf.

5.2 Flow Conversion

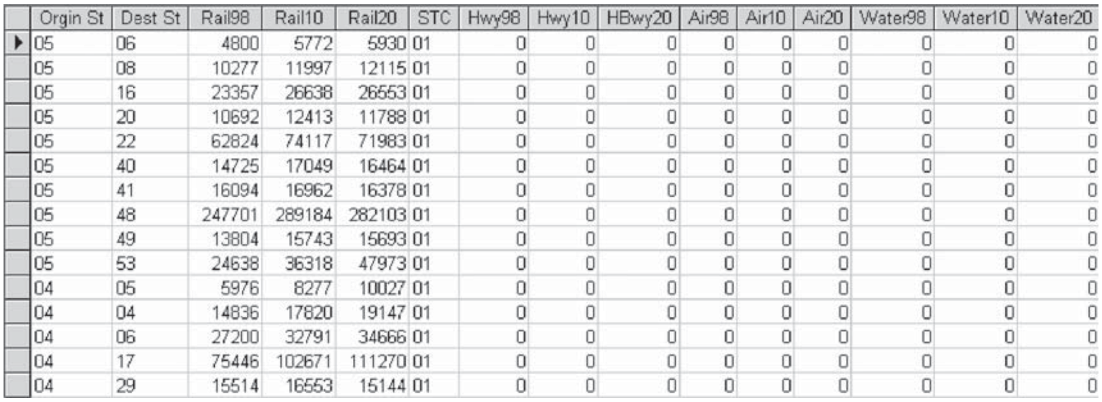
Flow data available or forecast using the methods in this Toolkit may require conversion into other units for processing or analysis. Commodity flow data, reported and forecast in terms of annual tons, is typically converted into vehicles and economic value. Vehicle conversion is generally done for commodity flow by trucks, since freight trucks are assigned together with automobiles and other trucks as daily trip tables.

Tons to Vehicles

The assignment model component for truck freight on highways, described in Section 4.0, is most often calculated in terms of daily truck trips. For the truck model class with forecasts in those units, this is obviously a straightforward procedure. For commodity models that forecast flow in annual tons per year up to and through mode split, a conversion process is required. The Indiana case study uses the Carload Waybill sample to relate tons shipped per carload to develop factors to convert from annual tons to rail carloads and then applies a factor relating the volume of a rail car to the volume of a combination truck trailer to develop tons per truck trailer. More commonly, the Vehicle Inventory and Use Survey (VIUS)from the Economic Census is used to develop these factors.

Vehicle Inventory and Usage Survey

VIUS, conducted every five years as part of the U.S. Economic Census, provides detailed information on the physical and operational characteristics of the nation’s truck population. VIUS is based on a sample of approximately 150,000 trucks, or 2,000 trucks per state. From this sample, state and national estimates are produced. Operational characteristics, which are of particular interest to forecasters, include major use, products carried, annual and lifetime miles, area of



Orgin St	Dest St	Rail98	Rail10	Rail20	STC	Hwy98	Hwy10	HBwy20	Air98	Air10	Air20	Water98	Water10	Water20
05	06	4800	5772	5930	01	0	0	0	0	0	0	0	0	0
05	08	10277	11997	12115	01	0	0	0	0	0	0	0	0	0
05	16	23357	26638	26553	01	0	0	0	0	0	0	0	0	0
05	20	10692	12413	11788	01	0	0	0	0	0	0	0	0	0
05	22	62824	74117	71983	01	0	0	0	0	0	0	0	0	0
05	40	14725	17049	16464	01	0	0	0	0	0	0	0	0	0
05	41	16094	16962	16378	01	0	0	0	0	0	0	0	0	0
05	48	247701	289184	282103	01	0	0	0	0	0	0	0	0	0
05	49	13804	15743	15693	01	0	0	0	0	0	0	0	0	0
05	53	24638	36318	47973	01	0	0	0	0	0	0	0	0	0
04	05	5976	8277	10027	01	0	0	0	0	0	0	0	0	0
04	04	14836	17820	19147	01	0	0	0	0	0	0	0	0	0
04	06	27200	32791	34666	01	0	0	0	0	0	0	0	0	0
04	17	75446	102671	111270	01	0	0	0	0	0	0	0	0	0
04	29	15514	16553	15144	01	0	0	0	0	0	0	0	0	0

Figure 5.3. Freight analysis framework domestic flows database in Microsoft Access.

operation, miles per gallon, operator classification, and hazardous materials transported. The sample also includes expansion factors for each record. VIUS uses product classes similar to the commodity classes used in the CFS or TRANSEARCH/FAF. It records the percentage of the miles that a truck carries certain products, equipment, materials, etc. "No Load" is treated by VIUS as a separate product category. The VIUS survey also includes buses and service trucks. Certain VIUS product categories, such as passengers carried, do not correspond to the freight model commodity classes. A correspondence between the VIUS product classes and the more common commodity classes can be easily developed based on the definition of each classification scheme.

The weighted annual mileage for each VIUS product carried distance class can be calculated for each record in a state database. That mileage can be multiplied by the average payload for that record to obtain the weighted annual pound-miles by product class. The weighted annual pound-miles and the weighted annual miles can be summed over all records by product class. The average payload for each commodity can be obtained by dividing the average annual pound-miles by the average annual miles. This payload does not include the percentage of mile that a truck travels while empty. This percentage by commodity also can be calculated from the VIUS "No Load" product class. The factor to be used to covert from annual tonnage to annual trucks could

Table 5.1. Contents of commodity flow datasets.

Database	File Name	Content
Domestic Flows	Domestic	State-to-state flows By commodity By mode By year (1998, 2010, 2020)
International Flows	International	International flows (by state origin or destination) By commodity By mode By year (1998, 2010, 2020)
International Flows	International Air	International flows By air By year (1998, 2010, 2020) • By state origin or destination • Foreign shipments only • Domestic shipments only
International Flows	STCC13-Petro	International flows of crude petro/natural gas (by state origin or destination) By pipeline (other) By year (1998, 2010, 2020)

account for both the average payload and the percentage of empty trucks in each commodity.

The 1997 VIUS is available on CD-ROM from the U.S Census Bureau at http://www.census.gov/svsd/www/97vehinv.html.

Tons to Value

Converting tons per year to dollars shipped is useful in economic analysis or to account for forecasting methods that consider the value of the freight being shipped. These conversion factors can be obtained from the CFS.

Commodity Flow Survey

The 1997 CFS reports commodities by SCTG code and contains both value and tonnage data for each commodity by state. This information can be used to develop conversion tables of value per ton by SCTG commodity. Values by commodity by mode can be used to account for differences in the mix of commodities at the SCTG two-digit level by mode. This is useful when, for example, high value commodities that only can be identified at the SCTG three- or four-digit level move preferentially by air and distort the overall average calculations of value at the two-digit level. Table 5.2 shows the values from the

Table 5.2. Value per ton by commodity and mode for the state of California.

Area	California				
SCTG	Electronic and other electrical equipment and components and office equipment				
Characteristic	Value ($ million)		Tons (000)		Value per Ton ($)
Item	**Data**	**Symbol**	**Data**	**Symbol**	
Mode					
All modes	$ 206,731	–	5,057	–	$ 40,880
Single modes	$ 132,620	–	4,274	–	$ 31,029
Truck	$ 109,862	–	4,050	–	$ 27,126
• For-hire truck	$ 78,259	–	2,796	–	$ 27,990
• Private truck	$ 29,664	–	1,129	–	$ 26,275
Rail	$ 414	–	–	2	
Water	$ 53	–	–	2	
• Shallow draft	–	2	–	2	
• Great Lakes	–	1	–	1	
• Deep draft	$ 53	–	–	2	
Air (includes truck and air)	$ 22,291	–	148	–	$ 150,615
Pipeline	–	2	–	2	
Multiple modes	$ 57,088	–	396	–	$ 144,162
Parcel, U.S. Postal Service or courier	$ 56,595	–	383	–	$ 147,768
Truck and rail	–	2	–	2	
Truck and water	–	2	–	2	
Rail and water	–	1	–	1	
Other multiple modes	–	1	–	1	
Other and unknown modes	$ 17,023	–	387	–	$ 43,987

Note: A symbol of 1 represents zero or less than one unit of measure.

A symbol of 2 represents data that does not meet publication standards due to high sampling variability or other reasons.

CFS that can be produced for electronics and electrical equipment, using the table for California. The average value per ton for all modes is about $41,000, based on an average of goods moving by land with values of approximately $27,000 per ton and goods of the same commodity moving by air with a value of approximately $151,000 per ton. Table 5.2 also shows that for many modes the data are not reported because the small sample size produces unreliable results.

The 1997 CFS is available on CD-ROM from the U.S. Census Bureau at http://www.census.gov/econ/www/cfsmain.html.

5.3 Network Data

Modeling truck freight movements requires the use of networks with physical information about the highway network links. The network used in assigning freight flows must account for characteristics such as segment capacity, volume, free flow speed, and travel time. Networks exist for other modes (rail, air, water), but typically do not include information to allow the calculation of congestion and route choice in the same fashion as truck/highway networks. Many freight shipments use more than one mode in a trip, and data on the intermodal terminals where freight can change modes also are required.

Modal Networks

National modal networks are needed in statewide freight forecasting, particularly for non-highway modes and for highway networks for areas of the United States beyond the area covered by a statewide model. The Bureau of Transportation Statistics provides attribute information for waterway and railroad networks, although this information is not compatible with conventional travel demand modeling software. The Oak Ridge National Laboratory has created a multimodal network to determine distances and routes for the CFS. However, Oak Ridge uses special software that other agencies may find difficult to use. A comprehensive source of network data can be created by matching the network of the National Highway Planning Network (NHPN) Geographic Information Systems (GIS) shapefile with the attribute data from the Highway Performance Monitoring System (HPMS) Data collected by each state. This task already was undertaken by the FAF and is described below.

Freight Analysis Framework Highway Capacity Database

The FAF road network leverages existing Federal road inventories that contain, or can be linked to, HPMS data. After analyzing data availability, the Federal Highway Administration (FHWA) developed the network as a subset of the NHPN, version 3.

The FAF highway network not only includes FAF truck counts, but passenger automobile counts and non-FAF truck counts. Data was obtained from traffic databases in HPMS and other state sources. After integrating the data sources, the FAF network was converted to TransCAD, a proprietary travel demand model software package. TransCAD allows the assignment of daily freight truck trips to routes using standard network assignment techniques. The end result was the completed FAF highway network database containing traffic volume, capacities, speeds, locations, and travel times for each road segment.

The Highway Capacity Dataset contains estimated truck volumes and system capacities for each road segment on the FAF network, obtained through freight demand analysis. The 1998 freight volume data are included, as well as forecasts for 2010 and 2020. Volume is provided for FAF trucks, non-FAF trucks, and general traffic. The non-FAF trucks were calculated by subtracting model-assigned trucks from observed truck counts. Both automobiles and non-FAF trucks were treated as preloaded volumes that contribute to highway congestion in the FAF route assignment model.

Additional attributes such as volume/capacity ratio, delay, and derived speed also are included. The data files are available in either TransCAD or ESRI GIS format, with all the querying and mapping capabilities of these two programs. The Federal Highway Administration also provides a data dictionary for use in understanding abbreviated column headings in the dataset.

One layer of the High-Capacity Dataset contains information on the FAF highway network, linked to information on each road segment. Figure 5.4 shows the GIS representation of U.S. highways on the FAF network.

Each road segment is described using up to 17 attributes. These attributes include length in miles, state and county identifiers, signs, road name, function class, status, National Highway System (NHS) designation, and rural code. In a separate file, the Highway Capacity Dataset contains freight flow data that can be overlaid on the FAF highway network maps. Using GIS software, a user can then identify segments with specified levels of congestion, delay, or capacity. Besides road characteristics, the freight volume data contained in this file includes annual average daily traffic, FAF/non-FAF trucks, speed, delay, flow, and capacity for both low and high growth estimates in 1998, 2010, and 2020.

The FAF Highway Capacity Database is available from the FHWA at http://ops.fhwa.dot.gov/freight/freight_analysis/faf.

Figure 5.4. Freight Analysis Framework highway network.

Intermodal Terminals

Intermodal terminals are facilities for transferring freight from one mode, such as truck, to another mode, such as rail. Knowing the location of these terminals is important when assigning a complete freight shipment from an initial origin to its ultimate destination. It also is important in forecasting the behavior of freight since freight is neither produced nor consumed at these terminals but merely transshipped. The Bureau of Transportation Statistics provides data on the location and attributes of these intermodal terminals, including the type of commodity handled. While intermodal freight is often considered freight moving in sealed containers, the intermodal terminals include all facilities where freight – including bulk shipments – changes modes.

Bureau of Transportation Statistics Intermodal Terminals

The Bureau of Transportation Statistics Intermodal Terminal Facilities data set contains geographic data for freight transfer facilities in the United States. Attribute data includes the modes serving the facility, the name of the railroad (if any) serving the facility, the type of cargo, and the direction of the transfer. The database provides location and attribute information for use in national and regional network analysis applications. Attribute data are extracted from a variety of railroad and port carriers operators and associations. Data reflects conditions at facilities in 1995-1996 and is subject to frequent change. Some facilities may be dormant or permanently closed.

The intermodal terminal database is available from the Bureau of Transportation Statistics Mapping Center at http://www.transtats.bts.gov/mappingcenter.asp.

National Transportation Atlas Database (NTAD)

The National Transportation Atlas Database (NTAD) is a collection of GIS data layers in 1:1,000,000 scale developed by the U.S. Department of Transportation and other Federal agencies. The NTAD is available from the Bureau of Transportation Statistics Mapping Center at http://www.transtats.bts.gov/mappingcenter.asp.

5.4 Forecasting Data

Population

Population data used in freight forecasting is typically used in traditional transportation forecasting. This includes both a base and a forecast horizon year or years for a variety of TAZ. For areas outside of the state study area, population data can be obtained from the U.S. Census Bureau, which typically is the basis for base year passenger transportation forecasting. Forecasts of national population only are available through commercial vendors.

Employment

While employment data are typically used in passenger transportation forecasting, the level of industry detail is insufficient for freight forecasting. Industry information is developed from mandatory quarterly ES-220 submittals by employers to state employment security agencies and used by the U.S. Bureau of Labor to compute unemployment statistics. However processed, the data released to the public is aggregated to suppress confidential information. That data, available from the Census Bureau's County Business Patterns, is described below. More geographic detail is available from private vendors such as Dun & Bradstreet, InfoUSA, Wood & Poole, and IMPLAN. These vendors also provide employment data in the more commonly used SIC system and provide forecasts not available from public agencies.

County Business Patterns

County Business Patterns is an annual series published by the U.S. Census Bureau that provides subnational economic data by industry. The series is useful for studying the economic activity of small areas, analyzing economic changes over time, and providing a benchmark for statistical series, surveys, and databases between economic censuses. Businesses use the data for analyzing market potential, measuring the effectiveness of sales and advertising programs, setting sales quotas, and developing budgets. Government agencies use the data for administration and planning.

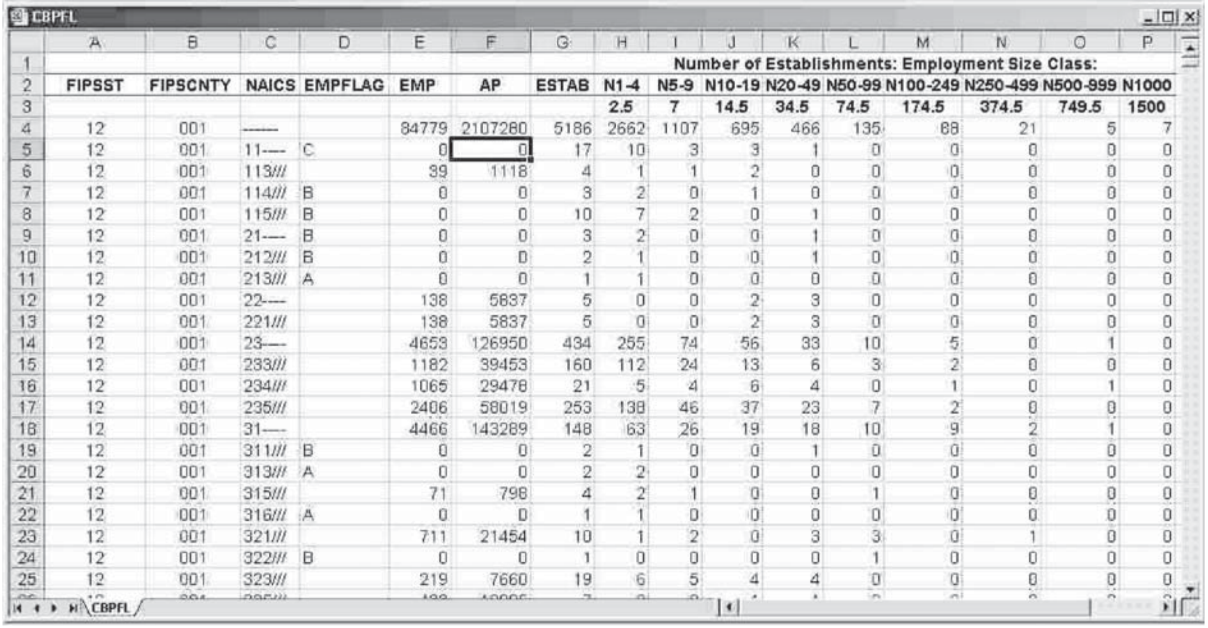
County Business Patterns covers most economic activity in the United States. The series excludes data on self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. Beginning in 1998, data was tabulated by industry as defined in the NAICS. Data for 1997 and earlier years is based on SIC codes, described in Section 5.6. As shown in Figure 5.5, the County Business Patterns data are available for all counties by three-digit NAICS code. Typically freight forecasting models need only two-digit data. Additionally where industrial employment is not available for a given county, it may be possible to estimate that data from the establishments in the employment ranges. For example, as shown in Figure 5.5, the employment data for industry 113 in County 12001 is suppressed but might be estimated at 2.5 employees from the one firm with one to five employees, seven employees from the one firm with five to nine employees, 14.5 employees from each of the two firms with 10 to 19 employees. This estimated total of 38.5 employees (2.5 + 7 + 14.5 + 14.5) agrees closely with the reported total of 39 employees. Since the County Business Patterns data are typically applied to already available TAZ data at a more aggregated scale, the resulting percentages by detailed industry are generally suitable for forecasting.

County Business Patterns data are available from the U.S Census Bureau at http://www.census.gov/epcd/cbp/view/cbpview.html.

5.5 Validation Data

In most cases validation data for freight forecasting is limited to observed trucks, which include both freight and nonfreight purposes. Thus, truck classification counts and weight and motion counts prepared by states can be used in validating the truck portion of freight models only in combination with a multi-class assignment of all vehicles.

Tolled facilities with electronic data collection mechanisms also can provide a way to validate freight forecasts, since trucks could theoretically be tracked on an individual basis and extensive data about truck movements (including entry-exit points) might be available. This type of data has been used to validate truck models on a study-by-study basis but is rarely used to validate a statewide model because tolled highways



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1								Number of Establishments: Employment Size Class:								
2	FIPSST	FIPSCNTY	NAICS	EMPFLAG	EMP	AP	ESTAB	N1-4	N5-9	N10-19	N20-49	N50-99	N100-249	N250-499	N500-999	N1000
3								2.5	7	14.5	34.5	74.5	174.5	374.5	749.5	1500
4	12	001	------		84779	2107280	5186	2662	1107	695	466	135	68	21	5	7
5	12	001	11----	C	0	0	17	10	3	3	1	0	0	0	0	0
6	12	001	113///		39	1118	4	1	1	2	0	0	0	0	0	0
7	12	001	114///	B	0	0	3	2	0	1	0	0	0	0	0	0
8	12	001	115///	B	0	0	10	7	2	0	1	0	0	0	0	0
9	12	001	21----	B	0	0	3	2	0	0	1	0	0	0	0	0
10	12	001	212///	B	0	0	2	1	0	0	1	0	0	0	0	0
11	12	001	213///	A	0	0	1	1	0	0	0	0	0	0	0	0
12	12	001	22----		138	5837	5	0	0	2	3	0	0	0	0	0
13	12	001	221///		138	5837	5	0	0	2	3	0	0	0	0	0
14	12	001	23----		4653	126950	434	255	74	56	33	10	5	0	1	0
15	12	001	233///		1182	39453	160	112	24	13	6	3	2	0	0	0
16	12	001	234///		1065	29478	21	5	4	6	4	0	1	0	1	0
17	12	001	235///		2406	58019	253	138	46	37	23	7	2	0	0	0
18	12	001	31----		4466	143289	148	63	26	19	18	10	9	2	1	0
19	12	001	311///	B	0	0	2	1	0	0	1	0	0	0	0	0
20	12	001	313///	A	0	0	2	2	0	0	0	0	0	0	0	0
21	12	001	315///		71	798	4	2	1	0	0	1	0	0	0	0
22	12	001	316///	A	0	0	1	1	0	0	0	0	0	0	0	0
23	12	001	321///		711	21454	10	1	2	0	3	3	0	1	0	0
24	12	001	322///	B	0	0	1	0	0	0	0	1	0	0	0	0
25	12	001	323///		219	7660	19	6	5	4	4	0	0	0	0	0

Figure 5.5. County business patterns employment data.

constitute a small percentage of the statewide highway network.

Some components of freight models are typically not validated since the only data available was used to develop the model and no independent data are available for validation.

For some industries it may be possible to find alternate information on production, and sometimes consumption for a particular market. Specific state agencies, such as agriculture, mining, or forestry departments, may maintain annual production information, particularly for sectors of the economy with significant levels of activity within the State. Industry-specific trade associations also may compile this type of information. However, in many instances these agencies will disseminate statistical information that comes from Federal government sources, or the other primary sources commonly used in freight forecasting and modeling.

5.6 Classification Schemes

The data sources used in freight forecasting report on shipments by commodity and their associated industries using different classification schemes. Understanding these schemes is necessary to properly utilize the data. Additionally, some models may require the use of multiple data sources based on different classification schemes. Understanding the relationships between the alternate coding systems is essential to properly integrate the information.

Commodity Classification

There are two primary commodity classification schemes. Prior to the 1997 CFS , U.S. freight data was collected and reported using the STCC code. This classification code was developed in the early 1960s by the American Association of Railroads to analyze commodity movements by rail. It also is the reporting system that continues to be used in the STB's *Carload Waybill Sample*. The United States and Canada have adopted the SCTG and this system was used in reporting the 1997 and subsequent CFSs. SCTG is similar to the Harmonized Schedule classification, which is the predominant product coding system currently in use worldwide. However much of the available commercial freight economic data are available using the older STCC codes.

STCC codes are numerical codes that group similar products, and the codes are arranged in a very structured, hierarchical manner. The first digit identifies a major Economic Division, such as 2-Nondurable manufacturing. The second digit identifies an Economic Major Group, such as 20-Food and kindred spirits. The third digit identifies an Industry Group, such as 202-Dairy products. The fourth digit identifies a Specific Industry, such as 2024 Ice Cream and Frozen Desserts. Additional detail is provided through up to seven digits, although this level of detail is primarily used by the carriers in setting rates and little volume information is available at this level. The STCC system also is compatible with the SIC industrial classification system discussed below, while the SCTG is not completely consistent with the SIC or the NAICS.

A correspondence table between the STCC and SCTG systems, at the two-digit level, is shown in Appendix A. At this hierarchical level there is considerable overlap between the two systems.

Industry Classification

Industry classifications are similar to commodity classifications. Historically, the United States has reported economic industry data using the SIC. SIC has being replaced with the new NAICS.

SIC codes are numerical codes that group companies that produce similar products or services. SIC codes are arranged in a very structured, hierarchical manner. The first digit identifies a major Economic Division, such as 2-Nondurable manufacturing. The second digit identifies an Economic Major Group, such as 20-Food and kindred spirits. The third digit identifies an Industry Group, such as 202-Dairy products. The fourth digit identifies a Specific Industry, such as 2024 Ice Cream and Frozen Desserts.

The United States has started collecting data using the NAICS codes. While similar in approach, the NAICS codes cover a much wider variety of industries, technologies, products and services, particularly new, emerging, and advanced technology industries. NAICS reorganizes industries into categories that reflect the service-oriented economy. The NAICS codes are detailed up to six digits. The correspondence between the SIC and NAICS codes exists only at the four-digit SIC and six-digit NAICS level. The NAICS is a joint effort of the United States, Canada, and Mexico and will make it easier to compare U.S. industrial statistics with economic data from other countries.

The SIC hierarchical structure matched that of the STCC commodity classification system, making it easy to compare between industrial activity and commodity shipment. Since the NAICS was only introduced in 1997, historical data in that system is lacking. While U.S. government information is only available in the NAICS, many private users of industry and employment data, particularly private data providers still use the SIC system. A correspondence table between the SIC and NAISC systems, at primarily the two-digit level, is shown in Appendix A. The exception is in NAICS categories 31-33 Manufacturing, 44-45 Retail Trade, and 48-49 Transportation and Warehousing which are distinguished only at the three-digit level. At this hierarchical level there is considerable overlap between the two systems.

CHAPTER 6

Forecasting Models

This Toolkit focuses on the five model classes for statewide freight forecasting listed in Section 4.0: the flow factoring method, the O-D factoring method, the truck model, the four-step commodity model, and the economic activity model. These model classes share many of the same components, differing from each other primarily in their organization and use of these components. The key differences between the five classes also are described in this section.

6.1 The Direct Facility Flow Factoring Method

Description

As shown in Figure 6.1, the direct facility flow factoring method provides freight volumes on transportation system links such as roads, railroad tracks, and ports. The method requires information about the facility itself and some forecasts of the factors affecting the facility.

Although flow factoring is often used in individual project planning, it neither provides overall system forecasts nor considers many factors important in freight forecasting. However, the method may be appropriate for developing forecasts for special generators, such as ports, within a more complex model.

The facility flow factoring method is used to rapidly apply existing data to determine one or several forecast volumes. Usually, the method is intended for short-term forecasts; many assumptions are needed to make it work effectively and its range of applicability is limited. Flow factoring is relatively simple, however, and commonly used by state departments of transportation across the United States. The method can be divided into two general classes: one that produces future estimates of flow on a facility based on applying growth factors to the flow on that facility, and one that produces estimates of flow on a facility based on applying factors that account for the diversion of flow from that facility to other routes or modes.

The flow factoring method relies on regression equations, which may be based on two methods: time series analysis and economic analysis. Time series analysis involves an examination of the historic flows on a transportation facility, with only time as an indicator variable. Economic analysis uses economic variables as indicator variables to explain the historical facility flows. Both methods are described below.

Time Series Analysis

Time series analysis is a means of understanding data variability over time. Because a time series model exclusively represents past events and relationships, it can be used to forecast the future as long as the future is expected to behave like the past. Time series analysis is particularly appropriate when the forecast is short term and insufficient time and resources exist to build and calibrate a behavioral model. Time series models can be used for modal, policy, and data considerations.

A simple time series analysis fits a straight line to a series of annual observations of freight flows, such as annual tons shipped through a port. Many statistical software packages, such as SAS or SPSS, or even spreadsheet programs such as Microsoft Excel have regression features to develop equations that can be used to forecast future freight flows based on the observed data.

Economic Analysis

Economic analysis can be used to forecast changes in freight demand due to changes in the level of economic activity or related factors. Forecasting based on growth in economic factors is useful because it recognizes the fact that demand for freight transportation is derived from underlying economic activities. The economic analysis method relies on

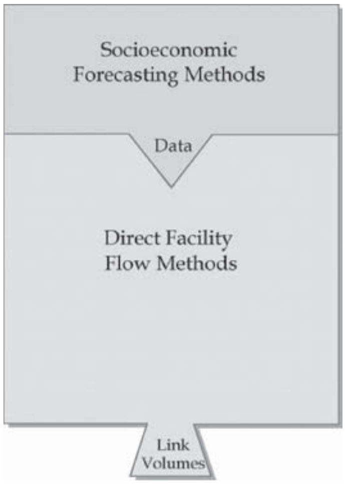


Figure 6.1. The flow factoring method.

forecasts of changes in economic variables to estimate the corresponding changes in freight traffic.

To simplify the approach for deriving forecasts of future freight traffic from economic forecasts, the demand for transport of a specific commodity is assumed to be directly proportional to an economic indicator variable that measures output or demand for the commodity. Consequently, growth factors for economic indicator variables, which represent the ratios of their forecast year values to base year values, can be used as the growth factors for freight traffic.

Economic Analysis Process

Economic analysis requires data or estimates of freight traffic by commodity type for a reasonably normal base year, as well as base year and forecast year values for the corresponding economic indicator variables. The basic steps involved in the process are as follows:

1. Select the commodity or industry groups that will be used in the analysis. This choice is usually dictated by the availability of forecasts of economic indicator variables. Much of the available forecasts are by SIC code.
2. Obtain or estimate the distribution of base year freight traffic by commodity or industry group. If actual data on the distribution are not available, state or national sources may be used to estimate this distribution. For example, the U.S. Census Bureau's VIUS provides information on the distribution of truck vehicle-miles traveled by commodity carried and industry group.
3. Determine the annual growth factor (AGF) for each commodity or industry group as follows:

   $$\mathrm{AGF} = (I_2/I_1)^{1/(\mathrm{Y2}-\mathrm{Y1})}$$

   where I_1 is the value of the economic indicator in year Y1 and I_2 is the value of the economic indicator in year Y2.
4. Using the annual growth factor and base year traffic, calculate forecast year traffic for each commodity or industry groups as follows:

   $$T_f = T_b\,\mathrm{AGF}^n$$

   where n is the number of years in the forecast period.
5. Aggregate the forecasts across commodity or industry groups to produce the forecast of total freight demand.

The most desirable indicator variables are those that measure goods output or demand in physical units (tons, cubic feet, etc.). However, forecasts of such variables frequently are not available. More commonly available are constant-dollar measures of output or demand, employment, or, for certain commodity groups, population or real personal income. The following subsection describes the data sources for forecasts of some of these economic indicator variables.

Data Sources of Economic Forecasts

Analysts at state departments of transportation, MPOs, and other planning agencies may use several sources to obtain estimates of growth in economic activity, by geographic area and industry or commodity type.

Many states fund research groups that monitor the state's economy and forecast changes. For example, the Center for the Continuing Study of the California Economy develops 20-year forecasts of the value of California products by two-digit SIC code. The Texas Comptroller of Public Accounts develops 20-year forecasts of population for 10 substate regions and 20-year forecasts of output and employment by one-digit SIC code and substate region. A private firm produces 20-year forecasts of output and employment in Texas by three-digit SIC code.

Long-term economic forecasts also are available from two Federal agencies. At two-and-one-half-year intervals, the Bureau of Labor Statistics (BLS) publishes low, medium, and high 12- to 15-year forecasts of several economic variables – including real domestic output, real exports and imports, and employment – for each of 226 sectors generally corresponding to groups of three-digit SIC industries. Also, at five-year intervals, the Bureau of Economic Analysis (BEA) develops 50-year regional projections of population and personal income as well as employment and earnings by industry sector. The BEA forecasts are published by state for 57 industries, and by metropolitan statistical area and BEA economic area for 14 industry groups.

Short- and long-term economic forecasts are available from several private sources as well. The private firms use government and industry data to develop their own models and analyses. One of the better known firms is Global Insights, formerly DRI/WEFA. Global Insights provides national, regional, state, Metropolitan Statistical Area (MSA), and county-level macroeconomic forecasts on a contract or subscription basis. Variables forecast include gross domestic product, employment, imports, exports, and interest rates. Global Insights also produces short-term (two-and-one-half to three-year) and long-term (20- to 25-year) industrial input and output forecasts for 250 industries (two-, three-, or four-digit SIC code). Industrial inputs include employment, energy, and materials used in production. These input/output forecasts are updated semiannually. Price and wage indices also are forecast for 650 different industries.

Case Studies and References

Two case studies demonstrate the truck model: the Minnesota Trunk Highway 10 Truck Trip Forecasting Model and the Heavy Truck Freight Model for Florida Ports. These are described in Sections 8.2 and 8.3, respectively.

The *Guidebook on Statewide Travel Forecasting* discusses time series methods for direct forecasts of vehicular volumes on highway and for forecasting the inputs to four-step models.[5] Major emphasis is on ARIMA models and on growth factor methods. Examples are primarily for passenger car forecasting, but the methods are equally applicable to truck forecasting. The Guidebook also describes a linear regression model to forecast truck volumes on I-40 in New Mexico. Commercial truck traffic was found to be a linear function of the year, the U.S. disposable income, U.S. gasoline costs, and the New Mexico cost of residential construction.

6.2 The Origin-Destination Factoring Method

Description

As shown in Figure 6.2, the O-D factoring method can use the conventional mode split and assignment model components. The O-D factoring method uses an existing and factored O-D table of freight as input to mode split and assignment, rather than a table prepared by trip generation and trip distribution model components.

The acquisition and factoring of commodity O-D tables is widespread. States and the FAF have generally used Reebie Associates' TRANSEARCH database as the source O-D table. While some efforts have been made to use an O-D Matrix Estimation process, the required observations on links of exclusively freight vehicles are rare and the tables produced by this method are usually exclusively based on truck counts that include freight and nonfreight trucks. The Bureau of Transportation Statistics' CFS, while available publicly, does not provide geography below the BEA's Economic Areas, which are insufficiently detailed for statewide freight forecasting. Based on certain economic indicators, some states have successfully disaggregated Commodity Flow Survey data to the county level, but this process is costly and time consuming. By using the TRANSEARCH database and its routing options, states can develop freight network assignments even in the absence of an existing state model network. This is particularly useful given the lack of rail assignment models.

Growth rates applied to the existing O-D tables can be based on economic, employment, or other indicators of growth at the zonal level and are often developed by using

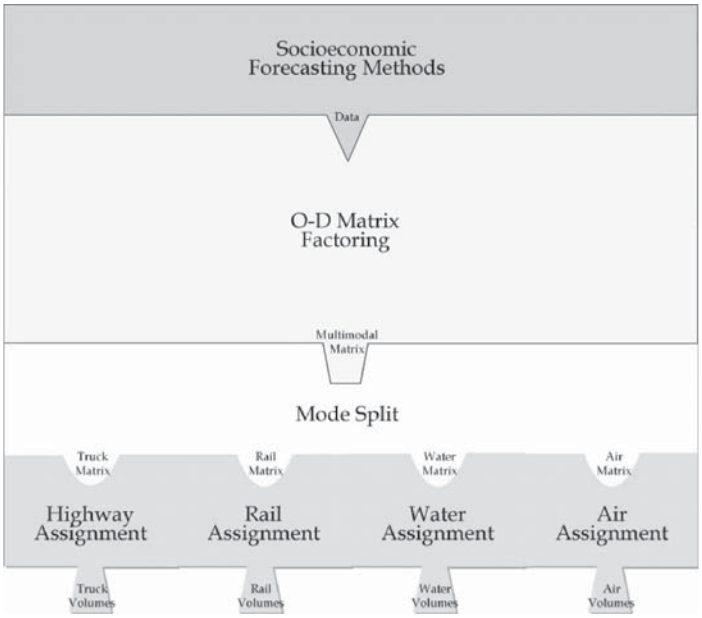


Figure 6.2. The original destination factoring method.

simple economic models. These zonal growth factors are usually applied to tables through an iterative proportional fitting technique that balances production and attraction growth rates. This technique, known as "Fratar factoring," is usually available in travel demand model packages (TP+, EMME/2, TransCAD). Many states and the FAF have purchased freight forecasts directly from consultants who produce the economic forecast and also update the O-D commodity tables. In most applications different growth factors are applied for each commodity.

The choice of mode split depends on the availability of variables. Because mode split is usually most pronounced for distances over 500 miles, a source of impedances outside the state is needed. If a national network is used, the utility of travel between zones, such as times and costs, can be obtained from the model. Otherwise the national utilities must be acquired from other sources.

The network assignment component depends on the availability of other data and is not limited by the O-D factoring models. O-D factoring models can always use a rules-based assignment component, depending on the ability to convert a tonnage table to truck trips. They can also use a modal network assignment process that either excludes other automobile or nonfreight traffic or recognizes this traffic only as preloaded volumes. Depending on the availability of complete auto and nonfreight truck trip tables within a complete statewide model, the commodity freight trucks can be assigned simultaneously with these other tables to allow the analysis of congestion.

Obtaining a Current O-D Freight Table

In order to factor an O-D table of freight flows, there must be an existing table of freight flows. There are three means of obtaining existing freight O-D tables:

- Acquire a trip table from a public or commercial source;
- Develop a trip table from a survey of freight shippers, receivers, and/or carriers; or
- Estimate a trip table from observed freight flows.

In practice, acquiring a trip table from public sources, such as the CFS, or from private sources, such as TRANSEARCH, are the most practical options.

Given the diversity of geographic and commodity coverage, the cost for a state to conduct sufficient surveys to develop a statistically reliable and sufficiently detailed O-D table would be prohibitive. Such surveys more often are conducted to develop the parameters in other model steps.

Estimating a trip table from observed freight flows involves the use of O-D Matrix Estimation techniques.[10] The observed freight flows in most applications are truck volumes. Truck volumes rarely provide information on the contents of the truck or purpose of its trip. Only in instances in which 1) all trucks can be assumed to be carrying freight, and 2) a breakdown by commodity is not desired can the method be used. In urban and suburban areas, freight trucks are only a portion of all observed trucks. According to the Federal Highway Administration's FAF web site, the freight truck percentage of VMT varies from 1% to 6% by urban area, and the total truck percentage (including nonfreight trucks) ranges from 5% to 18% by urban area.[11]

Due to the limitations of surveys and Origin Destination Matrix Estimation techniques, most statewide O-D factoring methods acquire existing trip tables from public or private sources.

Factoring the O-D Freight Table

The existing O-D freight trip table can be assigned to transportation networks to produce estimates of existing facility flows. To produce future flows it is necessary to factor the table to obtain an estimate of O-D freight flows in a future year. The factoring of O-D tables through an Iterative Proportional Fitting or Fratar process is an established practice in transportation planning. In this class of models the difference is the source of the growth factors and the party that does the factoring.

A state transportation agency that has obtained economic growth factors that apply to specific industry or commodity origins and destinations may choose to factor the table itself. However, an agency that has obtained the factors from an economic model provided by a private firm may find it advantageous for that firm to factor the table as part of the economic model.

Common Model Components

Mode Split

The O-D freight table can be processed by a mode split equation as described in Section 4.4. If network information is available to provide utilities for movement between origins and destination by mode, and the coefficients of a sophisticated mode split model have been developed or transferred from another setting, then that mode split model can be used as part of the O-D factoring class of models.

Network Assignment

The assignment of a trip table in an O-D factoring model can use a variety of options as described in Section 4.5. Rail, water, and air assignments typically follow the rules-based assignment process. The assignment of truck freight depends on the availability of a highway network model from other sources. If no statewide highway network or other vehicle trip tables are available from a statewide travel demand model or other source, a rules-based assignment model is used. If a highway network is available or can be developed, a freight truck only assignment can be used. If a highway network and other vehicle trip tables are available, a multiclass assignment can be used.

Case Studies and References

Two case studies demonstrate the O-D factoring method: the Ohio Freight Model Case Study and the Freight Analysis Framework Case Study. These are described in Sections 8.4 and 8.5, respectively.

Oklahoma Model – This model and forecast system were developed in 2000 by TranSystems Corporation. It is a conventional model based on Reebie TRANSEARCH data.

Kentucky Corridor Model – This model was developed in 1997 by Wilbur Smith Associates.[12] The network and base data were updated in 2001 by Wilbur Smith, without changing the model methodology.[13]

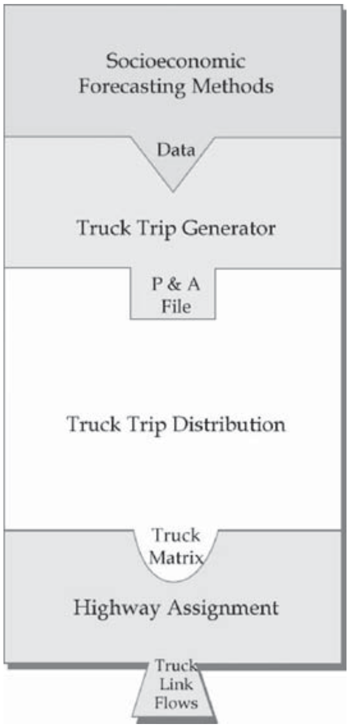


Figure 6.3. The truck model.

6.3 The Truck Model

Description

As shown in Figure 6.3, truck models use the trip generation and distribution model components to produce a table of truck trips and uses assignment model components to assign that table of truck trips. As truck models address only the single mode of trucks, they do not require a mode split component.

Truck models usually attempt to account for all shipments of goods, including local delivery. Freight truck volumes, as freight is defined in most data sources such as the CFS and TRANSEARCH, dominate in rural areas between distant cities. Truck models that include local delivery are more useful for states with closely spaced or contiguous urban areas. For this reason, the sole example of a state truck model identified for inclusion in this Toolkit was developed for New Jersey, the most densely populated state in the nation. However the nation's largest metropolitan planning organization, the Southern California Association of Governments, is included as an example of a statewide truck model because it uses the same techniques and the region's geographic and population size is greater than that of many states. Truck models are more commonly a component of urban travel forecasting models.

Truck models obviously cannot analyze shifts between modes, since by definition they include only the truck freight mode. They are usually part of a comprehensive model which forecasts both passenger and goods movement and consequently use a simultaneous assignment of truck trips with automobile trips.

Truck models follow a three-step process of trip generation, trip distribution, and traffic assignment. The truck types often considered in a truck model are broadly classified into light, medium, and heavy trucks based on gross vehicle weight (GVW) ratings. Although weight-based, these classifications are loosely correlated to other defining characteristics of trucks, which are described in the *Quick Response Freight Manual*.[3]

- **Light trucks** are defined as vehicles with four or more tires and two axles, with a GVW of less than 16,000 pounds.
- **Medium trucks** are defined as single-unit vehicles with six or more tires and two to four axles, with a GVW of 16,000 to 52,000 pounds.
- **Heavy trucks** are defined as double-unit, triple-unit, or combination vehicles with five or more axles, with a GVW greater than 52,000 pounds.

Using these definitions, medium trucks directly correlate to single-unit trucks collected in truck surveys and heavy trucks directly correlate to double- and triple-unit trucks. The truck counts do not usually separate light trucks from passenger cars and are sometimes estimated as part of passenger vehicle travel.

Common Model Components

Trip Generation

Trip generation components will produce daily truck productions and attractions using equations whose coefficients were developed based on local surveys or using parameters borrowed from other sources such as the *Quick Response Freight Manual.* Trip distribution is accomplished using a gravity model that recognizes that the friction factors from internal-internal and external-internal/external-internal trips will vary, reflecting the difference in average trip length between these types of trips. External-external trips are established based on surveys and factored independently.

Trip Distribution

In truck models, the trip distribution component follows the process described in Section 4.3. The geographic scope of the model area typically requires that external trips be distributed differently than internal-internal trips. Light, medium, and heavy trucks are distributed from origins to destinations using the gravity model technique. This is the same distribution method used in any typical auto passenger model. The friction factors in the gravity model can be developed from surveys or borrowed from other sources such as the *Quick Response Freight Manual*.

Network Assignment

Network assignment of the truck trips is based on the multiclass equilibrium highway assignment described in Section 4.5. Multiclass assignment is possible because truck models almost always are used as part of a complete travel demand forecasting process.

Case Studies

Two case studies demonstrate the truck model: the New Jersey Truck Model Case Study and the SCAG Heavy Duty Truck Model Case Study. These are described in Sections 8.6 and 8.7, respectively.

6.4 The Four-Step Commodity Model

Description

As shown in Figure 6.4, the four-step commodity model most closely resembles the four-step urban travel demand model for passengers; both use the trip generation, trip distribution, mode split, and assignment model components. The economic forecasts that serve as the basis for the four-step commodity model are not modified in response to the results of the model.

Four-step commodity models and the more familiar four-step passenger models both require the development of a statewide network and zone structure. If a statewide passenger model exists, it is often used to provide the zone and network structure within the state. Since trip distribution and mode split for freight typically involves average distances of hundreds of miles, a skeletal freight network is typically appended to that statewide highway network. While commodity models can

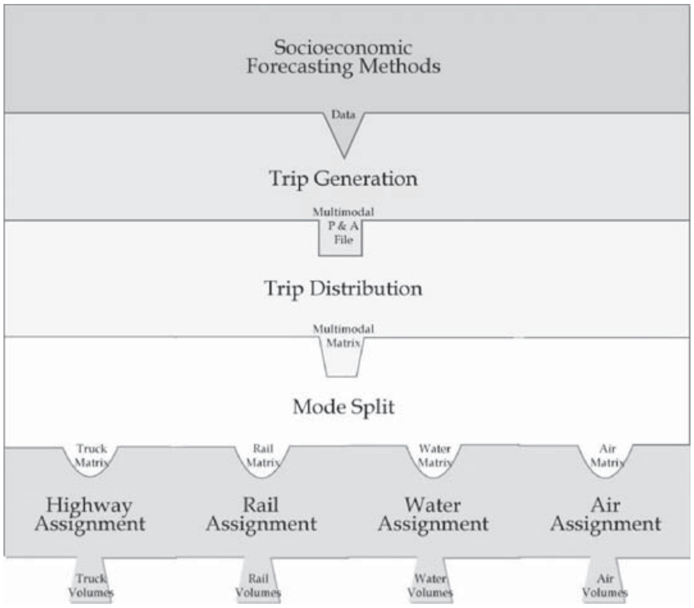


Figure 6.4. The four step commodity model.

analyze the impact of changes in employment, modal utility, trip patterns, and network infrastructure, they usually do not account for increases in labor productivity, or the interaction between industries. If the commodity model is integrated with highway passenger trip tables in assignment, the different routing procedures for large freight trucks can be accounted for by the use of passenger car equivalencies and separate volume-delay functions.

Common Model Components

Trip Generation

The four-step commodity model includes a set of annual or daily trip generation rates or equations by commodity providing annual or daily flows as functions of TAZ or county population and disaggregated employment data.

Trip Distribution

Four-step commodity models typically use gravity models for trip distribution. The commodity groups serve as trip purposes and are distributed separately. The unit of flow in the distribution table is typically annual tons shipped, independent of mode. The distribution of freight is to a national system of zones, recognizing the large average trip lengths that govern the development of friction factors.

Mode Split

Four-step commodity models may use any of the mode split models, developing highway modal utility information from their highway component and using this information to approximate the utilities by other modes even in the absence of other modal networks. Because developing mode split models for commodity models is very complex, a simple application of existing mode share or qualitative adjustments of mode shares using market segmentation or other approaches may be used. If a mode split model is developed, it typically uses an incremental or pivot point method to vary existing mode shares.

Commodity truck tonnage is converted to daily freight truck trips by applying payload factors. Commodity flow tonnage is converted to vehicles based on commodity-specific factors (tons per truck) developed from state-specific sources or from the national VIUS database. While conversion of rail freight to carloads is not commonly done, there are exceptions.

Network Assignment

There are a number of options for assigning a trip table. The rail, water, and air assignments typically follow the rules-based assignment process. The assignment of truck freight typically will use either a freight truck only or multiclass assignment model. Rules-based assignments typically are not used for freight trucks since a highway network must already be available to create the zone-to-zone impedances needed for trip distribution and mode split. If highway network is available or can be developed but there are no passenger vehicle tables, a freight truck only assignment can be used. If a highway network and other vehicle trip tables are available, a multiclass assignment can be used.

Case Studies and References

Two case studies demonstrate the truck model: the Florida Freight Model Case Study and the Indiana Freight Model Case Study. These are described in Sections 8.9 and 8.8, respectively.

The Wisconsin Freight Model is a four-step freight forecasting model. The purpose of the latest Wisconsin effort in freight forecasting was to determine the impact of new rail/truck intermodal facilities on highway truck volumes and on railroad tonnage.[14] The Wisconsin Department of Transportation principally used the method of factoring trip tables and traffic assignment to accomplish its impact analysis.

Cambridge Systematics developed a complete freight forecasting model as part of the Vermont Statewide Freight Study.[15] This model follows a variation of the classic four-step model.

6.5 The Economic Activity Model

Description

As shown in Figure 6.5, economic activity models use the trip generation, trip distribution, mode split, and assignment model components to produce freight forecasts for transportation facilities. The economic forecasts that serve as input to economic activity models are modified as a result of the performance determined by the model. Since the performance of the highway/truck freight system depends on the demand and usage of passenger autos, freight economic activity models are usually integrated with passenger forecasting models.

Economic activity models are the freight equivalent of integrated land use-transportation models used in urban passenger travel; both use an economic/land use model as a step before the traditional four steps. Economic activity models require special data concerning the availability of land and the rules governing the development and location of certain industries, and an understanding of the interdependencies of industries. This information is often unavailable to a state department of transportation, and is usually obtained in partnership with a state economic development agency that can explicitly account for changes in labor productivity.

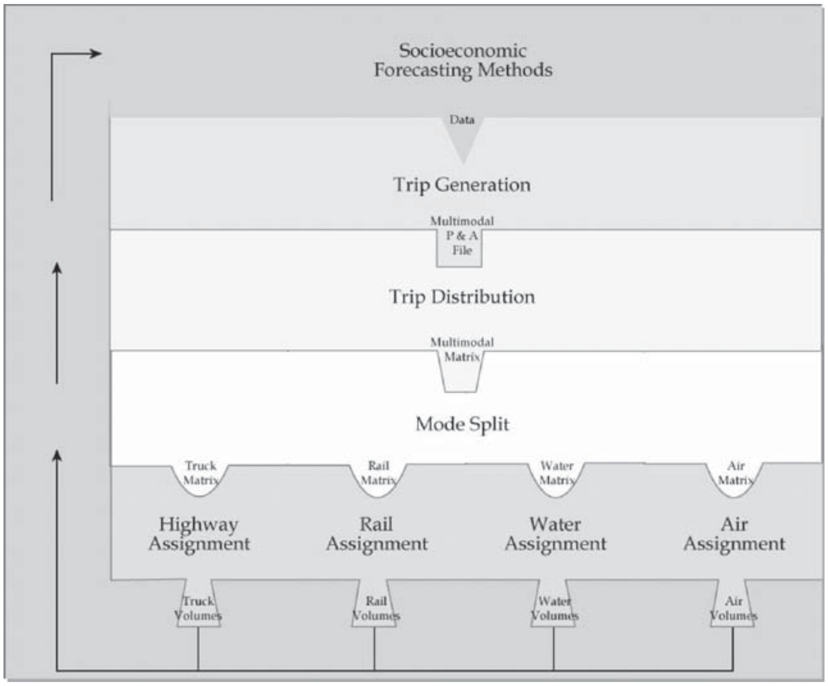


Figure 6.5. The economic activity model.

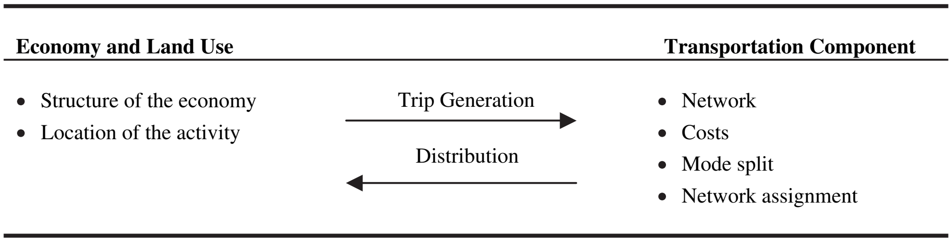


Figure 6.6. Integrated model interaction.

Economic activity models formulate the flows of commodities between economic sectors and between zones. The key assumptions in the economic activity models are that the zonal employment or economic activity is not directly supplied to the model but is created by applying an economic/land use model.

Economic activity models use a modeling technique known as a spatial I-O model. An I-O model distributes household and economic activity across zones, uses links and nodes of a transportation network to connect the zones and model the transportation system, and calculates transportation flows on the network. The spatial I-O model uses a land use component to generate and distribute trips and a transport component to generate mode split and network assignments. The two sides of the model inform each other, resulting in a dynamic model, as shown in Figure 6.6.

Economic activity models typically use an I-O structure to simulate economic transactions that generate transportation activity, identifying economic relationships between origins and destinations in the corridor. In future years, the spatial allocation of economic activity, and thus trip flows, is influenced by the attributes of the transport network in previous years. Thus, the model is dynamic both with respect to land use and transportation.

The economic activity class of models differs from the four-step commodity class of models in that the former uses an economic/land use model to forecast zonal employment or economic activity prior to the trip generation step and do not change those forecasts as a result of the forecast performance of the transportation facilities.

Case Studies

Two case studies demonstrate the truck model: the Oregon Economic Activity Model Case Study and the Cross-Cascades Economic Activity Model Case Study. These are described in Sections 8.11 and 8.10, respectively.

CHAPTER 7

Performance Measures

7.1 Introduction

Performance-based planning provides a consistent, repeatable, and transparent process for developing and selecting transportation projects and policies. This section presents a comprehensive list of freight performance measures and tools needed to address states' primary analytical and policy freight transportation needs. These needs, described in Section 3.0 and summarized in Table 7.1, were identified through telephone, Internet, and e-mail surveys targeted primarily to state departments of transportation. The table shows 15 primary analytical and policy areas, which were screened for forecastability and then further screened and matched according to appropriate tool components for calculating the measures. The performance measures were assembled from numerous current sources, then matched to the 15 analytical and policy areas.

Sections 7.2 and 7.3 list the freight performance measures that can be forecast and calculated using tool components from the toolbox. Section 7.2 also lists freight performance measures that cannot be forecast or calculated using the toolbox.

Section 7.3 matches the tool components to the performance measures. Section 7.4 presents an abbreviated, targeted list of measures for states to use to address their freight transportation analytical and policy needs, and describes each measure in detail.

7.2 Performance Measures for States' Primary Needs

Seven different state, Federal, and international sources were used to assemble a comprehensive list of freight-related performance measures:

- Cambridge Systematics, Inc. *National Transportation System Performance Measures Final Report.*U.S. Department of Transportation, Washington, D.C., April 1996.
- Cambridge Systematics, Inc. and David Evans and Associates. *ODOT Operations Program Performance Measures Draft Final Report.* Oregon Department of Transportation, June 2001.
- Cambridge Systematics, Inc. *NCHRP 446: A Guidebook for Performance-Based Transportation Planning. TRB, National Research Council,* Washington, D.C., 2000.
- *Performance Measures Summary.* Minnesota Department of Transportation, January 1999.
- Cambridge Systematics, Inc. *Texas Transportation Plan: Objectives and Outcome Measures.* PowerPoint presentation by Arlee Reno, April 13, 1999.
- Marbek Resource Consultants, Ltd. *How Jurisdictions are Measuring Performance of Transportation Policy and Planning.* Ministry of Transportation (Canada), October 16, 2001.
- *Measures, Markers and Mileposts: The Grey Notebook for the Quarter Ending June 30, 2002.* Washington State Department of Transportation, June 30, 2002.

The performance measures were first screened for forecastability. For example, future shipper satisfaction with modal or scheduling flexibility is not something that can be predicted with existing data and tools. Next, the measures were screened based on the available tools in the Toolkit. Thus, while freight dock availability could potentially be forecast if detailed data on a facility's current capacity and usage, as well as future demand, were available, there are currently no tools in the Toolkit to support such an analysis.

Table B.2 in Appendix B presents 55 freight-related performance measures that are forecastable and can be calculated using available tools. In addition, each of these measures addresses one or more of the freight transportation policy and analytical needs indicated by states. Italicized measures form a short list of recommended measures, and are explained in detail in Section 7.4. Tables 7.2 and 7.3 show performance measures in the context of policy needs and analytical needs, respectively.

Table 7.1. States' primary freight policy and analytical needs.

Need	Description
State Planning	State transportation planning including preparation of state multimodal transportation plans and/or freight plans.
Project Prioritization	Project prioritization, statewide transportation improvement plan development.
Modal Diversion	Modal diversion analysis.
Pavement and Safety	Pavement, bridge, and safety management.
Policy and Economic	Policy and economic studies for Governor, legislature, commission, etc.
Needs Analysis	Needs analysis.
Commodity Flow	Commodity flow analyses to understand the types, values, and economic importance of freight movement to, from, and within the state.
Rail Planning	Rail planning.
Trade and Border	Trade corridor and border planning.
Operational Needs	Operational needs.
Project Development	Project development or design needs, e.g., forecasts and loadings.
Terminal Access	Terminal access planning; forecasting truck loadings for highway access facilities to ports, other intermodal terminals, and grain or other heavy commodity terminals.
Truck Flows	Truck flow analysis and forecasting.
Performance Measurement	Performance measurement/program evaluation.
Bottlenecks	Bottleneck analysis.

Many more freight-related performance measures are available that are not easily forecastable or cannot be evaluated with the current available tools. However, if a state or agency is willing to collect extra data, build a new tool, or simply measure current performance, these additional measures could be useful. Table 7.4 presents these additional freight performance measures. Many of the measures evaluate very specific concerns, such as the number of docks at a port. Several others are measurements of people's opinions and perceptions.

7.3 Tools for Measuring Performance

Sections 4.0 and 6.0 provide detailed descriptions of five freight model classes and their various components. These classes and components are presented in Table 7.5. Section 4.0 also describes specific models currently being used in each class.

The most appropriate method of gathering data for input to the tools or of calculating performance measures is direct, continuous measurement of shipments, vehicles, or facilities (such as, vehicle travel time or average speed at a specific highway location). However, continuously collected data to develop freight performance measures are severely limited, at least currently. Monitoring individual vehicles and cargo on a large scale is problematic due to privacy concerns on the part of carriers and shippers as well as lack of standards for reporting. Roadway surveillance coverage is restricted primarily to urban areas, and the practice of archiving these data is not yet widespread. Therefore, while direct measurement and data collection are the desired goals, some degree of model application must be accepted if freight performance measures are to be enacted in the near term.

Appendix B presents the tool components required for generating data for each performance measure. Often, multiple tool components can be used for a single measure. For example, to calculate the "average cost per trip," one could potentially use the data from either the direct factoring of facility flows in a facility flow or O-D flow model, or from network assignment in an O-D flow, truck, four-step commodity flow, or economic activity model. For some performance measures, a tool component can only be used from a specific class of model. Though the mode split component can be found in O-D factoring, four-step commodity, and economic activity model classes, only mode split results from the four-step commodity class can be used to calculate "number of users of intermodal facilities." Italicized measures form a short list of recommended measures, and are explained in detail in Section 7.4.

7.4 Recommended Toolkit Performance Measures

The performance measures listed in Section 7.3 can all be calculated using tools available in the Toolkit and all address one or more of the states' analytical or policy concerns. This

Table 7.2. Policy needs and corresponding performance measures.

Policy Needs	Performance Measure
Modal Diversion	Average fuel consumption per trip for selected trips (or shipments). Fuel consumption per ton-mile traveled. Market share of international or regional trade by mode. Average cost per trip. Average shipment time, cost, variability in arrival time for freight shipments (local versus long distance, by commodity, by mode). Additional revenue earned by producers when shipping via rail. Average travel time from facility to destination (by mode).
Policy and Economic	Administrative, engineering and construction cost/ton-mile (owner cost). Economic indicator for goods movement. Freight transport system supply (route miles, capacity miles, number of carriers, number of ports/terminals) per "demand unit" (dollar of manufacturing output, ton-mile of commodity movement, capita, employee, etc.). Miles of freight routes with adequate capacity. Dollar losses due to freight delays. Mobility index (ton-miles of travel/vehicle-miles of travel times average speed).
Project Prioritization	Administrative, engineering and construction cost/ton-mile (owner cost).
Rail Planning	Delay per ton-mile traveled (by mode). Exposure (annual average daily traffic and daily trains) factor for rail crossings. Additional revenue earned by producers when shipping via rail.
Trade and Border	Market share of international or regional trade by mode.

section presents a simplified, abridged list of more targeted performance measures. These measures address all of the analytical and policy areas without overlapping, are easy to measure with available tools, and provide the most meaningful information to analysts, decision-makers, and the public. This subset of measures can be used to create comprehensive performance measurement. They are mostly multimodal, and address both the performance of facilities as well as trips.

Table 7.3 and Appendix B show the 17 recommended performance measures in italics. By referring to Table 7.3, one can see the analytical and policy areas the measures address. By referring to Appendix B, one can identify the modeling components required to calculate them. Below is a brief description of each recommended measure.

- **Administrative, Engineering, and Construction Cost/Ton-Mile (Owner Cost).** This measure of operating efficiency aids states in policy and economic studies; pavement and safety management; needs analysis; and project prioritization. It can help a state establish benefit/cost ratios. Ton-miles are derived from either direct factoring of facility flows or network assignment, and each agency generally has its own accepted unit costs.
- **Average Circuitry for Truck Trips of Selected O-D Pattern.** This travel time-based or distance-based measure addresses issues of accessibility and connectivity in truck routes. It can be used for states' truck flow and project development and design-related needs. Network assignment results can be used to find the average truck trip travel time or distance for a selected O-D pattern, which is then compared to an "optimal" time or distance (for example, based on a straight-line distance or an interstate connection between the O-D pair).
- **Average Fuel Consumption Per Trip for Selected Trips (or Shipments) or Per Ton-Mile.** This freight performance measure considers environmental and resource conservation, as well as operating efficiency. It is useful for modal diversion analysis (measuring the environmental and monetary costs associated with different modal options) and addressing states' performance measurement and program evaluation needs. Fuel consumption calculations, generally a function of vehicle type, roadway functional classification, and average speed, can use network assignment results and

Table 7.3. Analytical needs and corresponding performance measures.

Analytical Needs	Performance Measure
Bottlenecks	Frequency of delays at intermodal facilities
Commodity Flow	Average cost per trip. Average shipment time, cost, variability in arrival time for freight shipments (local versus long distance, by commodity, by mode). Business volume by commodity group.
Modal Diversion	Cost per ton of freight shipped. Cost per ton-mile by mode. *Delay per ton-mile traveled (by mode).*
Needs Analysis	*Administrative, engineering and construction cost/ton-mile (owner cost).* Average crash cost per trip. *Dollar losses due to freight delays.* Economic indicator for goods movement. *Freight transport system supply (route miles, capacity miles, number of carriers, number of ports/terminals) per "demand unit" (dollar of manufacturing output, ton-mile of commodity movement, capita, employee, etc.).* Fuel consumption per ton-mile traveled.
Operational Needs	Interference of movement at grade crossings – delay time and speed.
Pavement and Safety	*Administrative, engineering and construction cost/ton-mile (owner cost).* Average crash cost per trip. Exposure (annual average daily traffic and daily trains) factor for rail crossings.
Performance Measurement	*Average fuel consumption per trip for selected trips (or shipments).* *Mobility index (ton-miles of travel/vehicle-miles of travel times average speed).*
Project Development	*Average circuity for truck trips of selected O-D pattern.* Frequency of delays at intermodal facilities.
Project Prioritization	*Dollar losses due to freight delays.*
Terminal Access	Average travel time from facility to destination (by mode). *Average travel time from facility to major highway, rail, or other network.*
Truck Flows	*Average circuity for truck trips of selected O-D pattern.* Average speed (passenger and commercial vehicles) on representative highway segments. Interference of movement at grade crossings – delay time and speed.

standard fuel consumption rates. Also, some post-processors (such as the Intelligent Transportation Systems Deployment Analysis System or IDAS) take highway networks and O-D trip tables as inputs and calculate average fuel consumption for selected areas. System-specific or facility-specific fuel consumption can be divided by total trips or total ton-miles to normalize the result for comparison between different systems and facilities.

- **Average Travel Time from Facility to Major Highway, Rail, or Other Network.** Accessibility, mobility, and operating efficiency are all evaluated by this targeted travel time measure that addresses port and intermodal terminal access needs. Assignment results yield average times on the selected facilities. Substandard performance can indicate needs for upgraded facility access infrastructure or system management, or for a new major highway, rail, or other modal link closer to the facility.
- **Delay Per Ton-Mile Traveled (by Mode).** This travel time-based performance measure addresses mobility, and states' needs for rail planning and modal diversion analysis. Data for calculating this measure can be taken from direct factoring of facility flows or network assignment; delay on any facility is the difference between the actual travel time and the free-flow travel time. Dividing delay by total ton-miles

Table 7.4. Additional freight performance measures.

- Air cargo carrier route miles.
- Amount of turning radius from major highway to intermodal facility.
- Annual percent increase of unit costs of transport industries.
- Availability of real-time cargo information.
- Average distance to intermodal terminals from different community shipping points.
- Average processing time for shipments at intermodal terminals.
- Average time between arrival and clearance of hazardous materials spill.
- Average time between hazardous materials notification and response.
- Capacity of intermodal terminals.
- Capacity of package express carriers.
- Cost by commodity.
- Customer perception of time it takes to travel to places people/goods need to go.
- Customs delays.
- Delay time at primary commercial airports.
- Dollar expenditures for freight rail.
- Dollar value of property loss per ‘X’ users of intermodal transfer points.
- Double-stack capacity (or rating).
- Environmental impacts related to spills of hazardous materials.
- Freight carrier (or local shippers) appraisal of quality of highway service in terms of travel time/speed, delay, circuity, scheduling convenience.
- Freight dock availability.
- Grade crossing safety improvements.
- Lift capacity (annual volume).
- Miles of double-stack track.
- Miles of rail-line acquired and rehabilitated for rail service.
- Miles of roadway not usable by certain traffic because of design or condition deficiencies.
- Miles of track by Federal Railroad Administration’s speed rating.
- Miles of track in operation (by Federal Railroad Administration rating).
- Miles of track not usable by certain traffic because of design or condition deficiencies.
- Miles of trunk highway with springtime weight restrictions.
- Number (or percent) of shippers able to access desired suppliers or markets by preferred and secondary mode within specified service parameters (e.g., shipment time, cost, circuity).
- Number of air cargo carriers.
- Number of airports within X minutes of agricultural centers capable of supporting twin engine piston powered aircraft.
- Number of hazardous materials spills.
- Number of hazardous materials spills per vehicle-mile of hazmat traffic.
- Number of intermodal facilities that agency assists in development.
- Number of intermodal terminals by type.
- Number of marine barge operators.
- Number of overload permits rejected due to structural capacity deficiency.
- Number of package express carriers.
- Number of pipeline spills and accidents.
- Number of ports with railroad connections.
- Number of posted bridges and bridge load carrying capacity.
- Number of registered trucks by type/asset.
- Number of state-owned navigational aids
- Number of structures with vertical (or horizontal) clearance less than X feet.
- Number of 20-foot equivalent units (TEUs, 10’x 20’) (or railroad cars or containers) that can be stored on the premises of the intermodal facility.
- Number of track-miles abandoned or under threat of abandonment.
- Number of trucking companies by type.
- Number of trucks that can be loaded with bulk material per hour of loading time.
- Pavement condition on links to intermodal facilities.
- Percent lane-miles that are truck priority (or excluded)
- Percent of businesses that cite problems with transportation (access, travel time, cost, flexibility, reliability, damage/losses) as a major factor in productivity or expansion.
- Percent of commercial vehicles weighed that are overweight (by fixed and portable scales).
- Percent of intermodal connecting points and facilities accurately placed on a map.
- Percent of manufacturers/shippers that have relocated for transportation purposes.
- Percent of railroad grade crossings under electronic surveillance.
- Percent of road system carrying unrestricted loads year round.
- Percent of shippers satisfied with access and service to global markets.
- Percent of truck highway bridges sufficient in load capacity, vertical and horizontal clearance.
- Posted bridges and bridge load carrying capacity by functional class (number, percent, and area).
- Public expenditures on modal systems (freight versus passenger).
- Rail freight revenue versus operating expenses.
- Railroad/highway at-grade crossings.
- Route miles served by marine barge operators.

(continued on next page)

Table 7.4. (Continued).

- Number of commercial vehicle safety inspections performed.
- Number of commercial vehicles weighed (by fixed and portable scales).
- Number of crashes (or injuries or fatalities) caused by waterborne transportation.
- Number of crashes (or injuries or fatalities) per ‘X’ users of intermodal transfer points.
- Number of crashes per ton-mile traveled.
- Number of dockage days at seaports.
- Number of fatalities and injuries occurring on the rail system.
- Number of freight railroads by class.
- Shipment processing time at intermodal terminals.
- Shipper satisfaction with modal/scheduling flexibility.
- Shipper satisfaction with on-time reliability, shipping costs, or shipping time.
- Total duration of hazardous materials spill.
- Track capacity (size, acreage).
- Track condition.
- Truck delivery and loading interference with street traffic.
- Truck turnaround time at intermodal terminals.

normalizes the measure for comparison among different systems and facilities. Examining delay at a specific location, normalized by total trips passing through that location, is an effective tool for bottleneck analysis.

- **Dollar Losses Due to Freight Delays.** This measure is a function of “delay per ton-mile traveled (by mode)” and addresses mobility and operating efficiency. It can help states with policy and economic studies, project prioritization, and needs analysis. This measure is particularly useful for explaining performance improvements and reductions to shippers and carriers. Data for calculating this measure can be taken from direct factoring of facility flows or network assignment, and then applied to monetized values of time.
- **Freight Transport System Supply (Route Miles, Capacity Miles, Number of Carriers, Number of Ports/Terminals) Per Demand Unit (Dollar of Manufacturing Output, Ton-Mile of Commodity Movement, Capita, Employee, etc.).** This mobility measure more closely examines the supply side of transportation systems, helping states evaluate policy and economic studies and transportation needs. A variety of tool components can be used, depending on the desired demand unit. Any mileage-based unit, such as ton-miles or vehicle-miles, will require direct factoring of facility flows or network assignment. Other economic and production-related units may require an economic model component or a trip generation component based on exogenous data.
- **Mobility Index (Ton-Miles of Travel/Vehicle-Miles of Travel Times Average Speed).** This mobility measure considers policy and economic and performance measurement needs. It can be calculated using results from either direct

Table 7.5. Freight model classes and components.

	Model Component					
Model Class	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Split**	**Traffic Assignment**	**Economic/Land Use Modeling**
Facility Factoring Method	Of facility flows					
O-D Factoring Method	Of O-D flows			Included	Included	
Truck Model		Based on exogenously supplied zonal activity	Included	Not Applicable	Included	
Four-Step Commodity Model		Based on exogenously supplied zonal activity	Included	Included	Included	
Economic Activity Model		Based on outputs of economic model	Included	Included	Included	Included

factoring of facility flows or network assignment. The mobility index can be used as a primary marquee measure, with other supporting measures to address other concerns.

- **Mode Split (by Ton-Mile).** Mode split by ton-mile addresses operating efficiency, and aids states in model diversion analysis. It requires mode-split model component results, and to normalize by ton-mile requires data from direct factoring of facility flows or network assignment.
- **O-D Travel Times (by Mode).** This mobility and connectivity measure uses network assignment to derive modal travel times between selected O-D pairs and assess modal diversion and truck flow needs.
- **Percent of Freight Trips Occurring Within Peak Periods.** Calculating the percent of freight trips occurring within peak periods measures the operating efficiency within a region. This measure can assist states with their truck flow analysis and operational needs. While most work trips are confined to the peak periods and therefore the highest levels of congestion, freight trips are usually not confined to a particular time of day. Understanding the percent of freight trips occurring during the peak periods can help an agency find policies to shift freight trips to less congested times of day, thereby improving all of the other travel time-based measures for freight. This measure can be calculated using direct factoring of O-D flows and trip distribution tool components.
- **Percent of Manufacturing Industries Within X Miles of Interstate or Four-Lane Highway.** This accessibility measure addresses needs for upgrading highway facilities, building new four-lane or interstate facilities, or changes in land policies. Economic models can be used to forecast this measure.
- **Percent of Traffic on Regional Highway that is Heavy Truck.** High percentages of heavy truck traffic mixed with passenger vehicle traffic can be a concern for both safety and system preservation. This measure addresses states' pavement and safety management needs and operational needs. Direct factoring of facility flows or network assignment can be used to forecast this measure.
- **Ton-Miles Traveled by Congestion Level.** This measure, based on volume-to-capacity (V/C) ratio, measures mobility in a transportation system and addresses project prioritization and project development and design needs. It examines how often freight must travel in congested conditions. Direct factoring of facility flows or network assignment can be used to calculate this measure.
- **Tonnage Originating and Terminating.** This economic development performance measure helps states evaluate commodity flow issues. Although it does not measure specific or systemwide network problems, or shipment or vehicle performance, it can be used as an economic indicator for a region and can help states plan future infrastructure and create appropriate policies in the region. The measure can be calculated from trip generation tool components based on either exogenous data or an economic model.
- **Truck Vehicle-Miles Traveled by Light Duty, Heavy Duty, and Through Trips.** Truck vehicle-miles traveled (VMT), a basic measure of mobility, is useful for state planning and project prioritization. It can easily be obtained from tool components that directly factor facility flows or from network assignment. Stratifying the measure by light duty, heavy duty, and through trips helps states understand the nature and purpose of truck trips in a region, as well as predict safety and pavement preservation problems (see "Percent of Traffic on Regional Highway that is Heavy Truck").
- **Volume-to-Capacity Ratio on Facility Access Roads and at Border Crossings.** This targeted measure of mobility and economic development addresses states' trade and border, terminal access, and bottleneck analysis needs. The volume-to-capacity (V/C) ratio is a common and easy to understand measure of congestion, often conveyed to stakeholders by level of service (LOS) designations. It can be applied to any transportation facility under study. This measure can be forecast from the direct factoring of facility flows or network assignment.

CHAPTER 8

Case Studies

The model components, class of models, data, and other statewide freight forecasting issues discussed elsewhere in this Toolkit are not theoretical exercises. They are issues that transportation planners have confronted and will continue to confront. So that users of the Toolkit may have the benefit of the experiences of other planners and may see actual applications of the techniques, 10 case studies have been prepared. Two case studies have been chosen for each of the model classes defined in the Toolkit. The cases studies draw widely from the various model components, and represent a variety of data source applications. To the extent possible, the results of the coefficients, parameters, equations, validation, and other aspects of the case studies have been presented so that users of this Toolkit can compare their results with the results obtained by others.

The case studies have been presented using a common template, presented in Section 8.1. This template not only permits easy comparisons between case studies, but also serves as a useful organizing principle for anyone undertaking a statewide freight forecasting project. Answering the questions in the template helps freight forecasters better understand the specific issues they must face and the choices they can make given the available techniques.

This Toolkit is intended to present useful information on a variety of techniques in an accessible format. No single approach can be considered the correct one, nor does the use of one approach preclude the possibility of using another in the future. By answering the questions in the template, users should be able to develop an approach that best addresses their specific needs.

8.1 Development of a Forecasting Model Template

Background

Context

What is the nature of freight movement in the area for which the forecast model will be developed?

Objective and Purpose of the Model

What need will the forecasting model address? How will the model be used?

General Approach

Model class

Choose from one of the following:

- Flow Factoring;
- O-D Factoring;
- Truck Model;
- Four-Step Commodity Model; and
- Economic Activity Model.

Modes

What freight modes will the model address?

Markets

What is the nature of the market that the freight forecasting model must cover (geographic, industries, etc.)?

Framework

Will the freight model work within a larger process of preparing transportation forecasts for nonfreight demand, such as passenger travel? If it will be part of a larger process, how will the freight model be included?

Flow Units

What flow units will the model be expected to report (annual tons, daily trucks, daily trucks by truck type, etc.)? Will the flow units differ for the individual modal networks?

Data

Forecasting Data

Base and Forecast Year Socioeconomic Data

What base year data is available to support the model? What geographic units are available? What is the industrial breakdown? Is forecast data available, and if so what level of geographic and industrial detail is available? Is the forecast data developed by a land use/economic model? Is such a model to be integrated with the freight transportation model?

External Markets

What data is available for the geographic area outside of the state or primary study area? Is base data available on the amount of freight that travels to and from these external markets and the state or other primary study area? Is base data available on the amount of freight that travels between these external markets passing though the state or other primary study area? What level of geographic and industrial detail is available? Is forecast data available, and if so at what level of industrial detail?

Modal Networks

Freight Modal Networks

Are existing travel demand model networks for any of the freight modes to be included in the model? Does sufficient data exist to develop any missing modal networks? Are modal networks that cover any external zones to be included in the model?

Intermodal Terminal Data

Is data available on intermodal terminals where freight changes modes (ports, airports, and rail terminals, for example) that might be included in the model as special generators? Does this data include information on the location and capacity of the terminals? Does this data include demand/usage data for the terminals?

Model Development Data

Will model coefficients and parameters be developed specifically for this model? If so, what data will be used to develop these parameters and coefficients?

Conversion Data

Will the model need to convert flows from one unit to another (for example, from tons to vehicles)? Will the model need to convert flows from one time unit to another (for example, from annual to daily flows)? How will these conversion factors be obtained? If the conversion factors will be developed specially for this model, what data source will be used to develop these conversion factors?

Validation Data

Which of the model components will be validated using data obtained independently of the model development? What is the source of this data? How will it be used?

Model Development

Software

What software programs will be used in the development of this model? What software programs will be used in the operation of this model?

Commodity Groups/Truck Types

Will the freight flow units of the model be distinguished by purpose? For commodity models, what commodity groups will be separately included? Are these aggregations of existing commodity classification schemes? For truck models, what truck types will be separately included?

Trip Generation

Will a trip generation component be included? If so, how will the trip generation rates be developed? For production? For attraction?

Trip Distribution

Will a trip distribution component be included? If so, will a gravity model or some other model form be used? How will the model parameters and equations be developed?

Commodity Trip Table

If neither a trip generation model nor a trip distribution model will be included, will an existing origin-destination table of freight flows be obtained for inclusion in the model? How will this table be updated for forecasts?

Mode Split

Will a mode split model be included in the model? Will this component primarily rely on existing mode splits? If so, where will those existing mode splits be obtained? Will the existing mode splits be modified qualitatively based on expert opinion? Will the existing mode splits be modified qualitatively based on a market segmentation approach? Will a logit or other choice model be used? If so, what will be the form of that model and how will its parameters and coefficients be developed?

Flow Unit and Time Period Conversion

Will the model include a component to covert trip table flow units and time periods prior to assigning those trip tables to modal networks, such as converting annual ton flows to daily truck flows? If so, what will be the form of this conversion and where will the conversion factors be developed or obtained?

Assignment

Will the model include the ability to assign modal trip tables to modal networks? What assignment process will be used? Will other vehicles using the modal network be included?

If there are modal assignment components, will they be validated? If so, how will they be validated?

Model Application

What are the specific applications of the model? What outputs will be obtained and how will they be used and evaluated?

Performance Measures and Evaluation

Will the model be used to support performance measures? What performance measures are being supported? How will they be developed? How will they be used? How will performance standards or thresholds be established? Will performance measures be developed that are not supported by the forecasting model? highway with trucks? How will these additional users be assigned in conjunction with freight vehicles?

Model Validation

Trip Generation

If there is a trip generation component, will it be validated? If so, how will it be validated?

Trip Distribution

If there is a trip distribution component, will it be validated? If so, how will it be validated?

Mode Choice

If there is a mode choice component, will it be validated? If so, how will it be validated?

Modal Assignment

If there are modal assignment components, will they be validated? If so, how will they be validated?

Model Application

What are the specific applications of the model? What outputs will be obtained and how will they be used and evaluated?

Performance Measures and Evaluation

Will the model be used to support performance measures? What performance measures are being supported? How will they be developed? How will they be used? How will performance standards or thresholds be established? Will performance measures be developed that are not supported by the forecasting model?

8.2 Case Study – Minnesota Trunk Highway 10 Truck Trip Forecasting Model

Background

Context

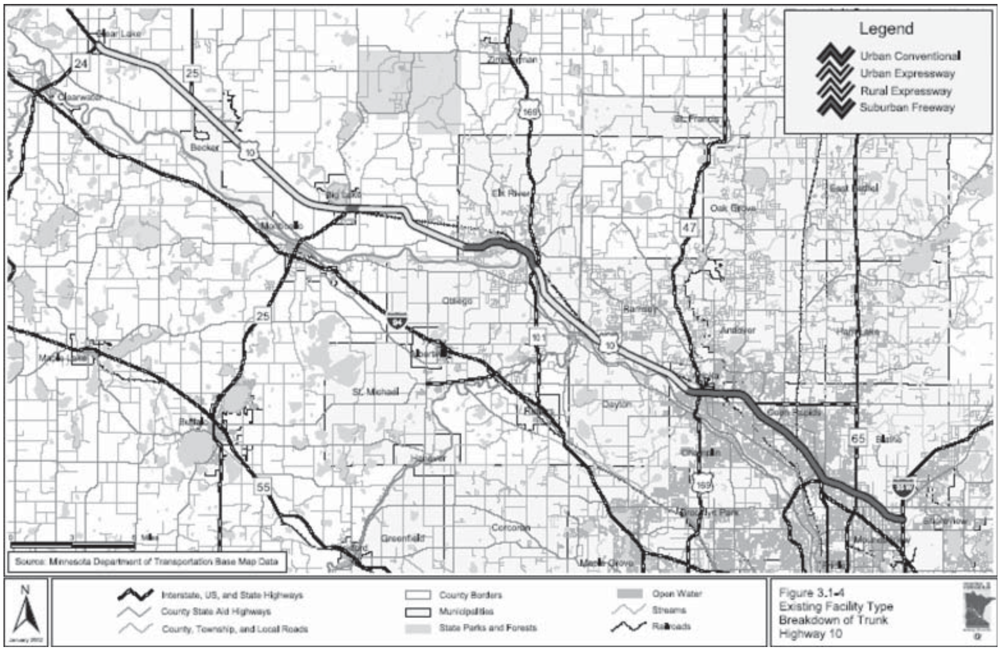
The Minnesota Department of Transportation (Mn/DOT) has identified a system of major highways connecting regional activity centers within the state and designated those highways as the Interregional Corridor System (IRC). Initially, Mn/DOT chose seven highway corridors to be the focus of an Interregional Corridor Management Plan. One of those seven is Trunk Highway 10 (TH 10) from TH 24 (Clear Lake) to I-35W (Mounds View).[16] The TH 10 corridor is shown in Figure 8.1.

The IRC Management Plan process included a comprehensive technical analysis and public involvement process in order to evaluate existing and future travel conditions, identify deficiencies, and weigh the various improvement alternatives. Current and future truck activity in the TH 10 corridor was studied through analysis of historical truck data and development of a truck traffic forecasting methodology that utilized historical truck count data, regional employment data, FHWA truck trip generation rates, and local truck trip-making activity.

The TH 10 study utilized direct flow factoring by applying economic activity indicators to project future truck volumes. This methodology is relatively straightforward and readily adaptable to other corridors in the Minnesota IRC system.

Objective and Purpose of the Model

Modal activity assessment is required under Mn/DOT's Interregional Corridor Plans. The TH 10 Truck Trip Forecast-



Source: Minnesota Department of Transportation, *TH 10 Corridor Management Plan*.

Figure 8.1. Trunk Highway 10 in Minnesota.

ing Model was developed specifically to assess current and future truck travel demand in the TH 10 corridor, but the process is applicable to other Minnesota IRC corridors.

General Approach

Model Class

The TH-10 model is a direct facility flow factoring class of model. It uses economic variables and existing truck flows to directly factor those flows and produce future truck volumes. A detailed description of the direct facility flow factoring class of model is provided in Sections 4.1 and 6.1.

Modes

The TH 10 model estimates only truck volumes on the TH 10 highway corridor.

Markets

The TH 10 model was specifically built for the TH 10 corridor, but the methodology is applicable to other corridors in Minnesota.

Framework

The IRC Management Plan process included a comprehensive technical analysis and public involvement process designed to evaluate existing and future travel conditions, identify deficiencies, and weight the various improvement alternatives. Current and future truck activity in the TH 10 corridor was studied through analysis of historical truck data and development of a truck traffic forecasting methodology that utilized historical truck count data, regional employment data, FHWA truck trip generation rates, and local truck trip-making activity. This method is appropriate for corridors where no network-based truck forecasting models exist.

Flow Units

The TH 10 Truck Trip Forecasting Model estimates daily truck trips in the corridor.

Data

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

Historical truck traffic data from 1992 through 1999 were obtained to estimate the growth trend in truck traffic along the TH 10 corridor.

Socioeconomic data included:

- Industrial employment projections (1996–2006) for Central Minnesota and the Twin Cities Metropolitan Area from the Minnesota Department of Economic Security; and
- Labor projections (1990–2020) for counties within Central Minnesota and the Twin Cities Metropolitan Area obtained from the Minnesota Department of Planning.

The economic forecasts were used to project the number of future employees by industrial sector within the corridor study area. By applying the appropriate truck trip generation rate by sector (truck trips per employee), the associated number of trucks was estimated.

EXTERNAL MARKETS

No external market data was provided.

Modal Networks

FREIGHT MODAL NETWORKS

No travel demand models were used in the TH 10 Truck Trip Forecasting Model.

INTERMODAL TERMINAL DATA

No intermodal terminal data was provided.

Model Development Data

No model coefficients or parameters were necessary in the TH 10 model. The economic forecasts were applied directly to the existing truck volumes.

Conversion Data

No conversion data were necessary in the TH 10 model. All truck data are presented and estimated in daily truck trips.

Validation Data

The model uses existing truck counts directly therefore those truck counts could not also be used for validation. No other independent validation data was available.

Model Development

The model process was to gather and review historical truck counts in the TH 10 corridor and develop a growth trend profile. Projections of future truck trips were developed based on regional employment forecasts (year 2020) applied to the truck trip generation rates from the Federal Highway Administration's *Quick Response Freight Manual*. The FHWA's truck trip generation rates were applied to existing county employment data to estimate existing truck trips in the corridor. This estimate was compared to observed truck counts, and the trip generation rates were adjusted for use in future year trip estimation. The adjusted forecast truck factors were applied to 2020 county employment projections to develop an estimate of 2020 truck volumes. Because 2025 was the desired study year, the 2020 projections were extrapolated to 2025.

Using data from private vendors, businesses along or near the corridor that generate truck trips were identified and the associated number of future truck trips was estimated. Based on future employment at these businesses and the adjusted FHWA truck trip generation rates, the number of truck trips associated with each employer were estimated. By geocoding the employment locations and the associated truck trips, highway segments with high truck volumes could be identified.

Software

The methodology developed for the TH 10 corridor relied primarily on spreadsheet calculation (such as Microsoft Excel), GIS software such as Business Map by ESRI, and the HarrisInfo database of manufacturers.

Commodity Groups/Truck Types

Trip demand analysis was based on trip generation rates from the *Quick Response Freight Manual* for 12 industrial sectors. No specific commodity groups or truck types were specified.

Trip Generation

Trip generation is not included in the direct flow forecasting model class. However, the TH-10 model used the *Quick Response Freight Manual* trip generation equations to develop the growth rates to be applied to the truck volumes.

As shown in Table 8.1, appropriate daily truck trip rates per employee (by sector) were identified using the *Manual*.

To estimate truck trips generated within a county, these truck trip generation rates were applied to base and future county employment forecasts by sector.

Trip Distribution

Trip distribution is not included in the direct flow forecasting model class. The TH-10 model geocoded the manufacturing employment along the corridor and applied the *Quick Response Freight Manual* rates to that location-specific employment to develop growth factors for individual sections of the corridor.

Commodity Trip Table

No commodity trip table was acquired or needed.

Mode Split

A mode split model is included in this class of models.

Table 8.1. Daily trip rates used in factoring truck trips.

SIC	Description	Trips/Employee
1-9	Agriculture, Forestry, and Fishing	0.5
10-14	Mining	0.5
15-19	Construction	0.5
20-39	Manufacturing, Total	0.322
40-49	Transportation, Communication, and Public Utilities	0.322
42	Trucking and Warehousing	0.7
50-51	Wholesale Trade	0.17
52-59	Retail Trade	0.087
60-67	Finance, Insurance, and Real Estate, Total	0.027
70-89	Services	0.027
80	Health Services (Including State and Local Government Hospitals)	0.03
N/A	Government	0.027

Flow Unit and Time Period Conversion

Existing truck volumes are directly forecast so no flow unit or temporal conversions were necessary.

Assignment

No assignment component is included in this model class. The existing truck flows on the TH-10 were directly factored.

Model Validation

Trip Generation

Not applicable.

Trip Distribution

Not applicable.

Mode Choice

Not applicable.

Modal Assignment

Not applicable.

Model Application

The TH 10 Truck Trip Forecasting Model was developed to assess current and future truck travel demand in the corridor and was directly used for that purpose. Table 8.2 shows the annual and total rates of employment growth along study area corridors, the annual and total rates of internal truck growth, and the resulting 2020 truck projections.

Performance Measures and Evaluation

Performance measures were not developed for the TH 10 model.

8.3 Case Study – The Heavy Truck Freight Model for Florida Ports

Background

Context

Ports are usually considered special generators of truck traffic in transportation planning models, in that they do not produce or attract truck trips proportionate to the employment or other socioeconomic variables at the port. Instead they generate truck traffic proportionate to the shipment of freight traffic through the port, which typically originates or terminates at an unspecified international location. It is important to accurately forecast the volume of truck traffic generated by port activity in order to forecast the volume of traffic on surrounding roadways, since truck traffic around ports is normally 10% to 50% higher than on roadways of similar functional classification located in other areas. This additional traffic can be directly attributed to the operations of the port.

The Florida Department of Transportation sponsored a series of research projects by the University of Central Florida whose goal was to provide planners with a tool for developing forecasts of freight traffic in the vicinity of Florida's major seaports, including Miami, Tampa, Jacksonville, and Port

Table 8.2. Results of Truck Highway 10 forecast daily trucks.

Location			Employment Growth 2000-2020		Internal Truck Growth 2000-2020		2020 Projections Based On	
From	To	County	Annual	Total	Annual	Total	1999	1995[a]
MN25	MN24 (Becker)	Sherburne	1.70%	39%	1.30%	30%	866	1,165
MN25 (Becker)	MN25 (Big Lake)	Sherburne	1.70%	39%	1.30%	30%	862	1,350
MN25 (Big Lake)	CR 14/15	Sherburne	1.70%	39%	1.30%	30%	902	1,462
CR 14/15	TH169	Sherburne	1.70%	39%	1.30%	30%	1,022	1,940
TH169	MN47	Sherburne/ Anoka	1.7% 0.80%	39% 18%	1.3% 0.40%	30% 8%	1,560	1,726
MN47	TH610	Anoka	0.80%	18%	0.40%	8%	3,019	2,763
TH610	MN65	Anoka	0.80%	18%	0.40%	8%	–	2,409
MN65	I35	Ramsey	0.40%	8%	0.40%	8%	–	1,979
I35	I694	Ramsey	0.40%	8%	0.40%	8%	–	1,610

Note: Gray indicates old roadway alignment.

[a] Assumes 2000 traffic rebounds to 1995 traffic, then continues to grow.

Everglades. The project was divided into three phases, and the first primarily focused on the Port of Miami.[17] This case study describes the methods used in this first phase as completed in 1999.

The Port of Miami, shown in Figure 8.2, is one of the largest container cargo ports in the United States. It is the largest freight port in Florida in terms of revenue and the third largest in terms of tonnage. Miami's freight operations are heavily influenced by the rapidly growing economies of the Caribbean and Latin American nations.

As shown in Table 8.3, truck movement at the Port of Miami takes place primarily on weekdays, peaking at any time between 9:30 a.m. and 3:30 p.m. However, vessel berthing, loading, and unloading activities occur seven days a week. Significant cargo vessel activity occurs between Friday evenings and Monday mornings.

Source: Port of Miami web site, http://www.co.miami-dade.fl.us/portofmiami.

Figure 8.2. The Port of Miami.

Objective and Purpose of the Model

The objectives of the Heavy Truck Freight Model for Florida Ports were as follows:

- To develop modeling systems for predicting truck traffic volumes;
- To estimate both inbound and outbound heavy truck trips;
- To use an alternative approach to estimate trips generated at ports, rather than the traditional land use approach that utilizes demographic and economic data; and
- To relate the volume models to the gross tonnage of truck movement.

General Approach

Model Class

The Heavy Truck Freight Model for Florida Ports is a direct facility flow factoring class of model. Flow factoring involves simple methods intended to apply existing data to determine near future freight volumes. The research project developed equations using linear and ARIMA regressions of time series data to produce forecasts of future year truck volumes. The Heavy Truck Freight Model was originally developed to estimate the truck trips produced from and attracted

Table 8.3. Distribution of truck movements (January 1996 through July 1996).

Day	Total	Percentage
Monday	40,173	18.0%
Tuesday	40,729	18.3%
Wednesday	43,484	19.5%
Thursday	45,585	20.5%
Friday	50,844	22.8%
Saturday	1,413	0.6%
Sunday	581	0.3%
Total	**222,809**	**100.0%**

to the Port of Miami. A detailed description of the model is provided in Sections 4.1 and 6.1.

Modes

The Heavy Truck Freight Model estimates the cargo truck traffic moving inbound and outbound at the Port of Miami. It is restricted to container and trailer truck configurations that transport virtually all of the port's freight.

Markets

The geographic limit of the model is the street network in Downtown Miami. The model estimates daily volumes of large inbound and outbound container and trailer trucks for specified timeframes.

Framework

The Heavy Truck Freight Model is a port-generated cargo truck estimation model. It does not include any other freight modes, and it is not part of a larger freight or passenger demand model. However, because ports often are considered special generators, the model can be used to estimate the production and attraction of truck trips from the port for inclusion as a part of a statewide or regional model.

Flow Units

The model starts with the monthly imported/exported freight units, and finally estimates the hourly volume of total trucks.

Data

Forecasting Data

The University of Central Florida team first collected sample truck traffic volumes by classification (type, number of axles, configurations). These data were obtained by interviewing local port personnel familiar with the many aspects of overall operation: personnel from administration, field operations, shipping companies, private terminals, trucking companies, security, accounting, and marketing.

The team entered the data into an electronic database and prioritized the sources according to quality, availability, and compatibility with the purposes and intent of the model. The objective was to develop a model with a minimum of inputs that used routine data collection methods. Table 8.4 summarizes the various types of data collected during this project.

Terminal Company's Truck Data. Four terminal operating companies collected all the heavy truck gate movements at the port. Some of the data were not separated by inbound and outbound movements. Since inbound and outbound traffic is modeled separately, these data were not suitable for developing the model, but were used in a general overview.

Gate Pass Data. Since the terminal company truck data were not broken down to hourly bi-directional data, data was needed from other sources that recorded entry and exit times. The Port of Miami collects and stores gate pass cards that record entering and exiting times of trucks, general vehicle configurations, the terminal operating companies visited, and the inbound gross weights of the vehicles. Gate pass data provided hourly volumes.

Videotape Counts. Port Boulevard traffic was videotaped on three days in 1997 (Friday, October 31, Monday, November 3, and Thursday, November 6). The corresponding truck gate passes maintained by Port Security for the selected days were counted to ensure the reliability of gate passes as a substitute data source for traffic counting.

Vessel Movements. Vessel movements data were collected along with the truck data from the gate passes and the terminal companies. Detailed records of vessel berthing for

Table 8.4. Summary of data collected.

Source of Data	Resolution	Period
Terminal Company Gate Movements	Daily Truck Movements	January 1996-December 1997
Port of Miami Gate Passes	Individual Truck Movements	January 1997-May 1997[a]
Video Counts	Individual Truck Movements	October 31, November 3, and November 6, 1997
Gantry Crane Activities	Start Time and End Time	January 1996-December 1997
Dock Reports	Individual Vessel Arrival and Departure Times	January 1996-December 1997
Trailer/Container Reports	Daily Trailer/Container Totals	January 1996-December 1997
Monthly Performance Reports	Monthly Trailer/Container Totals	October 1978-April 1998

[a] Only 57 days were collected.

1996 and 1997 were obtained from the daily dock reports, which include the entry and exit times and dates and various other data associated with berthing.

Gantry Crane Activities. Gantry crane data for 1996 and 1997 were also collected. Detailed records of crane activities were extracted from the gantry crane activity by ship line reports maintained by the port. These data include the start time and end time of service for each vessel.

Trailer/Container Activity Report. Trailer/container reports for the first six months of 1997 were obtained from the Port Accounting Office. These data include the number of freight units (trailers and containers) moved on and off each vessel.

Statistical Monthly Trailer/Container Performance Reports. Monthly trailer/container performance reports were obtained for the period October 1978 through April 1998. These data include monthly activity summaries and can be useful for determining historical trends in the trip generation model input for long-term forecasts.

Model Networks

A layout of the external road network surrounding the Port of Miami is shown in Figure 8.3. This small region covers an area about one mile to the west of the port and is located within the central business district of Miami. The network covers the following roads:

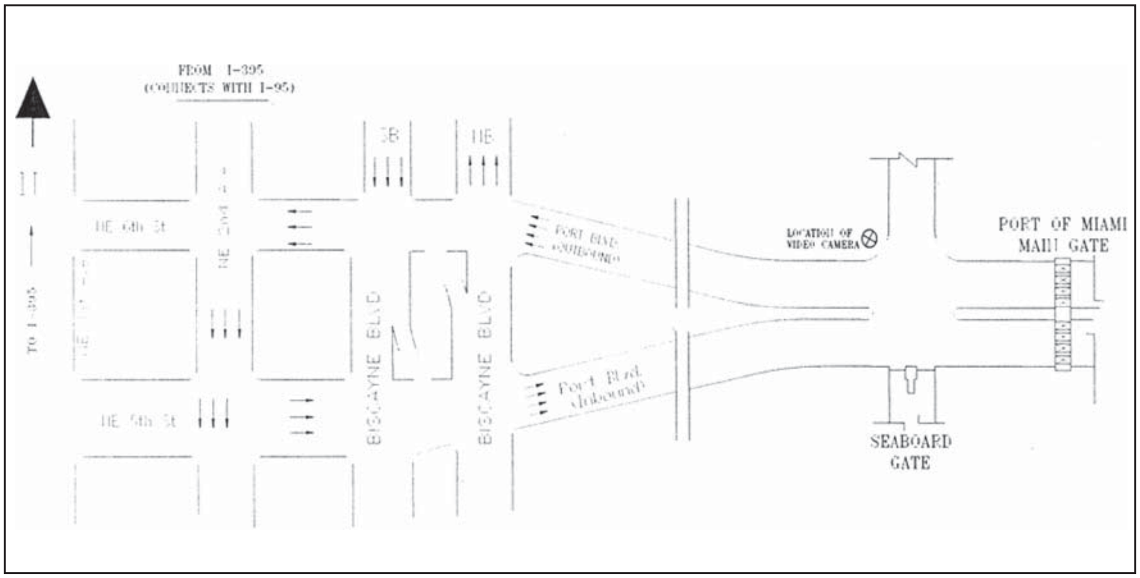


Figure 8.3. Street network in the Port of Miami region.

1. Biscayne Boulevard northbound and southbound, between the Port Boulevard entrance and exit.
2. NE 5th Street between Biscayne Boulevard and NE 2nd Avenue. This is a one-way, eastbound roadway.
3. NE 6th Street between Biscayne Boulevard and NE 2nd Avenue. This is a one-way, westbound roadway.
4. NE 2nd Avenue between NE 6th Street and NE 5th Street. This is a one-way, southbound roadway.

Model Development Data

The project team experimented with various types of data to develop the model, ultimately determining that the daily number of freight units (containers and trailers) handled by the Port of Miami was the best-fit independent variable.

Conversion Data

The model produces total daily heavy trucks using the total freight units.

Validation Data

The model was validated using 29% of the total available observations. The remaining 71% were used for developing the model. The model validation statistics are shown in the model validation section.

Model Development

The following methodology was used to develop truck trip generation model(s) for the Port of Miami:

1. Collect sample truck traffic volumes by classification (type, number of axles, configurations);
2. Interview local port personnel familiar with the many aspects of the overall operation, including personnel from administration, field operations, shipping companies, private terminals, trucking companies, security, accounting, and marketing;
3. Enter data samples into an electronic database, prioritizing the sources according to quality, availability, and feasibility, with the objective of developing a model with minimum input and routine collection practices;
4. Determine the independent variables for formulating models to correlate the volume of freight truck movement with internal port activity, focusing on Port Boulevard, the only road available for port access;
5. Develop the trip generation model by applying regression analysis, with Port Boulevard's daily directional truck volumes – inbound and outbound – as the dependent variables. Inbound refers to truck trips entering the port (the trip attraction model), while outbound refers to truck trips leaving the port (the trip production model);
6. Validate the model by entering survey data not used during the model formulation process;
7. Estimate gross weight of heavy truck movement generated on Port Boulevard by applying regression model(s) with the monthly gross weight of cargo as the dependent variable and the cargo vessel freight unit volume;
8. Perform a time series analysis to examine long-term and seasonal trends applying the analysis to the monthly totals of the main independent variable, cargo vessel freight unit volume (containers and trailers);
9. Determine hourly distribution of truck movements from gate pass data; and
10. Interpret the results to establish conclusions and make recommendations for future analysis.

Software

No specific modeling or planning software was applied to develop this model. Standard statistical software was used to develop the regression equations and the ARIMA models.

Commodity Groups/Truck Types

The Heavy Truck Freight Model estimates total freight trucks. It does not segregate by commodity group or by purpose.

Trip Generation

The University of Central Florida research team used a process similar to trip generation to develop the factors and forecast variables in the model. The research team used different equations and data to estimate inbound and outbound traffic. Since the Port of Miami has a higher percentage of exports than imports, it was essential to distinguish between the inbound and outbound directions and apply the two components accordingly.

The Heavy Truck Freight Model predicts the daily volumes of large inbound and outbound truck trips. As shown in equations 1 and 2, the inbound truck model component predicts truck trips attracted to the port while the outbound model component predicts truck trip produced by the port activities. The dependent variables are the daily inbound and outbound loaded truck volumes, and the independent variables are the total number of exported and imported freight units.

The team also developed equations for forecasting future year inbound and outbound freight units, which are required to estimate future year truck trips. The team developed two time series models, as shown in equations 3 and 4, and two regression models, as shown in equations 5 and 6.

$$\text{INTK} - 1.197 * (\text{EXPFU}) \tag{1}$$

$$\text{OUTK} = 310.079 + 0.698 * (\text{INPFU}) \tag{2}$$

$$\text{Ln}\,(\text{IMPFU}_{m}) = 0.0135 + \text{Ln}\,(\text{IMPFU}_{m-1}) - 0.218\,(\text{Ln}(\text{IMPFU}_{m-9}) - \text{Ln}\,(\text{IMPFU}_{m-10})) \tag{3}$$

$$\text{Ln}\,(\text{EMPFU}m) = 0.01275 + \text{Ln}\,(\text{EMPFU}_{m-1}) - 0.18\,(\text{Ln}(\text{EMPFU}_{m-9}) - \text{Ln}\,(\text{EMPFU}_{m-10})) \tag{4}$$

$$\text{IMPFU} = \text{Exp}\,(8.771 + 0.009506\,(\text{Month Index})) \tag{5}$$

$$\text{EMPFU} = \text{Exp}\,(8.767 + 0.00885\,(\text{Month Index})) \tag{6}$$

where:

INTK = Inbound loaded freight truck volume;
OUTK = Outbound loaded freight truck volume;
IMPFU = Total imported freight unit;
EXPFU = Total exported freight unit;
Month Index = 1, 2, 3, 4, 5, etc.; and
m = current month.

Trip Distribution

The model does not include a trip distribution step.

Commodity Trip Table

Since the model estimates the trip ends of a special generator, it does not develop any trip tables.

Mode Split

The model estimates total trucks; the mode split step is not available in the model.

Flow Unit and Time Period Conversion

Assignment

No assignment step was necessary in this model.

Model Validation

This is a flow factoring model, which does not include separate trip generation, trip distribution, mode choice, and traffic assignment steps. This section describes the model validation statistics available in the research report.

Tables 8.5 and 8.6 present the inbound and outbound linear regression models summary statistics. The *R*-squared values for the inbound (attraction) and outbound (production) models indicate that the Heavy Truck Model explains almost 80% of the variability in the number of inbound loaded truck movements, and almost 70% of the variability in the number of outbound loaded truck movements (dependent variable).

Table 8.5. Inbound loaded freight trucks regression model statistics.

Summary Statistics	
Regression Statistics	
Multiple *R*	0.8855865
***R* Square**	**0.7842635**
Adjusted *R* Square	0.7316319
Standard Error	303.59594
SSE/Mean	0.2392403
Observation	20

These two models are adequate to represent the relationship between the number of loaded truck movements and the number of freight units.

To validate the Heavy Truck Freight Model, the team used a total of 20 observations (71% of the total available observations) to fit the regression component and eight observations (29% of the total available observations) to validate the completed model. The team used a paired *t*-test to compare the total number of loaded freight trucks predicted by the model equations and their actual values. The results of these tests for both the inbound and outbound models are shown in Tables 8.7 and 8.8, respectively. There is no significant difference between the predicted values and the observed values for both models at the 95% confidence level.

Model Application

The most important application of the model is to forecast the daily and hourly truck movements for the future year. The following steps are needed to forecast daily truck volumes.

1. *Forecast Monthly Imported/Exported Freight Units.* Forecast imported and exported monthly freight units using time series ARIMA and regression equations.

Table 8.6. Outbound loaded freight trucks regression model statistics.

Summary Statistics	
Regression Statistics	
Multiple *R*	0.82805933
***R* Square**	**0.68568225**
Adjusted *R* Square	0.66822015
Standard Error	203.248744
SSE/Mean	0.20846025
Observation	20

Table 8.7. Statistical comparison between the observed total number of inbound loaded freight trucks and the predicted values by the attraction regression model.

Paired t-Test	Actual	Predicted
Mean	1,148	1,225
Variance	417,489	417,474
Observations	8	8
Pearson Correlation	0.81	
Hypothesized Mean Difference	0	
Df	7	
T Stat	-0.55	
P (T<=) One-Tail	0.30	
T Critical One-Tail	1.89	
P (T<=) Two-Tail	0.60	
T Critical Two-Tail	2.36	

2. *Forecast Weekly Imported/Exported Freight Units.* Forecast the total number of weekly imported and exported freight units by multiplying the monthly number of freight units from Step 1 by the average percent of each week of the month.
3. *Forecast for Each Group of Days.* Forecast for each group of days by multiplying the weekly number of freight units resulting from Step 2 by the average percentage of each group.
4. *Forecast Loaded Trucks for Each Group of Days.* Forecast the total number of loaded trucks generated by the Port of Miami for each group of days for each direction by applying the attraction and the production models developed.
5. *Forecast for Each Day of the Week Within Each Group.* Estimate the daily number of inbound and outbound loaded freight trucks by multiplying the regression model results for the number of loaded trucks for each group by the average of truck movement percentage for each day of the week.
6. *Forecast Hourly Truck Volumes.* Estimate the total hourly volume of trucks by using the results from Step 5 and multiplying these figures by the percentages of trucks for each hour.

Performance Measures and Evaluation

Not developed for this model.

Table 8.8. Statistical comparison between the observed total number of outbound loaded freight trucks and the predicted values by the production regression model.

Paired t-Test	Actual	Predicted
Mean	1,004	906
Variance	57,150	104,258
Observations	8	8
Pearson Correlation	0.86	
Hypothesized Mean Difference	0	
Df	7	
T Stat		1.61
P (T<=) One-Tail	0.08	
T Critical One-Tail	1.89	
P (T<=) Two-Tail	0.15	
T Critical Two-Tail		2.36

8.4 Case Study – Ohio Interim Freight Model

Background

Context

Federal regulations call for specific consideration of freight in the development of statewide plans and programs as a condition of Federal funding. This requirement obliged the Ohio Department of Transportation (ODOT) to address freight in its 2002 update of Access Ohio, its statewide transportation plan. Although ODOT was in the process of developing a comprehensive, statewide, travel demand forecasting model that would include sophisticated freight-planning capabilities, an interim study was needed until the new model was fully functional, sometime in 2005.

The interim freight study was designed to provide information and tools to assess freight trends and impacts on Ohio's roadways.[18] The data developed was used in four individual Ohio case studies each addressing a different aspect of freight movement. The model associated with the study is referred to here as the Ohio Interim Model. Figure 8.4 shows existing truck flows on Ohio highways.

The model developed in the interim study produces estimates of freight truck volumes that match the pattern and magnitude of all existing truck volumes in Ohio, but with the additional ability to identify the characteristics of those freight movements (origin, destination, payload, value, commodities carried, etc.). The model is easy to maintain and adapt and uses standard inexpensive commercially available software. It is compatible with the forecasts of freight movements being developed nationally for the Federal Highway Administration. The forecasts of truck traffic developed from an annual survey of shippers produce a broader geographic distribution of truck traffic than is produced by a factored roadside intercept survey.

Objective and Purpose of the Model

The purpose of the Ohio study was to determine how readily available freight databases could be used to:

- Provide ODOT with a clear picture of existing and future freight movements on Ohio's most critical highway corridors;

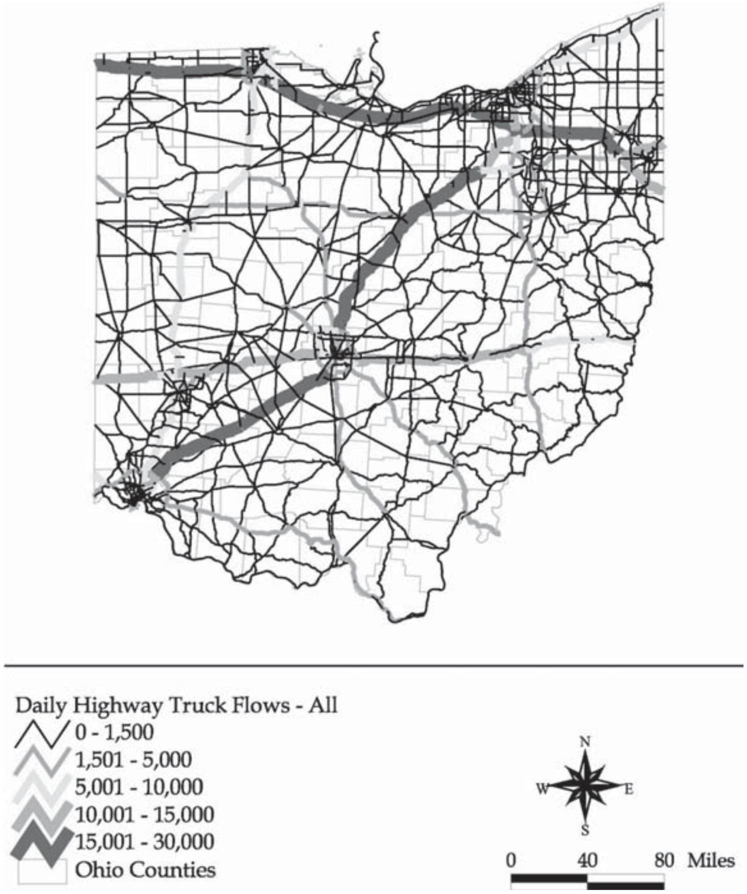


Figure 8.4. Ohio highway truck ton flows.

- Forecast freight flows and assess the impact that future changes in the freight system and freight movement may have on Ohio's roadways; and
- Make recommendations to meet these demands, while maintaining Ohio's strong economic growth.

General Approach

Model class

The Ohio Interim Freight Model developed facility freight flows by directly obtaining and factoring an O-D table of commodity freight flows, splitting the commodity flow to modes based on existing shares or a market segmentation diversion method, and assigning the modal O-D tables to modal transportation networks using fixed paths. The research study found that the O-D tonnage information could be converted to daily trucks and mapped to Ohio's roadways. A detailed description of the O-D factoring method is provided in Section 6.2.

Modes

The model was primarily developed to address truck movements on major highways, but includes water, air, and two rail submodes (carload rail and intermodal containers).

Existing and future commodity flows were summarized by mode share (truck, rail, water, air) and were presented by weight, value, direction (inbound/outbound), origin, and destination.

Markets

The model was developed to address freight issues throughout the state of Ohio and included information on the top 13 truck commodities. Key trading partners (states and regions) were identified. The four Ohio case studies addressed different markets.

The methods do not produce estimates of the shipments of nonmanufactured goods, local delivery trucks, construction trucks, service trucks, and other heavy vehicles not involved in the shipment of freight. The forecasts of these localized truck volumes must be obtained elsewhere.

Framework

The purpose of the model and the study was to address Ohio's needs for interim freight information and tools to assess freight trends and impacts on Ohio's roadways while ODOT updates its statewide travel demand model. When complete, the updated statewide model will include more sophisticated freight planning capabilities.

Flow Units

Existing and future commodity flows were summarized by mode share (truck, rail, water, air) and were presented by weight, value, direction (inbound/outbound), origin, and destination. Additionally conversion factors were applied to convert tonnage by trucks into annual trucks and then to daily truck trips.

Data

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

The Ohio Interim Freight Model used the 1998 TRANSEARCH database of freight shipments traveling to, from, or through Ohio. Forecasts of Ohio's economy were obtained from the firm of DRI-WEFA and used to estimate freight flows for the year 2025.

EXTERNAL MARKETS

An assessment of intrastate and through freight movements is included in the model. The rail network included the entire country and the highway network included only Ohio highways, with external stations at the state boundaries.

Modal Networks

FREIGHT MODAL NETWORKS

Shapefiles provided with the TRANSEARCH network were used to assign freight flows.

INTERMODAL TERMINAL DATA

The information in the commodity flow database was at the county level. No information was available for zones representing intermodal terminals.

Model Development Data

No model coefficients or parameters were necessary in the Ohio Interim Freight Model.

Conversion Data

CONVERSION OF TONNAGE INTO VALUE

Factors to convert annual tonnage into annual value were developed from the CFS conducted by the U.S. Bureau of the Census and the U.S. Department of Transportation. The 1993 Commodity Flow Survey, which reports commodities by

STCC, was chosen in order to be consistent with TRANSEARCH. The 1997 CFS reports commodities by the newer SCTG codes that are not directly transferable to STCC at a two-digit level. The values per ton were converted to 1998 dollars using the consumer price index.

CONVERSION OF TRUCK TONNAGE INTO DAILY TRUCK TRIPS

Factors to convert annual tonnage into annual trucks trips were developed from the VIUS conducted by the U.S. Bureau of the Census. The VIUS national microdata database consists of 105,545 records, with 1,974 records of the trucks based in Ohio. Of these, 1,399 included loaded weight information that make it possible to develop average payloads for the two-digit STCC codes included in the Ohio TRANSEARCH database. The sample includes expansion factors that equate to over 82 billion ton-miles of shipments.

Validation Data

The estimates of daily freight trucks produced by TRANSEARCH were qualitatively compared with ODOT's volume counts for all trucks.

Model Development

Methods were developed to assign the flow of freight shipments to Ohio's major roadway using database queries within TRANSEARCH. The resulting network flows were then mapped as a roadway network using the ArcView GIS software.

The Ohio Interim Freight Model developed facility freight flows by directly using a method of freight forecasting described as O-D table factoring and assignment. This method (with some variation) has been used by many states. The most prevalent application of this method follows these general steps:

1. Obtain base-year O-D tables (in tons per year) by commodity and by mode that matches the desired traffic zone system. Typically, flows between external zones that do not pass though the internal portions of the network are excluded. (For the Ohio Interim Freight model 1998 TRANSEARCH databases were used.)
2. Obtain base-year and future-year levels of economic activity (by industrial sector) for all zones. (For the Ohio Interim Freight Model, forecasts of Ohio's economy were obtained from DRI-WEFA and used to estimate freight flows for the year 2025.)
3. Establish a mapping between industrial sectors and commodity categories, such that a percent increase in an industrial sector can be associated with a percent increase in a commodity. (For the Ohio Interim Freight Model, the Ohio data contained 40 separate classifications by STCC codes, but the separate codes were aggregated into the top 13 commodity codes.)
4. Determine the percent increase in each commodity's origins and destinations by applying growth factors obtained in Steps 2 and 3.
5. Apply Fratar factoring to each O-D table to achieve the percent increases determined in Step 4.
6. Determine the number of vehicles necessary to carry each O-D flow for one equivalent weekday.
7. Assign each factored vehicle trip table to its respective modal network.

This method assumes that the mode split for any given commodity and for any given O-D pair is a constant. Any modal shifts that occur in this method are due to economic growth (or decline) or spatial shifts in economic activity and the resulting effects on commodity production and consumption patterns. Shifts due to changes in costs, supply chain practices, shipping and transfer times or vehicle technology are not included.

The method further assumes that the production, consumption, and shipping characteristics of commodities remain unchanged. Such assumptions can be eliminated by careful consideration of changes in a) shipping density of commodities, particularly due to packaging materials; b) worker productivity when economic activity forecasts are given in number of workers in an industry; c) value per ton when economic activity forecasts are given in monetary units; d) the routing patterns of the supply chain; and e) competitiveness of modes or intermodal combinations to carry specific commodities.

Software

The Ohio Interim Freight Model was developed using several software packages readily available and familiar to transportation professionals. These included Microsoft Access, Microsoft Excel, ArcView GIS, and the Highway Economic Requirements System (HERS). While Access and Excel are common software packages, ArcView GIS and HERS typically require specialized knowledge. By using Access queries, truck flows by highway segment can be exported in DBF format for use in other programs.

Maps of truck flows can be prepared from the DBF file of flows by highway segment ID using ArcView. TRANSEARCH contains a shapefile containing all the information in the highway network. By joining the highway segment field in the DBF file with the same field in the network shape file, maps of the flows can be produced.

Commodity Groups/Truck Types

Commodity groups serve a function similar to trip purposes in the passenger travel demand models. The TRANSEARCH commodity database purchased for Ohio includes 40 separate classifications of commodities by STCC code at the two-digit level and 440 separate classifications at the four-digit level. While this level of detail is useful for identifying specific commodity movements, such a large number of commodity classifications makes reporting and analysis difficult. In order to reduce the commodity groups to a more manageable level, the top 13 commodities at the two-digit STCC level by tonnage were identified. These 13 represent over 93% of the truck tonnages by truck as well as 86% of the total tonnage originating in Ohio. These STCC codes were each assigned as a single commodity group for analysis and reporting purposes. The remaining commodities were assigned to groups in the following categories: agricultural products, other nondurable manufactured products, other durable manufactured products, minerals, and miscellaneous freight.

The commodity groups for the model are shown in Table 8.9. Shown in each row are the STCC commodities assigned to each group and the total tonnage reported as traveling in Ohio by all modes and by truck. The commodity groups are organized in the order of the numeric STCC code that they represent, not by the amount of tonnage represented by that group. These commodity groups serve as the basis for the report and accompanying tables. Tables 8.9 and 8.10 do not include nonmanufactured goods. For example, agricultural products transported to a food processing plant are included, but agricultural products transported to a supermarket are not.

Trip Generation

Not applicable. The Ohio Interim Freight model used TRANSEARCH origin/destination data as purchased for this particular study.

Trip Distribution

Not applicable. The Ohio Interim Freight Model used TRANSEARCH origin/destination data as purchased for this particular study.

Commodity Trip Table

The Ohio Interim Freight Model used TRANSEARCH O-D data as purchased for this particular study.

Table 8.9. Commodity groups used in the Ohio Interim Freight Model.

Commodity Group		STCC Codes in Commodity Group	1998 Annual Tonnage by All Modes	1998 Annual Tonnage by Truck
Code	Name			
1	Agriculture	1, 7, 8, 9	28,898,426	6,679,545
2	Metallic Ores	10	43,887,516	–
3	Coal	11	132,797,767	11,135,211
4	Other Minerals	13, 14, 19	26,096,634	–
5	Food	20	96,036,220	76,781,243
6	Nondurable Manufacturing	21, 22, 23, 25, 27	13,311,467	12,646,266
7	Lumber	24	27,041,926	22,128,079
8	Paper	26	31,175,374	24,416,542
9	Chemicals	28	94,527,499	66,666,943
10	Petroleum	29	46,791,003	29,842,434
11	Rubber/Plastics	30	18,797,786	18,442,466
12	Durable Manufacturing	31, 36, 38, 39	23,187,380	22,128,609
13	Clay, Concrete, Glass	32	70,984,985	64,114,794
14	Primary Metals	33	87,342,217	62,115,438
15	Fabricated Metal Products	34	27,871,702	27,107,319
16	Transportation Equipment	37	47,048,025	31,064,887
17	Miscellaneous Freight	40-48, 5020, 5030	43,143,468	–
18	Warehousing	5010	82,420,938	82,420,938

Table 8.10. Ohio tonnage to truck conversion factors (tons per truck).

Two-Digit STCC		Distance Class				
Codes	**Commodity Name**	**Local (<50 Miles)**	**Short (50 to 100 Miles)**	**Short-Medium (100 to 200 Miles)**	**Long-Medium (200 to 500 Miles)**	**Long (>500 Miles)**
1	Farm Products	12.04	18.37	19.10	18.71	17.67
8	Forest Products	13.36	11.64	13.27	13.27	13.27
9	Fresh Fish or Marine Products	8.20	8.13	14.42	15.89	16.11
10	Metallic Ores	16.98	18.81	25.77	25.77	25.77
11	Coal	16.98	18.81	25.77	25.77	25.77
13	Crude Petroleum or Natural Gas	14.43	19.58	17.84	17.84	17.84
14	Nonmetallic Minerals	16.98	18.81	25.77	25.77	25.77
19	Ordnance or Accessories	7.05	4.42	11.47	9.84	11.30
20	Food or Kindred Products	8.20	8.13	14.42	15.89	16.11
21	Tobacco Products	11.50	16.25	16.03	11.47	15.96
22	Textile Mill Products	1.34	3.57	18.18	18.16	17.48
23	Apparel or Related Products	1.34	3.57	18.18	18.16	17.48
24	Lumber or Wood Products	10.33	12.35	17.50	17.61	17.83
25	Furniture or Fixtures	2.92	3.25	11.02	11.26	11.38
26	Pulp, Paper, or Allied Products	4.07	7.67	15.66	15.17	14.59
27	Printed Matter	4.07	7.67	15.66	15.17	14.59
28	Chemicals or Allied Products	5.18	15.39	19.55	19.25	19.25
29	Petroleum or Coal Products	14.43	19.58	17.84	17.84	17.84
30	Rubber or Miscellaneous Plastics	7.05	4.42	11.47	9.84	11.30
31	Leather or Leather Products	1.34	3.57	18.18	18.16	17.48
32	Clay, Concrete, Glass, or Stone	10.69	14.47	18.53	18.63	18.81
33	Primary Metal Products	11.82	14.73	19.96	20.14	20.13
34	Fabricated Metal Products	4.00	11.33	14.49	14.49	14.49
35	Machinery	6.97	12.55	17.42	17.21	17.21
36	Electrical Equipment	4.05	7.42	14.81	14.62	14.62
37	Transportation Equipment	2.48	14.12	17.21	16.92	14.18
38	Instruments, Photo Equipment, Optical Equipment	6.97	12.55	17.42	17.21	17.21
39	Miscellaneous Manufacturing Products	5.48	5.40	11.63	13.04	14.23
50	Drayage, Warehousing, Distribution	7.05	9.67	14.85	14.98	14.93

Source: Derived from Vehicle Inventory and Usage Survey records for Ohio.

The annual tonnage data from TRANSEARCH were converted into annual values based on factors from the CFS. The annual tonnage data from TRANSEARCH also were converted into number of annual trucks based on VIUS. The number of annual trucks was disaggregated into the number of daily truck trips. To simplify summary analysis and reporting, the 40 separate classification categories of two-digit STCC codes were grouped into the top 13 commodities. Future freight flows for each commodity group were determined based on economic model forecasts for 2010 and 2020. Using the TRANSEARCH database, truck flows on individual highway segments, including origin, destination, and commodity type, can be exported into a DBF file and then mapped to Ohio's roadways.

The economic model used in this study consisted of a set of unique commodity flow models that specify the likely pattern of goods movement by commodity and by transport mode. The forecasts are based on economic factors that affect changes in demand. The projections are based on regional, industry, and commodity models and have been developed to support a variety of public agencies and private firms studying freight transportation.

Mode Split

The base year split among highway, rail, air, and water modes from TRANSEARCH was assumed too constant into the future for the Ohio Interim Freight Model. However, a mode split by market segmentation used to assess potential freight diversion between highway and rail was developed for the Northern Ohio Rail Highway Corridor case study. This case study addressed an important issue in Ohio's state planning by assessing the potential to reduce the number of trucks traveling on the turnpike and the parallel alternate highway routes. It was assumed that only trips longer than a certain length, carrying only particular commodities, and larger than a certain size (weight) would be suitable for diversion to rail. Specifically, three major characteristics that influence the diversion potential were analyzed: 1) the origin and destination of the traffic; 2) the commodity mix of traffic between these origins and destinations; and 3) the total distance between them.

Flow Unit and Time Period Conversion

The VIUS microdata includes the empty weight of the vehicle; the average loaded weight of the vehicle; expansion factors based on the miles traveled; the percentage of the miles that the vehicle's trip falls in one of five different distance-classes; the percentage of the miles that the vehicle is empty; and, when full, the percentage of the miles that the vehicle is used to carry 31 distinct product classes.

Average payloads were calculated by the five distance-classes established in VIUS: 1) local (less than 50-mile trips); 2) short (50- to 100-mile trips); 3) medium-short (100- to 200-mile trips); 4) medium-long (200- to 500-mile trips), and 5) long (over 500-mile trips). The payloads were calculated by distance-class because the average payload and truck size varied by distance-class. Shorter-distance trips tend to be dominated by single unit trucks, which carry smaller average payloads. Longer-distance trips are dominated by combination tractor-trailer trucks, which carry larger average payloads.

The product classes used by the VIUS are similar to the two-digit STCC codes established for TRANSEARCH. The VIUS survey records the percentage of the mileage that a truck is carrying certain products, equipment, materials, etc. "No Load" is treated by VIUS as a separate product category. VIUS also includes buses and service trucks in the survey. Thus, certain VIUS product categories do not correspond to STCC commodity classes. A correspondence between the VIUS product classes and the Ohio Model commodity groups was developed. Passenger and service truck product classes not included in the commodity data (for example, Craftsmen's Tools or Household Possessions) were excluded.

The weighted annual mileage for each VIUS product carried by distance-class was calculated for each record in the Ohio VIUS database. The mileage was multiplied by the average payload for that record to obtain weighted annual ton-miles by product class and by distance-class for each record. The weighted annual ton-miles, and the weighted annual miles were summed over all records. The average payload for each commodity by distance-class was obtained by dividing average annual ton-miles by average annual miles.

Calculating payloads by two-digit STCC code is the first step in developing factors to convert tonnage to trucks. This payload does not include the percentage of miles that a truck travels empty. This percentage of empty miles by commodity group can also be calculated from the VIUS "No Load" product class. The factor to be used to covert from annual tonnage to annual trucks must account for the average payload, including percentage of empty trucks, in each STCC commodity class. The values by STCC code and distance-class are given in Table 8.10.

After converting annual tons to annual trucks, the resulting annual truck trip table is converted into a daily truck trip table. The *Highway Capacity Manual* (HCM) suggests that an average truck working week consists of five weekdays at full capacity and two weekend days at 44% capacity.[19] This equates to 306 truck working days per year. In addition, six Federal holidays are excluded from working calculations. It is recommended that the annual truck trips should be divided by 300 average weighted truck working days to calculate daily truck trips.

The 1993 CFS values were used to develop value per ton by STCC code. The values per ton are reported in Table 8.11.

The Ohio model converted the observed tonnages to values and annual trucks. The Ohio model used 306 working days per year to convert from annual to daily trucks.

Assignment

The assignment process used a predetermined, fixed path routing method based on the National Highway Network (NHN) as developed by the Oak Ridge National Laboratory. Reebie Associates has used routing information in the NHN to develop a database of highway segments that form the paths between the geographic centers of each county in the United States. Ohio's purchase of TRANSEARCH includes routing information showing all highway paths used within a state.

The national O-D table of commodity flows between counties in the United States is aggregated into the specific regions developed as part of Ohio's TRANSEARCH database. While the tonnage flow information is aggregated to these regions, groupings also are maintained by highway path, with origin, destination, and commodity information attached. Total truck flows on individual highway segments can be identified and selectively chosen to show origin, destination,

Table 8.11. Shipment values per ton by STCC commodity.

STCC Code	Description	Value Per Ton (1998$)
1	Farm Products	$1,147
8	Forest Products	$40
9	Fresh Fish or Other Marine Products	$5,493
10	Metallic Ores	$50
11	Coal	$24
13	Crude Petroleum, Natural Gas, or Gasoline	$31
14	Nonmetallic Minerals	$19
19	Ordnance or Accessories	$11,590
20	Food or Kindred Products	$1,408
21	Tobacco Products, Excluding Insecticides	$32,610
22	Textile Mill Products	$6,735
23	Apparel or Other Finished Textile Products	$25,732
24	Lumber or Wood Products, Excluding Furniture	$2,363
25	Furniture or Fixtures	$5,465
26	Pulp, Paper, or Allied Products	$1,333
27	Printed Matter	$3,054
28	Chemicals or Allied Products	$2,064
29	Petroleum or Coal Products	$239
30	Rubber or Miscellaneous Plastics Products	$7,290
31	Leather or Leather Products	$29,268
32	Clay, Concrete, Glass, or Stone Products	$205
33	Primary Metal Products	$1,273
34	Fabricated Metal Products	$3,544
35	Machinery, Excluding Electrical	$21,980
36	Electrical Machinery, Equipment, or Supplies	$28,724
37	Transportation Equipment	$13,904
38	Instruments, etc.	$39,343
39	Miscellaneous Products or Manufacturing	$11,270
40	Waste or Scrap Materials	$26
41	Miscellaneous Freight Shipment	$4,763
42	Containers Returned Empty	$1,120
43	Mail and Contract Traffic	$1,333
45	Freight Forwarder Traffic	$1,606
46	Mixed Commodity Shipments	$1,606
47	Small Packages	$1,606
48	Waste Hazardous Materials	$291
49	Hazardous and Corrosive Materials	$2,064
50	Secondary Cargos and Drayage	$1,606
99	Commodity Unknown	$8,917

Source: Derived from the Commodity Flows Survey records from Ohio.

or commodity. By using the query capabilities of Microsoft Access, these flow records by highway segment can be exported as a DBF file for use in other programs.

Maps of truck freight flows can be prepared from the DBF file of flows by highway segment ID using ArcView. TRANSEARCH contains a shapefile containing all of the information in the highway network. By joining the highway segment field in the DBF file with the same field in the network shapefile, maps of the flows can be produced.

Model Validation

Trip Generation

No trip generation validation was conducted.

Trip Distribution

No trip distribution validation was conducted.

Mode Choice

No mode choice validation was conducted.

Modal Assignment

The modal assignment was validated by comparing the estimates of daily freight trucks produced by TRANSEARCH with the Ohio DOT's truck volumes. Comparisons were made between the pattern of the modeled freight truck volumes and the observed truck volumes crossing screenlines.

The pattern of truck volumes estimated by TRANSEARCH was mapped using ArcView and was overlaid on the map of ODOT truck volumes. The TRANSEARCH freight truck flows include only a subset of all heavy trucks counted by ODOT. They include only trucks involved in the private or for-hire transport of freight, not service trucks, construction trucks, local delivery trucks, etc. On rural interstate facilities, where freight trucks predominate, the difference between observed truck volumes and TRANSEARCH freight trucks is minimal. On urban highways, where urban activity generates significant additional trucking activity, the differences are greater. Generally, freight traffic at the statewide level represents 60% or more of all truck vehicle-miles of travel.

The selected Ohio screenline locations generally show a relationship between the total observed and the total estimated truck volumes within the expected levels. The variation exists because the truck observations include all types of trucks while the estimate is of one type of truck: trucks carrying freight. In rural areas, freight trucks will constitute almost 100% of all trucks. In urban areas, the percentage is much lower.

The estimated truck volumes were derived by assigning truck flows to the single shortest highway path between county centers. TRANSEARCH does not take into account diversion of traffic among several available routes, nor can it distinguish shortest paths from points not at the county centers. As such, the TRANSEARCH flows are best considered general flows along a corridor rather than actual facility flows.

Model Application

The Ohio Interim Freight Model freight data was used in four case studies to address various freight operations and policy issues. Each of these case studies is described below.

Macro-Corridor Case Study

OVERVIEW

This case study examined Ohio's macro-corridors and the impact of an increase in truck traffic that is greater than the expected increase in traffic.

The 1995 Ohio State Transportation Plan *Access Ohio,* identified "Transportation Efficiency and Economic Advancement Corridors," also known as macro-corridors, throughout the state. Macro-corridors form a network of approximately 2,300 miles of roads determined to be the most critical. One of the factors used in the designation of a macro-corridor is high truck volumes. Based on the analysis of the Ohio model outputs, those macro-corridors were found to carry over 96% of the freight-truck volumes. Truck traffic on these corridors was found to be growing at an annual rate of 2.3%, faster than the 2.0% annual growth rate of general traffic on these same corridors. This caused ODOT to express concern about performance and funding.

The macro-corridors in Ohio were evaluated using the Highway Economic Requirements System model and the PONTIS bridge management model. These models represent the state-of-the-practice in evaluating highway and bridge systems and rely on databases that are prepared by the states.

For HERS, the Highway Performance Monitoring System data prepared annually by ODOT and submitted to the U.S. DOT was used. (No analysis was undertaken using PONTIS. Previous analysis with PONTIS in other states has indicated that bridge costs and conditions vary little with changes in demand and are instead a function of environmental and maintenance factors. For that reason, the case study was performed using only HERS.) HERS analysis provided data on congestion, speeds, pavement conditions, safety, air pollution, and program expenditures.

CONCLUSIONS

- The impacts caused by the growth in truck traffic, which is greater than the comparable increase in general traffic, are minimal and should be manageable.
- According to HERS, the costs to maintain the existing system are considerable, but not appreciably greater, when adjusted for growth, than Ohio's current expenditures. Trucks are responsible for a large share of those costs — approximately 30% according to relationships in the Highway Cost Allocation Study.
- HERS produced reasonable and useful results for this study. ODOT is currently testing HERS/ST, a specially tailored version for state DOTs, and should be encouraged to implement the software.
- HERS considers only the direct benefits to users of the highway system. It does not consider the economic development impacts of changes in transportation costs. The changes in these costs are available from HERS and consideration should be given to applying economic models to identify the larger impacts on Ohio's economy.

I-75 Corridor Case Study

OVERVIEW

This case study examined how improved truck forecasts might be utilized in a corridor planning study. The freight-truck forecasts provide detailed information about the industries served and commodities carried now and in the future on Interstate 75 in Ohio.

I-75 is one of the major trucking corridors in the United States, running from Miami to Detroit and continuing as

Highway 401 to Toronto. I-75 has been the subject of the multi-state I-75 Advantage Program to reduce congestion, increase efficiency, and enhance the safety of motorists and other users through the application of Intelligent Transportation System (ITS) technologies. ODOT was a major partner in the I-75 Advantage Program.

During the preparation of the I-75 study, ODOT became concerned about the accuracy of the truck information on I-75. The data, forecasts, and methods developed as part of this freight study were examined to determine how they could be used in the I-75 study. The truck data and forecasts can provide detailed information about the industries served and commodities carried on I-75, both now and in the future.

Conclusions

- Analysis indicates that of the top five commodities carried ranked by value, four are industrial commodities (transportation equipment, general machinery, electrical machinery, and fabricated metal), which account for 28% of the value of freight carried on I-75. This information can help identify those industries and firms that will benefit from I-75 improvements.
- The truck forecasts for I-75 are specific to the economic forecasts, not historic trends, and are available for individual sections. In general, I-75 truck volumes are expected to increase by 1.8% per year. This growth is below the average growth of 2.3% per year forecast for all roads in Ohio. These forecasts can support specific truck-related design considerations.
- By providing O-D information for trucks using I-75, the demand for interchanges in specific counties can be identified. The analysis indicated that the major interchanges of I-75, from north to south, include I-280, I-475, U.S. 68, U.S. 36, I-70, SR 43, Ronald Reagan Highway in Hamilton County, and I-71. The interchanges refer generally to the urban principal arterials and are consistent with the corridor level of the TRANSEARCH assignment procedures. The relative growth in truck percentages can support truck-specific design considerations at interchanges.
- Key features on major interstate highways are weigh stations and rest areas. These facilities are particularly important for trucks traveling on I-75 without an Ohio origin or destination and for trucks traveling over 500 miles. The truck forecasts for 2020 indicate that 28% of the trucks on I-75 are passing though. The truck forecasts for 2020 further indicate that 30% of the freight trucks are traveling more than 500 miles and may require a driver rest stop. This information can support the sizing of weigh stations and indicates the relative need for rest areas. It cannot support the detailed location of rest areas, since that determination requires knowledge of the national origin and destination of trucks, their temporal movement over the national network, and the hours-of-service rules. These issues are beyond the scope of this study.
- The truck forecast supports the identification of specific industries and geographic areas served by corridors (such as I-75) that can assist in public outreach and economic development efforts.

Northern Ohio Corridor Case Study

Overview

This case study in northern Ohio examined the relative share of 1998 traffic in the Northern Ohio Corridor among truck traffic on the Ohio turnpike, truck traffic on Ohio arterial highways, and rail traffic and the factors that might influence diversion among these modes.

The case study attempted to answer several important questions related to Ohio's state planning: Would it be possible, and feasible, to lessen the number of trucks traveling on the turnpike and the parallel alternate highway routes? Could enough traffic be diverted to rail to warrant a public investment in rail infrastructure and operations, or to offer other incentives to shippers or rail carriers? Is diversion even an issue that can be controlled and managed within the geographic scope of the state's borders?

Although there were no simple answers, there were ways to analyze freight flow data to intelligently explore the issues surrounding the Northern Corridor, and methodologies were in place to help determine how many trucks might be diverted in this corridor. Given the nature of the corridor, it could also be assumed that no diversion would take place to water or air freight.

The current profile of traffic in the corridor became the basis for traffic diversion estimates. The current mix of traffic on the Ohio Turnpike and the alternative east-west corridors was analyzed in an effort to determine if the traffic exhibits characteristics favorable for diversion to rail. Specifically, three major factors that influence diversion were analyzed. These were: 1) the origin and destination of the traffic; 2) the commodity mix of traffic between these O-D points; and 3) the total distance between these points.

Conclusions

- There are an estimated 13.6 million annual truckloads traveling in the Northern Ohio Corridor.
- The current intermodal rail market carries 7.3% of all loads in the corridor.

- The potential divertible market, including only loads with a distance and commodity that is likely to divert, is 2.1 million annual tons presently carried by trucks.
- The estimated annual truck tonnage that would be diverted to rail if rail costs decreased by 10% is 300,000, or 15% of the total divertible market segment and 2.2% of all freight truck loads in the corridor.
- The diversion analysis would not be possible without the commodity and O-D information available from Ohio's TRANSEARCH database.
- Because most of the divertible market had origins and destination outside of the state, Ohio should form coalitions with other states to address rail and trucking issues.

Mid-Ohio Regional Planning Commission Case Study

OVERVIEW

This case study examined how statewide freight-truck information might be applied in improving the travel demand models at a regional and metropolitan level.

MPO-supported travel demand models in Ohio generally forecast truck trips at external stations by extending the trend of observed historical growth. This method of forecasting the external-external truck trips passing through the MPO or the external-internal truck trips between the MPO and areas outside the MPO suffers from an important weakness: It is not sensitive to economic changes outside of the MPO's boundaries. The Microsoft Access-supported TRANSEARCH freight-truck database was examined to determine whether the forecasts of truck traffic in that database could be used to improve the model's forecasts of truck trips. In order to test this process, the Mid-Ohio Regional Planning Commission (MORPC), the MPO for the Columbus urban area, was selected to evaluate such a process.

CONCLUSIONS

- Freight-truck trip tables can be converted to a standard travel demand model package, such as TRANPLAN, and the information can be extracted for a specific region.
- Reasonable expansion factors can be developed to convert the county-level trip table to the TAZ system supported by a metropolitan region.
- The truck forecast is particularly valuable for external stations, which are generally problematic in regional forecasting processes and often are forecast based only on historical trends. However, because the number of external stations that have substantial volumes in the subarea freight truck trip table is fairly limited, the most appropriate use of the freight truck forecasts may be to qualitatively guide the adjustment of the model's external forecasts.
- The converted truck trip table is valuable in identifying and planning for major regional freight corridors and terminals. In addition, the complete statewide freight model can identify the routing and demand for regional trucks on the entire Ohio system. For example, the relative importance of I-71 in Cleveland to trucking in the MORPC region can be identified.

The freight-truck trip table and assignment represent only a small portion of the total truck movement in a region. They do not include local delivery, construction truck, service trucks, etc. The need to forecast these truck trips at the regional level will remain.

Performance Measures and Evaluation

Performance measures were not developed in the Ohio Interim Freight Model.

8.5 Case Study – Freight Analysis Framework

Background

Context

The FHWA's Office of Freight Management and Operations has developed the FAF as a policy tool to estimate commodity flows and related freight activity at national, state, and county levels. FAF not only covers domestic freight movements, but major international freight movements as well. The tool has been developed to provide an accurate, comprehensive forecast of commodity flows and freight activity for the analysis years 1998, 2010, and 2020. These forecasts are sensitive to changes in economic conditions, the transportation system, and other factors.

Objective and Purpose of the Model

The FAF provides the U.S. Department of Transportation with a policy analysis tool to help it understand commodity flows and the pressures these flows place on the transportation system. A better understanding of goods movement helps the agency identify deficiencies in the transportation infrastructure and formulate the means to address them.

The FAF was developed initially for use as a national policy analysis tool but has proven to be useful at other levels as well. Although it can never replace more detailed analysis tools developed for states and metropolitan planning organizations, FAF can assist by:

- Providing a benchmark for state and local freight planning;
- Identifying current and future congested links on a national, corridor, and regional scale;

- Providing nationally consistent forecasts of freight growth by commodity type and mode;
- Understanding nationwide flows and their potential impact at the local level, thus allowing state and local agencies to identify crucial freight connections to serve external markets;
- Establishing a framework for converting and consolidating multistate and multi-agency transportation, traffic, and freight information; and
- Supporting policy development at all levels, including the Federal transportation reauthorization process.

General Approach

Model Class

As a commodity flow factoring class of model, the FAF is a comprehensive estimate of origins and destinations for freight moving by truck, rail, water, and air. Freight flows are assigned to the transportation system to evaluate or determine current and future deficiencies. The general approach of the FAF is to estimate the flows of commodities at the four-digit STCC level for each mode at the county level for the entire United States. This county-level flow table is then converted to transport units of each mode and assigned to a network. A detailed description of the commodity O-D flow factoring method is provided in Section 6.2.

Modes

The county-level flow table consists of four primary modes, with various subsets, for a total of seven modes as listed in Table 8.12.

Freight moved by truck is the most difficult of the major freight modes to estimate due to the extent of the service markets and the lack of a cohesive dataset. FAF estimates truck production volumes by first estimating total freight production by state using the U.S. Census Bureau's Annual Survey of Manufactures and the Census of Manufactures. It estimates truck freight production by subtracting the other major modes—rail, water, pipeline, and air—from the total.

FAF splits truck productions into two major groups, private and for-hire, dividing the for-hire trucks into truckload and less-than-truckload. Payload factors are used to convert tons of commodity into trucks. The payload factors vary depending upon the type of truck, the type of commodity, and the distance of the trip.

Three different truck types are used to allocate the freight to trucks:

- Single units trucks;
- Combination tractor-trailer trucks; and
- Double tractor-trailer trucks.

FAF highway freight movements capture only intercounty flows, not intracounty. However, the 1997 CFS indicates that intracounty freight flows are a substantial component of the overall highway freight market.

WATERBORNE FREIGHT

Waterborne freight is estimated using data from the U.S. Army Corps of Engineers. The Corps collects data on all U.S. waterway shipments, which it reports at the aggregate state-to-state level by commodity group. The data is disaggregated for use in FAF by using individual port data and data for both private and public facilities. Domestic, international, and total waterborne movements are listed in Table 8.13.

After estimating flows, FAF assigns waterborne freight to waterways based on the shortest path between an origin and a destination. It does not capture the drayage portion of waterborne freight.

AIR FREIGHT

In terms of tonnage carried, air freight is the smallest of the major modes included in FAF. In 1998, air freight accounted

Table 8.12. Modes included in the Freight Analysis Framework.

Primary Mode	Subset Mode
Truck	Private
	For-Hire – Truckload
	For-Hire – Less than Truckload
Rail	Conventional Rail
	Rail/Truck Intermodal
Water	Water
Air	Air

Table 8.13. Freight Analysis Framework waterborne freight shipments by ton and value.

	Tons (Millions)			Value (Billions of Dollars)		
	1998	2010	2020	1998	2010	2020
Domestic						
Waterborne	1,082	1,345	1,487	146	250	358
Total	**13,484**	**18,820**	**22,537**	**7,876**	**15,152**	**24,075**
International						
Waterborne	136	199	260	17	34	57
Total	**1,787**	**2,556**	**3,311**	**1,436**	**3,187**	**5,879**
Domestic and International						
Waterborne	1,218	1,544	1,747	163	284	415
Total	**15,271**	**21,376**	**25,848**	**9,312**	**18,339**	**29,954**

Source: Federal Highway Administration, Freight News, October 2002.

for just nine million tons (0.1%) of domestic freight included in the FAF. While the overall tonnage carried by air is low, the value is considerably higher, almost 7% of the total in 1998.

The Bureau of Transportation Statistics Airport Activity Statistics (AAS) is the basis for the air freight component of FAF. The AAS contains data on the total tonnage originating from airports. This data is combined with flow data also provided by the AAS to determine the tonnage origins and destinations for the nation's airports. Individual airports are aggregated to the county level for use in the FAF. Domestic, international, and total air movements are listed in Table 8.14.

The commodity flow table is used to disaggregate the county-to-county tonnage flows into individual commodities. Using the commodity flow table, each airport market area is examined to further refine the flow of commodities. Similar to the rail freight portion, the truck drayage portion of air freight flows is included in the FAF.

Markets

FAF is designed to be a comprehensive database of freight movement, and as such is intended to include all markets. FAF reports both national and international freight movements throughout the United States at the county level. International freight is recorded as having an origin or destination at the county in which it enters or exits the United States.

Table 8.14. FAF air freight shipments by ton and value.

	Tons (Millions)			Value (Billions of Dollars)		
	1998	2010	2020	1998	2010	2020
Domestic						
Air	9	18	26	545	1,308	2,246
Total	**13,484**	**18,820**	**22,537**	**7,876**	**15,152**	**24,075**
International						
Air	9	16	24	530	1,182	2,259
Total	**1,787**	**2,556**	**3,311**	**1,436**	**3,187**	**5,879**
Domestic and International						
Air						
Total	**15,271**	**21,376**	**25,848**	**9,312**	**18,339**	**29,954**

Source: Federal Highway Administration, Freight News, October 2002.

Framework

FAF data is used in many regional, statewide, and urban models. Since FAF is a national commodity flow model and the output is public data, other freight models for any subregion within the U.S. may use FAF as a data source.

FAF modeling procedure does not lend itself to forecasting passenger vehicles and no complementary passenger model has been developed.

Flow Units

Units of flow in FAF are in annual tons per commodity type. Annual tons are reported for all four major modes in the FAF, truck, rail, water, and air.

FAF also provides an assignment of the converted tonnage flows for the highway freight component. These flows are represented in the network as daily trucks for each of the forecast years of 1998, 2010, and 2020. The trucks are identified as being commodity-carrying trucks or noncommodity-carrying trucks.

Data

As a comprehensive forecast of commodity flows, FAF draws upon many sets of data from both public and proprietary sources. These data are used to create the Freight Analysis Framework Database (FAFD). FAFD contains county-to-county freight flows for truck, rail, water, and air at the four-digit STCC level.

The basis for the FAFD is Reebie Associates' TRANSEARCH visual database. The TRANSEARCH database is derived from, but not limited to, the following sources:

- Bureau of Transportation Statistics' 1997 CFS;
- Surface Transportation Board's Railroad Waybill Sample;
- U.S. Census Bureau's Annual Survey of Manufacturers and Census of Manufacturers;
- U.S. Census Bureau's VIUS;
- HPMS;
- FAF State to State Commodity Flow Database; and
- Data from a proprietary motor carrier traffic sample.

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

Forecasts of the base year data are based primarily on economic forecasts, as the economy and freight movement are integrally tied to each other. The Macroeconomic Service Long-Term Trend Scenario prepared by WEFA, Inc. (now Global Insights, Inc.) is used as the basis for the freight flow forecasts. WEFA has three forecasts: a baseline and lower and higher versions of the baseline. The freight forecasts are based on the baseline forecast. The economic forecasts address growth in the supply side of commodity production.

The WEFA forecast makes a number of long-term assumptions about the United States economy, including:

- The civilian labor force will grow more slowly;
- The manufacturing sector will continue to shrink and the service sector will continue to grow;
- The gross domestic product (GDP) will grow more slowly as a result of slower labor force growth;
- The increase in the government sector's share of the GDP will slow due to a decrease in defense spending;
- The share of real total expenditures devoted to services and durable goods will rise, while the share of expenditures devoted to nondurable goods, such as energy, will fall;
- The fastest growing sector of the economy for investment will be producers' durable equipment; and
- Manufacturing of durable goods will grow faster than manufacturing of nondurable goods.

WEFA's economic assumptions are posted on the Office of Freight Management and Operations web site at: http://www.ops.fhwa.gov/freight/adfrmwrk/index.htm.

For forecasting the base year, data is aggregated into Bureau of Economic Analysis Economic Areas and Census Divisions. This reduces the number of areas for the forecasts to be developed. The forecast goes through various steps required to determine the supply and demand of particular commodities in the future. The forecast data is then disaggregated to the county and STCC four-digit codes.

EXTERNAL MARKETS

FAF accounts for external markets as well, primarily Canada and Mexico. Asia, Europe, Latin America, and the rest of the world also are included in FAF. Only the portion of the trip on the U.S. domestic freight network is included, with the international freight origin or destination taken as the U.S. county through which it crosses the border. This data is mostly based on proprietary data from the TRANSEARCH international database.

Modal Networks

FAF has four modal networks, one for each mode, with the rail and air modes also using the highway network for the drayage portion of their movements. Of the four networks, the highway network is the most complex. The rail network is the second most complex, but is not nearly as intricate as the highway network.

The waterways network consists of the nation's navigable waterways and uses a shortest distance path to determine the route of the movement. The air freight network is based on the straight-line distance between airports.

HIGHWAY NETWORK

FAF highway network has its origins in the NHPN. NHPN is a national planning network that consists of approximately 450,000 miles of roadway, including:

- Interstate Highway System;
- NHS;
- National Network (NN);
- National Truck Network; and
- Other state highways.

FAF network is basically a subset of the NHPN. Additional highway links are added to FAF network for connectivity purposes. Counties not adequately served by NHPN have additional urban streets and rural minor arterials added to them. FAF network is shown in Figure 8.5.

INTERMODAL TERMINAL DATA

FAF highway network has centroid connectors coded for the intermodal terminals identified by the Bureau of Transportation Statistics. No information is provided for O-D flows at these terminals. These flows may be separated from the county-to-county flows in subsequent FAF updates.

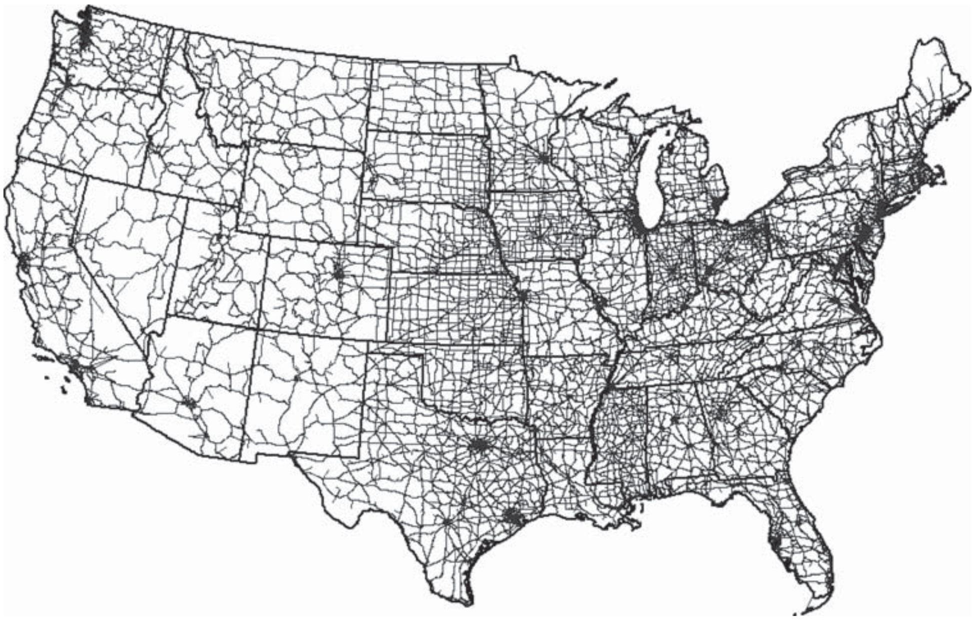
Model Development Data

The commodity table eliminates the need to develop trip generation or trip distribution parameters or coefficients. The use of existing (circa 1998) mode splits for future mode splits also does not require the development of a mode choice model.

Conversion Data

A series of conversions is required to transform the commodity flow tonnages by STCC code to number of trucks. The FAF uses these procedures to convert the tonnages into trucks, but the specifics of the procedures are proprietary. The conversion process utilizes the data from VIUS, TIUS, the Comprehensive Truck Size Weight Study, as well as adjustments from industry experts.

The conversion process is a four-step process. First, each commodity is allocated to a truck body type. Several truck types are considered in the allocation process. Some commodities are allocated to only one truck type, while others are allocated to many types. Secondly, distributions by truck configuration for each body type are developed. The distributions are based on the VIUS data for the state of origin. Third, the tons are converted to trucks, based on VIUS data, for payload weight distributions for each body type, STCC code, and configuration. Finally, an estimate is made for the number of empty tucks. By definition, empty trucks are not commodity-carrying trucks,



Source: Freight Analysis Framework Highway Capacity Analysis Methodology Report, April 2002, Figure 2.

Figure 8.5. The Freight Analysis Framework highway network.

but they must be considered in the number of trucks needed to ship freight.

Validation Data

No validation data was used in FAF.

Model Development

Software

FAF highway assignment process utilizes the TransCAD modeling software package. Networks with the assigned volumes are available in TransCAD, ESRI Inc.'s shape file and database formats at the Office of Freight Management and Operations web site at: http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf_highwaycap.htm.

FAF nonhighway assignment uses the proprietary fixed path routing files in TRANSEARCH. These routing files are use in Microsoft Access to develop DBF files of water and railroad network flows. These network flow files can be mapped using FAF railroad and waterway network shapefiles in ESRI's ArcGIS family of software.

Commodity Groups/Truck Types

The commodity groups used in the derivation of the FAF commodity truck trip table are listed in Table 8.15.

Truck types considered in the trip table are single units and combination tractor trailers, as listed in Table 8.16.

While commodity groups and truck types are factored into the truck traffic assigned to the network, they are not assigned separately. FAF reports only commodity-carrying trucks.

Trip Generation

Not applicable for this model class.

Trip Distribution

Not applicable for this model class.

Commodity Trip Table

Flows are estimated for a base year of 1998 and the forecast years of 2010 and 2020. This section describes the methods used to estimate domestic and international freight flows for each mode and the procedures used to map them to the transportation network.

RAIL FREIGHT

Rail freight flows are estimated using the STB's confidential data set, the Carload Waybill Sample. The Waybill Sample is a stratified sample of carload waybills for terminated shipments by railroad carriers, encompassing 62 railroad systems (including all Class I and II railroads) and the major short lines.

The Waybill Sample contains detailed information about each sampled movement. Included in these data are the type of commodity and volume being carried as well as the origin and destination of the trip.

The rail volumes and types of commodities being carried are classified as carloads, and the rail intermodal volumes are classified as trailer-on-flatcar or container-on-flatcar. The trailer-on-flatcar and container-on-flatcar freight move-

Table 8.15. Commodity types.

STCC 2	Product	STCC 2	Product
1	Farm	32	Clay/Concrete/Glass/Stone
8	Forest	33	Primary Metal
9	Fish/Marine	34	Fabricated Metal
10	Metallic Ores	35	Machinery except Electrical
11	Coal	36	Electrical Mach/Equip/Supp
13	Crude Petroleum/Natural Gas	37	Transportation Equipment
14	Nonmetallic Minerals	38	Instruments/Optical/Watches/Clocks
19	Ordnance/Accessories	39	Miscellaneous Manufacturing
20	Food/Kindred	40	Waste/Scrap Materials
21	Tobacco	41	Miscellaneous Shipping
22	Textile Mill	42	Shipping Containers
23	Apparel	43	Mail
24	Lumber/Wood	44	Freight Forwarder
25	Furniture/Fixtures	45	Shipper Association
26	Pulp/Paper/Allied	46	Freight All Kind
27	Printed Matter	47	Small Package
28	Chemicals/Allied	48	Hazardous Waste
29	Petroleum/Coal	49	Hazardous Materials
30	Rubber/Plastics	50	Secondary Moves
31	Leather	99	Less-than-Truckload-General Cargo

Table 8.16. Truck types.

Truck Body Types	Truck Configurations
Dry Van	Single Unit
Reefer	Combination tractor semi-trailer or double trailer
Flat	Combination tractor semi-trailer or double trailer
Automobile	Combination tractor semi-trailer or double trailer
Bulk (Including hoppers and open-top gondolas)	Combination tractor semi-trailer or double trailer
Tank	Combination tractor semi-trailer or double trailer
Livestock	Combination tractor semi-trailer or double trailer

ments consist of a long rail movement with short truck drayage on both ends of the rail trip. Domestic, international, and total rail movements are listed in Table 8.17.

HIGHWAY FREIGHT

Of the modes covered by FAF, highway freight is the greatest in terms of both tonnage and value. As shown in Table 8.18, highway freight accounted for 10.4 billion of the 13.5 billion domestic tons estimated for the year 1998.

With some exceptions, the commodity flow table used in the FAF is approximately at the county level. While this table is proprietary and is not available to the public, an aggregation is available at the state-to-state level online at: http://ops.fhwa.dot.gov/freight/freight_analysis/faf/fafstate2state.htm.

The commodity flow table includes flows for truck, rail, water, and air freight for the years 1998, 2010, and 2020. The assemblage of this data is described online at: http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm.

The forecasted commodity flow tables are based largely on the WEFA's Macroeconomic Service Long-Term Trend Scenario.

Mode Split

The FAF does not have a policy-sensitive mode split component. Mode shares are defined and forecasted using growth rates based on historical freight movement. Differences in mode shares for future years may be reflected in the aggregate due to different growth rates for particular commodities. At a disaggregate level, the mode shares do not change for each O-D pair by commodity.

Flow Unit and Time Period Conversion

The FAF flow table is not adjusted for time period.

Commodity-based trip generation models typically start with an estimate of commodity flow tonnage, generally county-to-county or state-to-state flows. The annual tonnage

Table 8.17. Freight Analysis Framework rail freight shipments by ton and value.

	Tons (Millions)			Value (Billions of Dollars)		
	1998	2010	2020	1998	2010	2020
Domestic						
Rail	1,954	2,528	2,894	530	848	1,230
Total	**13,484**	**18,820**	**22,537**	**7,876**	**15,152**	**24,075**
International						
Rail	358	518	699	166	248	432
Total	**1,787**	**2,556**	**3,311**	**1,436**	**3,187**	**5,879**
Domestic and International						
Rail	2,312	3,046	3,593	696	1,096	1,662
Total	**15,271**	**21,376**	**25,848**	**9,312**	**18,339**	**29,954**

Source: Federal Highway Administration, Freight News, October 2002.

Table 8.18. Freight Analysis Framework highway freight shipments by ton and value.

	Tons (Millions)			Value (Billions of Dollars)		
	1998	2010	2020	1998	2010	2020
Domestic						
Highway	10,439	14,930	18,130	6,656	12,746	20,241
Total	**13,484**	**18,820**	**22,537**	**7,876**	**15,152**	**24,075**
International						
Highway	419	733	7,069	722	1,724	3,131
Total	**1,787**	**2,556**	**3,311**	**1,436**	**3,187**	**5,879**
Domestic and International						
Highway	10,858	15,663	25,199	7,378	14,470	23,372
Total	**15,271**	**21,376**	**25,848**	**9,312**	**18,339**	**29,954**

Source: Federal Highway Administration, Freight News, October 2002.

flows are then converted to daily truck trips using payload factors. These payload factors may come from local survey or from national data, such as VIUS. Commodities in the TRANSEARCH database are aggregated to 14 basic commodity groupings. VIUS is used to develop payload factors by commodity group and by length of haul groups, and these payload factors are applied to the tonnage flows to convert to truck trips.

Payload factors developed in the FAF using the four steps described in the Conversion section of this case study are summarized in Table 8.19. The resulting payload factors are adjusted for observed vehicle weights from VIUS.

Assignment

Network attributes on the FAF highway network are from the HPMS, NHPN, and state department of transportation data. Each highway link contains, at a minimum, a travel time and a capacity. The highway capacity is used in the evaluation of routes used, but not in the assignment process. Since all-or-nothing assignments assume that all trips are assigned to the shortest path and do not reflect congestion and other mitigating effects, the assignments were carefully checked.

The assignment uses a preload process for nonfreight (local) trucks and passenger traffic to account for congestion as a result of non-commodity-carrying trucks. Figure 8.6 illustrates the results of assigning the 1998 base truck table to the highway network.

Model Validation

Trip Generation

Not applicable.

Trip Distribution

Not applicable.

Mode Choice

Since the mode choice is based on the surveyed existing mode shares, validation of the mode choice is not applicable.

Modal Assignment

While there is no validation of the assignment of FAF, freight flows in terms of trucks may be compared to observed trucks on the network. This can only serve as an indicator of the performance of the FAF because there is no way to know how many of the total trucks are actually commodity-carrying trucks, the only type accounted for by FAF.

No data is available to validate the railroad or waterway assignments because no source of independent observations exists that can be used in validation.

Model Application

FAF is a comprehensive national freight flow model. As such, it is used at all levels of government. FAF provides information for Federal, state, and local transportation agencies to allow them to determine which transportation corridors will become heavily congested in the future and to better plan congestion relief measures.

Federal applications of FAF utilize the commodity flow data between states, major urban centers, major ports, and border crossings. Some states use the state-to-state flows to estimate the through-movement of freight (the county-to-county

Table 8.19. Payload factors by STCC and truck type.

Commodity	STCC	Single Unit Trucks			Semi-Trailer			Double Trailers			Triples		
		Initial	Refined	Percent Difference	Initial	Refined	Percent Difference	Initial	Refined	Percent Difference	Initial	Refined	Percent Difference
Farm Products	1	6.1	12.2	-101.81	21.3	39.7	-85.78	28.1	49.3	-75.72	9.8	41.3	-320.03
Forestry and Other Products	8	7.7	12.5	-62.56	27.1	46.8	-72.44	35.7	60.9	-70.52	12.5	61.5	-392.48
Fresh Fish or Marine Products	9	6.1			21.3			28.1			9.8		
Metallic Ores	10	8.6			30.4			40.0			14.0		
Coal	11	8.6			30.4			40.0			14.0		
Mining Products	14	8.6	20.5	-138.04	30.4	45.3	-49.06	40.0	20.5	48.65	14.0		100
Ordnance or Accessories	19	7.6			26.7			35.2			12.3		
Processed Foods	20	6.5	7.7	-17.89	23.1	33.5	-45.3	30.4	35.9	-18.15	10.6		100
Tobacco Products	21	6.2			21.8			28.7			10.0		
Textile Mill Products	22	6.1	4.7	22.15	21.3	30.2	-41.51	28.1	38.3	-36.33	9.8		100
Apparel or Related Products	23	4.6			16.2			21.3			7.4		
Lumber and Fabricated Products	24	7.7	8.3	-8.07	27.1	37.1	-36.86	35.7	48.1	-34.58	12.5		100
Furniture or Hardware	25	4.2	4.0	5.35	14.8	28.3	-91.6	19.4	35.0	-80.08	6.8		100
Paper Products	26	6.8	7.4	-8.15	24.0	34.3	-43.26	31.5	31.8	-0.68	11.0	12.5	-13.33
Printed Matter	27	5.1			17.9			23.5			8.2		
Chemicals	28	6.2	10.4	-67.59	21.8	38.9	-78.03	28.7	50.3	-74.98	10.0		100
Petroleum	29	7.9	12.5	-57.81	27.8	47.3	-69.79	36.6	52.3	-42.67	12.8		100
Plastics and/or Rubber	30	3.4	5.8	-72.44	11.9	32.6	-173.37	15.7	29.4	-87.07	5.5	54.0	-883.92
Leather or Leather Products	31	4.2			14.6			19.3			6.7		
Building Materials	32	5.2	18.8	-257.85	18.5	42.1	-127.72	24.3	48.5	-99.23	8.5	62.4	-633.18

(continued on next page)

Table 8.19. (Continued).

		Single Unit Trucks			Semi-Trailer			Double Trailers			Triples		
Commodity	**STCC**	**Initial**	**Refined**	**Percent Difference**	**Initial**	**Refined**	**Percent Difference**	**Initial**	**Refined**	**Percent Difference**	**Initial**	**Refined**	**Percent Difference**
Primary Metal Products	33	7.3	6.5	10.49	25.7	37.9	-47.15	33.8	54.2	-60.27	11.8		100
Fabricated Metal Products	34	5.2	5.0	5.3	18.5	35.3	-90.99	24.3	26.1	-7.53	8.5		100
Machinery	35	4.0	6.5	-63.52	14.0	33.1	-136.51	18.4	35.4	-91.74	6.4		100
Electrical Equipment	36	4.7			16.7			21.9			7.7		
Transportation Equipment	37	4.1	5.3	-28.72	14.6	33.3	-128.36	19.2	31.9	-66.54	6.7	12.5	-86.48
Instruments, Photo Equipment, Optical	38	3.6			12.5			16.5			5.8		
Miscellaneious products of Manufacturing	39	5.4	5.6	-3.21	19.1	33.4	-75.06	25.1	28.9	-15.06	8.8		100
Scrap, Refuse or Garbage	40	6.0	13.2	-121.23	21.1	36.6	-73.63	27.7	45.9	-65.38	9.7		100
Mixed cargo	41	5.9	5.5	5.56	20.7	33.3	-60.79	27.3	32.4	-18.85	9.5	16.1	-68.88
Average payload		6.0	8.9	-50.53	21.1	36.6	-80.38	27.7	39.2	-47.2	9.7	37.2	-63.07

Source: Freight Analysis Framework Highway Capacity Analysis Methodology Report, April 2002, Table 4-3.

Source: Freight Analysis Framework Highway Capacity Analysis Methodology Report, April 2002, Figure 2.

Figure 8.6. Freight Analysis Framework highway network assignment.

flows are not available for public release). States also can identify key flows to major trading partners. Metropolitan and rural areas also may use the commodity flows for county or local planning purposes.

Performance Measures

Transportation system performance measures available from the FAF are limited primarily to truck vehicle-miles of travel by highway level of service. Truck travel times can be imputed based on relationships between volume, capacity, and speed. FAF outputs can support estimation of a variety of other performance measures.

8.6 Case Study – New Jersey Statewide Model Truck Trip Table Update Project

Background

Context

Geographically, New Jersey is among the smallest states in the union, yet it ranks ninth in terms of total population and first in terms of population density. New Jersey's density is even greater than that of the Netherlands, the most densely populated country in Europe. New Jersey is a major industrial center and an important transportation corridor and terminus. In 2001 its gross state product was approximately $365 billion. The 1997 CFS showed $286 billion of goods shipments originating in New Jersey, representing 224 million tons. The 1997 CFS also indicated that 73% of those shipments by value and 85% by weight were moved by truck.

New Jersey is noted for its output of chemicals, pharmaceuticals, machinery, and a host of other products, including electronic equipment, printed materials, and processed foods. Bayonne is the terminus of pipelines originating in Texas and Oklahoma, and there are oil refineries at Linden and Carteret. Today, telecommunications and biotechnology are major industries in the state, and the area near Princeton has developed into a notable high-tech center. Finance, warehousing, and "big box" retailing also have become important to the state's economy, attracting corporations and shoppers and to a large extent reversing New Jersey's onetime role as a suburb for commuters to New York City and Philadelphia.

An extensive transportation system, concentrated in the industrial lowlands, moves products and a huge volume of interstate traffic through the state. Busy highways like the Garden State Parkway and the New Jersey Turnpike are part of a network of toll roads and freeways. New Jersey is linked to Delaware and Pennsylvania by many bridges across the Delaware River. Traffic to and from New York is served by railway and subway tunnels and by the facilities of the Port Authority of New York and New Jersey. These include the George Washington Bridge, the Lincoln and Holland vehicular tunnels, and three bridges to Staten Island. Airports are operated by many cities, and Newark Airport (controlled by the Port Authority) ranks among the nation's busiest. Shipping in New Jersey centers on the ports of Newark Bay and New York Bay areas, notably Port Newark and Port Elizabeth, with relatively minor seagoing traffic on the Delaware River as far north as Trenton.

Objective and Purpose of the Model

As part of a study titled *Effects of Interstate Completion and Other Major Improvements on Regional Trip Making and Goods Movement* undertaken by the New Jersey Department of Transportation (NJDOT), a truck trip table was developed to study truck trips as one component of the statewide transportation model. A major impact on regional truck trips was expected after the completion of I-287 in northern New Jersey and the completion of the remaining section of I-295 in the Greater Trenton Area. The revised New Jersey Truck Model is an update of the previously existing truck trip model.[20]

General Approach

Model Class

As a truck model, the New Jersey Truck Model develops highway freight truck flows by assigning an O-D table of freight truck flows to a highway network. The O-D table is produced by applying truck trip generation and distribution steps to existing and forecast employment or other variables of economic activity for analysis zones. A detailed description of the Truck Model, including its components is included in Section 6.3.

Modes

By definition, truck models like New Jersey's deal with freight served only by the truck mode.

Markets

Analysis of the trip table and the assignment results from the previous truck model indicated that key market segments critical to painting a comprehensive picture of truck travel in New Jersey were missing. Primary commodity flows were included in the data, but not the subsequent truck trips used to distribute the commodities to the individual users and retail outlets. Excluded were distribution-related truck traffic as well as other flows, such as express air delivery services and municipal water. The revised New Jersey Truck Model was developed to include all these important components of truck traffic.

Framework

The original truck trip table for the New Jersey Statewide Model was estimated through the use of commodity data provided by DRI-McGraw Hill. Truck trips were estimated by converting the tonnage data into truck trips using custom algorithms provided by Gellman Research. These trips were estimated at the county level and then disaggregated to the zonal level using employment data. New Jersey previously had a commodity flow-based model and the truck trip table was developed outside the modeling process and imported into the model system.

The revised New Jersey Truck Model was developed at the zonal level using traditional modeling techniques. It was assumed these techniques would provide a reasonable estimate of short distance, delivery-type trips not within the commodity-based trip table. The zonal-level trips were estimated as a function of employment by type, the number of households, and area type. The distribution of these trips was performed with standard gravity model techniques.

Flow Units

As a truck model, the flow units are average weekday truck trips and volumes.

Data

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

For trip generation, the observed data was obtained from a number of sources. At highway-based external zones, external trips were generated using observed data and 24-hour count data provided by several agencies, including the NJDOT, the New York Department of Transportation, the Delaware Department of Transportation, and the Delaware Valley Regional Planning Commission. The observed data for intermodal terminals were more difficult to obtain. Since most of the needed information was proprietary in nature, the available data were fairly aggregate. The observed data for all rail intermodal terminals in the New York metropolitan area were estimated by site using information provided by the New York/New Jersey Port Authority. In addition, 1990 U.S. Census Bureau data was used to obtain sociodemographic information. This information was supplemented with discussions with Port Authority staff and then allocated to the individual rail intermodal terminals.

EXTERNAL MARKETS

For rail and marine intermodal terminals near Philadelphia, data was obtained from the Pennsylvania Intermodal

Management System Phase II report provided by Delaware Valley Regional Planning Commission. In several cases, commodity tonnages were converted to equivalent truck trips by Gellman Research Associates. Truck trips from South Jersey port facilities near Philadelphia were obtained through discussions with Delaware River Port Authority staff and local operators. For Kennedy International Airport in New York, crude estimates of truck trips and overall commodity tonnages were available.

Modal Networks

FREIGHT MODAL NETWORKS

The existing New Jersey Statewide Model's highway network was used for the revised truck model without modification.

INTERMODAL TERMINAL DATA

For rail and marine intermodal terminals near Philadelphia, data was obtained from the Pennsylvania Intermodal Management System Phase II report. In several cases, commodity tonnages were converted to equivalent truck trips. Truck trips from South Jersey port facilities near Philadelphia were obtained through discussions with Delaware River Port Authority staff and local operators. For Kennedy International Airport, crude estimates of truck trips and overall commodity tonnages were available.

Model Development Data

The trip generation and distribution rates and coefficients were developed using survey data

Conversion Data

Because truck models that forecast daily truck trips require no conversion factors, no data was necessary.

Validation Data

See the section on model validation.

Model Development

Software

The revised truck model was developed using TRANPLAN software and custom FORTRAN scripts. In addition, spreadsheets also were used for the model development. These modules will be discussed more fully in the individual sections on the model components in the revised truck model.

Commodity Groups/Truck Types

No commodity groups were used. Trucks were split into two categories based on weight, medium and heavy. Medium trucks were defined as all two-axle, six-tire trucks with weights generally between 8,000 and 28,000 pounds. Heavy trucks were defined as all trucks with three or more axles and weights greater than 28,000 pounds.

Trip Generation

The revised trip generation process divided external truck trips into three categories in order to provide a flexible method for resolving inconsistencies between aggregate commodity flows and survey data. External trips were designated as either external-external (E-E) through-trips or external-internal (E-I) trips with at least one stop inside the statewide model region. External-internal trips were then further stratified into singular E-I trips or external trips that stopped at a truck terminal and then continued their trip, eventually leaving the region. These trips were referred to as external-internal-external (E-I-E) trips.

The revised New Jersey Truck Model also focused on major truck trip generators that would be poorly represented by employment-based trip generation equations. These special generators were categorized into two groups. The first group covered all large generators that carried commodity flows (in the form of containers or trailers) out of the region. Large generators were generally intermodal facilities (rail intermodal yards, ports, and airports) and were designated as "external zones" or entry points into the region.

The second category of special generators was geared to internal sites that would service primarily local truck trips. This category was initially designed to include sites such as landfills, pipeline terminals, petroleum refineries, truck terminals, and warehouses. The final model restricted this category to truck terminals, warehouses, and pipelines.

Under the revised approach, truck trips generated at the external boundary of the five region statewide model would be estimated with data provided by the individual state departments of transportation and selected agencies. The revised approach also utilized the available survey data to the maximum extent possible. For many external zones at the major interstate routes, cordon surveys were available to estimate trucks by vehicle type as well as type of movement (through, internal-external, external-internal). At other locations, only daily traffic estimates were available to control travel into the region.

The trip generation process estimated truck trips generated within the five region study area as well as in the adjacent regions. Internally, trip generation was performed at the zonal level using employment, households, and truck terminals as the independent variables. For trips generated outside the region, a series of external zones was developed that represented entry points into the region. These entry points included both stations at major highways at the border of the region, as well as intermodal terminals within the region.

The revised trip generation process was structured to estimate truck trips primarily as a function of employment. Special generators, in the form of truck terminals, warehouses, and pipeline terminals, were utilized for conditions where the typical employment relationships would poorly estimate truck trips. In addition, the truck terminals served as attractors for a portion of the long-haul truck trips entering the study area from the adjacent regions. Truck trips were generated separately for medium and heavy trucks.

Total external trip travel was divided into three categories in order to provide a flexible method for resolving inconsistencies between aggregate commodity flows and survey data. External trips were designated as either E-E (through trips) or E-I. E-I trips were further stratified into singular E-I trips or external trips that stopped at a truck terminal and then continued on, eventually leaving the region. These trips were called E-I-E trips.

Wherever possible, truck trip surveys were used to allocate truck trips to the E-E market segment. The revised forecasting process was developed to utilize the survey data in an efficient and flexible manner. The process was structured to have two layers of E-E travel patterns. These patterns form the basis of simulating E-E truck trips across the region. The first layer, referred to as primary E-E patterns, included E-E movements obtained from all survey-related information. The second layer, called secondary E-E patterns, provided movements based on the analyst's professional judgment. The truck trip generation program processed both sets of these patterns, allowing the primary patterns to govern secondary patterns in the case of duplicate movements.

Total E-I trips were calculated by subtracting the estimated E-E trips from the total truck volumes at each external zone. This calculation was performed for each truck type. As part of the revised truck trip generation process, a procedure was developed to estimate a portion of the E-I trips that went to an intermediate transfer point, such as a truck terminal of a major trucking company. At this location, cargo would be transferred between vehicles for subsequent shipment. After leaving the truck terminal, these trips were assumed to continue traveling to an external zone in order to reach a final destination outside the region. These trips are the E-I-E trips.

The E-I-E trips were created to account for a perceived inconsistency between survey data and commodity data. The survey data accounts for the final destination of the truck trip, but not the ultimate destination of the commodity being shipped. In contrast, the commodity data has the true origin and destination of the commodity being shipped, but does not provide any information on the actual route and/or intermediate transfer points.

Since it was not possible to estimate the E-I-E trips directly, these trips were estimated by assuming that 25% of the E-E trips on interstate facilities were E-I-E trips. This process was limited to external zones representing interstate highways since it was assumed that long-distance truck travel would most likely approach the region using these routes. In addition, it was anticipated that major trucking firms would locate their major terminals near these facilities, which would increase the likelihood that these trips would use the interstate routes.

After removing the E-E and E-I-E truck trips from the external truck counts, the remaining truck trips were designated as highway-based E-I trips. These trips then were divided into both the medium and heavy truck categories based on survey data. E-I trips also were generated at the intermodal facilities, since the airports, rail yards, and ports were designated as external entry points into the modeled region. The majority of all rail intermodal truck trips was assumed to be E-I, as were most of the air intermodal movements generated by the regional airports. Using the available survey data, a significant portion of all the port and airport intermodal traffic also was designated as E-I trips.

The calibration process yielded the following equation:

$$\mathrm{EITRKP}_i = 0.003192 * \sum(\mathrm{EITRK}_j / \mathrm{TIME}_{ij} **2.0) - 0.00998$$

where

EITRKP_i = Percentage of truck trip ends at internal zone i that are E-I,

EITRK_j = Volume of E-I truck trips at external station j, and

TIME_{ij} = Travel time from internal zone i to external station j.

The regression results provided a statistically significant model with an *R*-squared value of 0.43. Due to this low value, the coefficients from the Delaware Valley Regional Planning Commission (DVRPC) regression were adopted for use in this model.

The attraction equation was stratified by truck type. This was performed since it is assumed that there should be some variation in the E-I attraction percentages for each zone by truck type. The final attraction equation is:

$$\mathrm{EITRKP}_{im} = 0.003192 * \sum(\mathrm{EITRK}_j/\mathrm{TIME}_{ij} ** \mathrm{EXP}_m) - 0.00998$$

where

EITRKP_{im} = Percentage of trip ends for truck mode m at internal zone i that are E-I,

EITRK_j = Volume of E-I truck trips at external station j,

TIME_{ij} = Travel time from internal zone i to external station j, and

EXP_m = Exponential term for truck type m (heavy = 2, medium = 2.1).

The revised truck trip generation process requires employment data by type and household data for each of the internal study area zones. The employment types used for the New Jersey Truck Model are shown below, where SIC refers to the Standard Industrial Classification:

- Retail (SIC Codes 52-59);
- Industrial (SIC Codes 20-39);
- Public (SIC Codes 91-98);
- Office (SIC Codes 60-89); and
- Other (SIC Codes 1-19, 40-51).

This data for each of the five regions was prepared for the 1990 base year using several data sources. Within New Jersey, Pennsylvania, and Delaware, demographic data was provided from the existing metropolitan planning organization models. For New York, this data was obtained from the 1990 U.S. Census Bureau Census Transportation Planning Package data. Table 8.20 shows the internal truck trip generation rates.

The final element of internal truck trip generation is special generator sites. The revised trip generation approach provided a mechanism to independently simulate major truck trip generators that would be poorly represented by employment-based trip generation equations. For internal trips, special generators related primarily to local truck trips were coded in several ways. First, a special generator could

Table 8.20. Internal truck trip rates (New Jersey Department of Transportation Statewide Model).

	Model				Final New Jersey Truck Model
Variable	**Phoenix (1991)[a]**	**Washington, D.C.**	**Vancouver[b]**	**San Francisco (1993)[c]**	
Equations and Coefficients (Heavy Trucks)					
Retail Employment	0.0615	0.0300		0.0001	0.0590
Industrial Employment	0.0833	0.0300	0.0665	0.0293	0.0800
Public Employment	0.0400	0.0200		0.0220	0.0384
Office Employment	0.0053	0.0200	0.1640	0.0220	0.1207
Total Employment				0.0112	
Households	0.0210				0.0202

[a] Trucks over 28,000 pounds – attraction rates only.

[b] Trucks over 44,000 pounds.

[c] Assumed three- and four-axle truck rates are "heavy truck"– production rates only.

	Model				Final New Jersey Truck Model
Variable	**Phoenix (1991)[a]**	**Washington, D.C.**	**Vancouver[b]**	**San Francisco (1993)[c]**	
Equations and Coefficients (Medium Trucks)					
Retail Employment	0.2213	0.1700	0.0212	0.0140	0.1264
Industrial Employment	0.1665	0.1400	0.0212	0.0110	0.0522
Public Employment	0.0100	0.0400	0.0212	0.0460	0.0032
Office Employment	0.0354	0.0100	0.0212	0.0105	0.0202
Total Employment				0.0324	
Households	0.1145	0.0400	0.0041		0.0240

Source: URS Greiner Woodward Clyde, "Statewide Model Truck Trip Table Update Project," prepared for the New Jersey Department of Transportation, January 1999.

[a] Trucks between 8,000 and 28,000 pounds – attraction rates only.

[b] Trucks between 9,000 and 44,000 pounds.

[c] Assumed two-axles are "medium trucks"– production rates only.

be designated as one of several special categories for which default trip generation rates were available. Currently, only truck terminals and pipeline terminals are available as default special generators. In addition to these categories, a generic special generator field is provided for each zone in order to code zone-specific generators that have truly unique characteristics.

Trip Distribution

For the revised New Jersey Truck Model, truck trip distribution was performed with standard gravity model techniques, using highway travel time to represent the spatial separation between zones.

Internal trip distribution was performed using a synthetic data set derived from the 1991 Phoenix Truck Model Update Project. This data was as an observed distribution, adjusted as necessary to establish a reasonable target for the calibration process for both medium and heavy truck trips. Trip distribution for E-I and E-I-E trips was based on truck cordon surveys conducted by the Port of New York/New Jersey and NJDOT. The survey-based distribution patterns were modified to yield average travel times approximately 30% less than the observed times.

Intermodal E-I trip distribution was performed as a separate process. This was necessary since observed patterns, in terms of average travel times, were significantly different from E-I highway-based observed data. The E-I intermodal distribution was based on an attractiveness measure developed using truck terminals, warehouses, and industrial employment. An average observed travel time of 37.2 minutes was used for all intermodal trips, including those generated by the intermodal rail yards and airports, since distribution data for these facilities was not available. Table 8.21 shows observed truck trip distribution.

The Port Newark/Elizabeth Port complex is an extremely large generator of truck trips. Information provided by the Port Authority indicates that approximately 17,000 trucks enter or exit the site on a daily basis. For this reason, the distribution calibration also focused on replicating the travel patterns generated by the port traffic. Table 8.22 shows the estimated and observed distribution of truck trips related to Port Newark/Port Elizabeth.

Commodity Trip Table

A commodity trip table was not used.

Mode Split

Because the model only addresses freight carried by trucks and the forecasting unit is daily truck trips, not annual tons, this step is not needed.

Flow Unit and Time Period Conversion

Because the model class only addresses freight carried by trucks and the forecasting unit is daily truck trips, not annual tons, this step is not needed.

Assignment

The highway assignment of the daily truck table was an equilibrium multiclass process that loaded the daily auto and truck trips by type to the highway network. Prior to the actual assignment, the network links were posted with the free flow speed and capacities necessary for the TRANPLAN equilibrium routine. For all toll links, capacities were set to zero. For all time penalty links such as left turn movements, the time values were hard-coded into the assignment control and the

Table 8.21. Truck distribution average time in minutes.

	Truck Trip Type					
	Internal-Internal		External-Internal		Total	
Study	Medium	Heavy	Medium	Heavy	Medium	Heavy
San Francisco (Alameda County)	16-24	22-31	54	59		
Phoenix (Maricopa County)					12	19
Vancouver					12	18
New Jersey Cordon Surveys	44	52	77	84		
New Jersey Observed Values	14.6	26.3	60.3	74.4		
Current Estimates	18.2	32.9	51.7	76.7		

Source: URS Greiner Woodward Clyde, "Statewide Model Truck Trip Table Update Project," prepared for the New Jersey Department of Transportation, January 1999.

Table 8.22. External and internal trip origins for Port Newark/Port Elizabeth.

Origin of Trip	Heavy Truck		Medium Truck		Total Truck		
	Volume	Percent	Volume	Percent	Volume	Percent	Observed
Bergen	364	5.22%	125	7.63%	489	5.68%	3.99%
Essex	652	9.36%	256	15.63%	908	10.55%	14.49%
Hudson	1,060	15.21%	413	25.21%	1,473	17.12%	19.20%
Hunterdon	47	0.67%	20	1.22%	67	0.78%	0.00%
Middlesex	674	9.67%	288	17.58%	962	11.18%	4.35%
Monmouth	38	0.55%	13	0.79%	51	0.59%	0.36%
Morris	62	0.89%	19	1.16%	81	0.94%	1.09%
Ocean	13	0.19%	5	0.31%	18	0.21%	0.00%
Passaic	328	4.71%	138	8.42%	466	5.41%	0.36%
Somerset	103	1.48%	43	2.63%	146	1.70%	0.00%
Sussex	0	0.00%	0	0.00%	0	0.00%	0.00%
Union	279	4.00%	109	6.65%	388	4.51%	7.61%
Warren	3	0.04%	0	0.00%	3	0.03%	0.36%
New York City Remainder	114	1.64%	72	4.40%	186	2.16%	5.80%
Orange	3	0.04%	0	0.00%	3	0.03%	0.72%
Atlantic	0	0.00%	1	0.06%	1	0.01%	0.36%
Cape May	0	0.00%	0	0.00%	0	0.00%	0.36%
Cumberland	1	0.01%	0	0.00%	1	0.01%	
Salem	0	0.00%	0	0.00%	0	0.00%	0.36%
Gloucester	3	0.04%	2	0.12%	5	0.06%	
Camden	20	0.29%	7	0.43%	27	0.31%	0.36%
Burlington	13	0.19%	5	0.31%	18	0.21%	0.36%
Mercer	41	0.59%	16	0.98%	57	0.66%	1.09%
Others	3,150	45.21%	106	6.47%	3,256	37.83%	36.77%
Total	**6,968**	**100.00%**	**1,638**	**100.00%**	**8,606**	**100.00%**	**100.00%**

Source: URS Greiner Woodward Clyde, "Statewide Model Truck Trip Table Update Project," prepared for the New Jersey Department of Transportation, January 1999.

capacity was set to zero. With this approach, the time penalty was held constant for each iteration of the assignment. The time penalties were used only for medium or heavy truck trips.

The assignment simultaneously loaded the auto trips, medium truck trips and heavy truck trips. The loading of each of these trip types was restricted to links permitted to carry these vehicle types. Toll links for each vehicle type also were coded in the network for all toll facilities in New Jersey.

Model Validation

Trip Generation

Using the Phoenix values and definitions as a starting point, truck trips were estimated and summed together with the truck terminal special generators. As part of the overall validation, it became necessary to substantially reduce the trip generation rates for medium trucks. This was primarily done to limit total medium VMT. The total truck trip is approximately 3.9% of total trip generation in the region.

Trip Distribution

The trip distribution validation required several adjustments to the modeling process. In order to provide reasonable travel times, it was necessary to adjust the highway travel skim estimates. This adjustment was performed by reducing the speed for non-freeway facilities in the central business district and urban area types. For the suburban and rural area types, speeds were reduced 10% on expressway facilities and 25% on all other facilities.

A penalty of 10 minutes was assessed for all skims that utilized the trans-Hudson bridges between New Jersey and New York. These penalties are considered as surrogates for both the impacts of tolls and excessive congestion at these facilities. A set of corrective K-factors was added to the E-I highway-based truck trips. These K-factors were applied specifically for external stations on the western side of Philadelphia not included in the model and approaching New Jersey via I-78. K-factors also were applied to the reverse movement to reduce similar trips moving in the other direction. The K-factors were included directly in the trip distribution controls.

Mode Choice

Not applicable for this class of model since no mode split component is included.

Modal Assignment

The validation of the revised model approach focused primarily on aggregate VMT statistics by facility type and area type. The validation provided separate summaries of trips by vehicle type, including medium, heavy, and total trucks, as well as total vehicles. Site-specific validation analysis was performed for key interstate facilities and major river crossings. This validation analysis indicates that the model is replicating observed statistics reasonably well at the aggregate level.

Overall, the regionwide estimated VMT for the truck highway assignment was 3.9% greater than the observed VMT. As shown in Table 8.23, comparisons by area and facility type

Table 8.23. Model estimates of truck VMT by area and facility type.

		Central Business District 1	Urban 2	Suburban 3	Rural 4
Heavy Truck Percentages					
Freeway	1	8.5	11.0	12.0	10.5
Expressway	2	7.5	8.0	11.5	8.0
Principal Divided	3	6.0	10.0	6.0	7.5
Principal Undivided	4	5.8	6.0	5.5	6.0
Major Divided	5	4.7	7.0	5.0	6.0
Major Undivided	6	4.6	7.0	4.0	5.0
Minor	7	4.5	8.0	5.0	4.0
Collector-Local	8	4.5	8.0	5.0	4.0
Medium Truck Percentages					
Freeway	1	1.1	1.4	1.6	1.4
Expressway	2	1.0	1.0	1.5	1.0
Principal Divided	3	1.6	2.6	1.6	2.0
Principal Undivided	4	1.5	1.6	1.4	1.6
Major Divided	5	1.2	1.8	1.3	1.6
Major Undivided	6	1.2	1.8	1.0	1.3
Minor	7	1.5	2.6	1.7	1.3
Collector-Local	8	1.5	2.6	1.7	1.3
Total Truck Percentages					
Freeway	1	7.4	9.6	10.4	9.1
Expressway	2	6.5	7.0	10.0	7.0
Principal Divided	3	4.4	7.4	4.4	5.5
Principal Undivided	4	4.3	4.4	4.1	4.4
Major Divided	5	3.5	5.2	3.7	4.4
Major Undivided	6	3.3	5.2	3.0	3.7
Minor	7	3.0	5.4	3.3	2.7
Collector-Local	8	3.0	5.4	3.3	2.7

Source: URS Greiner Woodward Clyde, “Statewide Model Truck Trip Table Update Project,” prepared for the New Jersey Department of Transportation, January 1999.

were also made. For each of the area types, the assignment difference was within 5%, while comparisons by facility type indicated that the differences were mostly within the ± 10% range. At the regional level, the assignment differences for both medium and heavy trucks were within 1%, which is quite reasonable. By area type, the differences between both truck types were within approximately 10%, while by facility type the differences were within 20%. In general, the model replicates heavy truck trips with less variation than medium truck trips, which is important considering that the heavy truck VMT is a higher percentage of total VMT than the medium truck category. Finally, Table 8.24 shows the examination of the root mean square error (RMSE) term. The percent deviations are smaller for the large volume roadways, but increase in magnitude as traffic decreases.

Model Application

As of this writing, the revised New Jersey Truck Model is being used as a component of the Statewide Travel Demand Model to produce aggregate-level VMT statistics by facility type and area type for use in planning and air quality studies.

Performance Measures and Evaluation

In order to gauge how the model performs and reacts to policy changes such as toll increases and network changes, the study performed three types of sensitivity analyses:

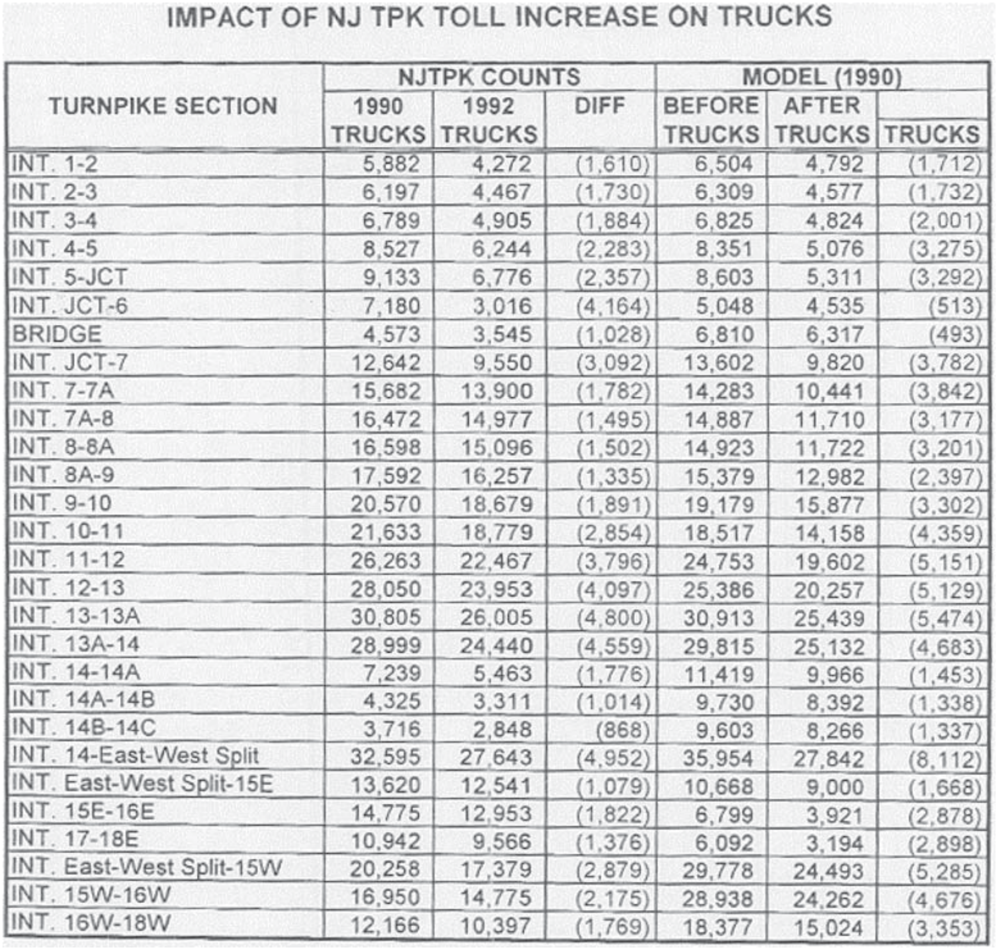
- **Toll Sensitivity Run:** To mimic the toll increase for trucks in the New Jersey Turnpike at the end of 1991;
- **I-287 Completion:** To analyze the impact of the completion of the northern section of I-287 on the highway network; and
- **Trenton Complex Completion:** To analyze the impact of the Trenton Complex Projection on the highway network.

The toll sensitivity analysis was performed by doubling the truck toll costs along the New Jersey Turnpike. Figure 8.7 shows the results of the toll sensitivity run. The before and

Table 8.24. RMSE by volume group.

Volume Group	Number of Observations	Average Observations	Average Estimate	R-Squared	RMS Percent	Percent Deviation
Total Traffic						
> 80,000	30	90,270	88,224	0.5812	7.8	6.0
70,001-80,000	12	71,989	70,937	0.7864	26.9	20.0
60,001-70,000	43	64,724	67,357	0.1050	22.5	18.2
50,001-60,000	54	55,209	57,900	0.0055	22.8	18.5
40,001-50,000	94	44,963	48,682	0.1177	32.6	24.3
30,001-40,000	159	34,295	38,763	0.0063	41.8	30.5
20,001-30,000	232	25,323	26,359	0.0002	44.9	26.9
10,001-20,000	485	13,955	15,718	0.1684	51.9	35.9
1-10,000	1,077	5,211	5,863	0.3159	78.5	50.8
Total	**2,185**	**17,050**	**18,411**	**0.8334**	**48.4**	**29.4**
Total Trucks						
> 8,000	32	10,738	10,840	0.5336	21.1	13.9
7,001-8,000	13	7,455	5,639	0.0312	39.2	33.4
6,001-7,000	55	6,493	5,778	0.1891	31.7	23.4
5,001-6,000	56	5,446	4,576	0.0585	28.8	25.0
4,001-5,000	82	4,464	4,271	0.0179	27.6	21.8
3,001-4,000	122	3,438	3,078	0.0244	37.9	29.0
2,001-3,000	107	2,501	2,788	0.0068	78.1	44.6
1,001-2,000	285	1,414	1,585	0.0771	65.1	45.4
1-1,000	1,373	368	440	0.3820	105.4	65.1
Total	**2,125**	**1,442**	**1,447**	**0.8100**	**64.0**	**35.0**

Source: URS Greiner Woodward Clyde, "Statewide Model Truck Trip Table Update Project," prepared for the New Jersey Department of Transportation, January 1999.



IMPACT OF NJ TPK TOLL INCREASE ON TRUCKS

TURNPIKE SECTION	NJTPK COUNTS			MODEL (1990)		
	1990 TRUCKS	1992 TRUCKS	DIFF	BEFORE TRUCKS	AFTER TRUCKS	TRUCKS
INT. 1-2	5,882	4,272	(1,610)	6,504	4,792	(1,712)
INT. 2-3	6,197	4,467	(1,730)	6,309	4,577	(1,732)
INT. 3-4	6,789	4,905	(1,884)	6,825	4,824	(2,001)
INT. 4-5	8,527	6,244	(2,283)	8,351	5,076	(3,275)
INT. 5-JCT	9,133	6,776	(2,357)	8,603	5,311	(3,292)
INT. JCT-6	7,180	3,016	(4,164)	5,048	4,535	(513)
BRIDGE	4,573	3,545	(1,028)	6,810	6,317	(493)
INT. JCT-7	12,642	9,550	(3,092)	13,602	9,820	(3,782)
INT. 7-7A	15,682	13,900	(1,782)	14,283	10,441	(3,842)
INT. 7A-8	16,472	14,977	(1,495)	14,887	11,710	(3,177)
INT. 8-8A	16,598	15,096	(1,502)	14,923	11,722	(3,201)
INT. 8A-9	17,592	16,257	(1,335)	15,379	12,982	(2,397)
INT. 9-10	20,570	18,679	(1,891)	19,179	15,877	(3,302)
INT. 10-11	21,633	18,779	(2,854)	18,517	14,158	(4,359)
INT. 11-12	26,263	22,467	(3,796)	24,753	19,602	(5,151)
INT. 12-13	28,050	23,953	(4,097)	25,386	20,257	(5,129)
INT. 13-13A	30,805	26,005	(4,800)	30,913	25,439	(5,474)
INT. 13A-14	28,999	24,440	(4,559)	29,815	25,132	(4,683)
INT. 14-14A	7,239	5,463	(1,776)	11,419	9,966	(1,453)
INT. 14A-14B	4,325	3,311	(1,014)	9,730	8,392	(1,338)
INT. 14B-14C	3,716	2,848	(868)	9,603	8,266	(1,337)
INT. 14-East-West Split	32,595	27,643	(4,952)	35,954	27,842	(8,112)
INT. East-West Split-15E	13,620	12,541	(1,079)	10,668	9,000	(1,668)
INT. 15E-16E	14,775	12,953	(1,822)	6,799	3,921	(2,878)
INT. 17-18E	10,942	9,566	(1,376)	6,092	3,194	(2,898)
INT. East-West Split-15W	20,258	17,379	(2,879)	29,778	24,493	(5,285)
INT. 15W-16W	16,950	14,775	(2,175)	28,938	24,262	(4,676)
INT. 16W-18W	12,166	10,397	(1,769)	18,377	15,024	(3,353)

Figure 8.7. Impact of toll increase on trucks.

after counts were obtained from the New Jersey Turnpike Authority Traffic Volume Between Interchanges Summary. In general, the results point to a similar trend between the model's prediction and count data.

Figure 8.8 shows the results of the I-287 completion sensitivity analysis. Two sets of traffic counts were collected:

- Traffic counts just before the project was opened and traffic counts just after the project was opened; and
- Annual average daily traffic (AADT) counts along sections of the New Jersey Turnpike and Garden State Parkway.

The traffic volumes estimated by the model match the counts with a reasonable degree of accuracy.

The results of the Trenton Complex Project are shown in Figure 8.9. The total traffic volumes estimated by the model after the opening of the Trenton Complex match the counts with a reasonable degree of accuracy.

Overall, the model performs reasonably well and produces results reasonable for policy testing.

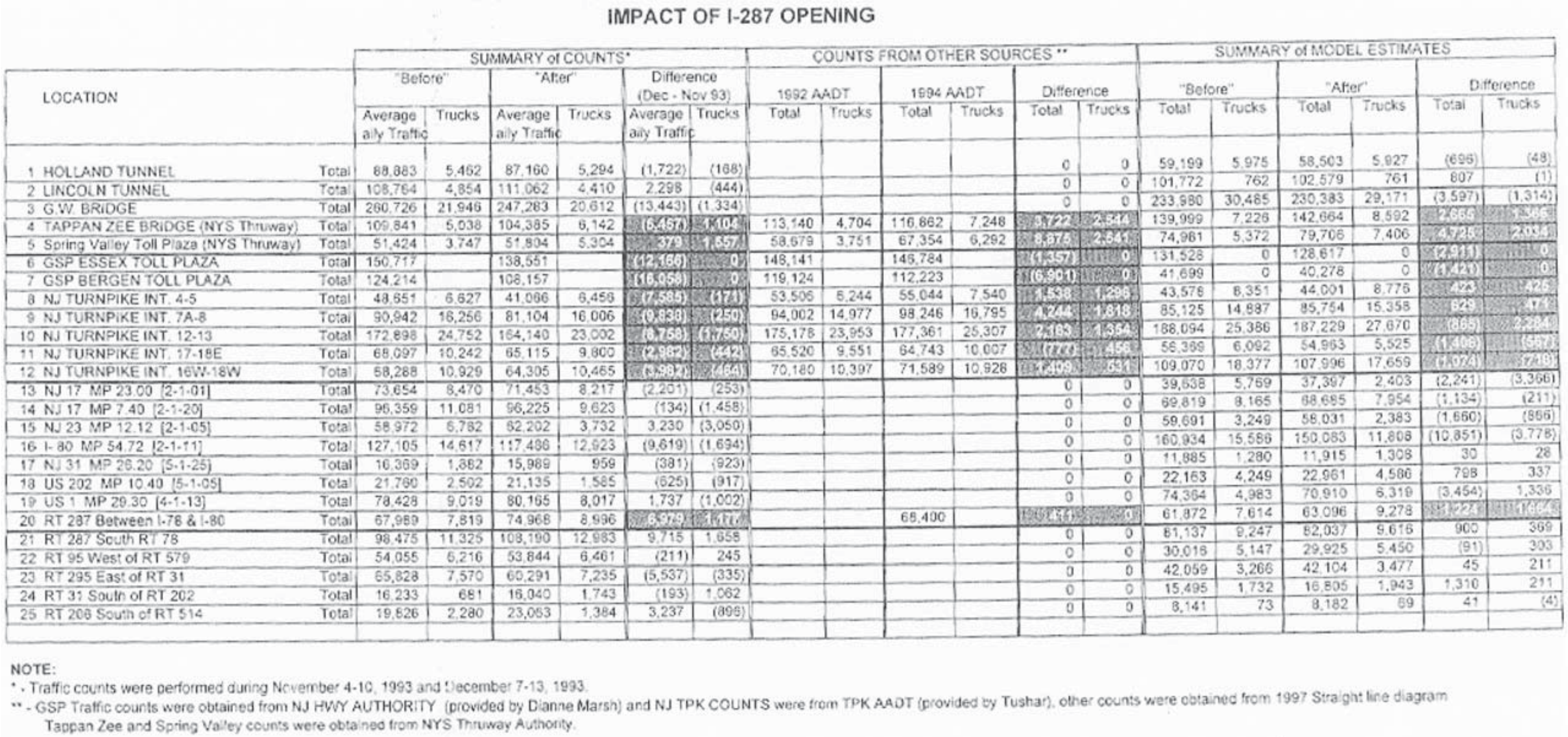
8.7 Case Study – SCAG Heavy-Duty Truck Model

Background

Context

The SCAG is the largest association of governments in the United States. SCAG functions as the MPO for six counties: Los Angeles, Orange, San Bernardino, Riverside, Ventura, and Imperial. This region encompasses a population exceeding 15 million people in an area of more than 38,000 square miles.

SCAG has a Regional Transportation Model (RTM) that is used in preparing forecasts of traffic volumes and speed and is used in transportation conformity analysis to demonstrate that air quality reductions required by the State Implementation Plan for Air Quality are being achieved. While the RTM had estimates of truck volumes and speeds, the California Air Resources Board (CARB), concerned about the impact of mobile source emissions on regional air quality, has been actively pursuing improvements to emissions models for



IMPACT OF I-287 OPENING

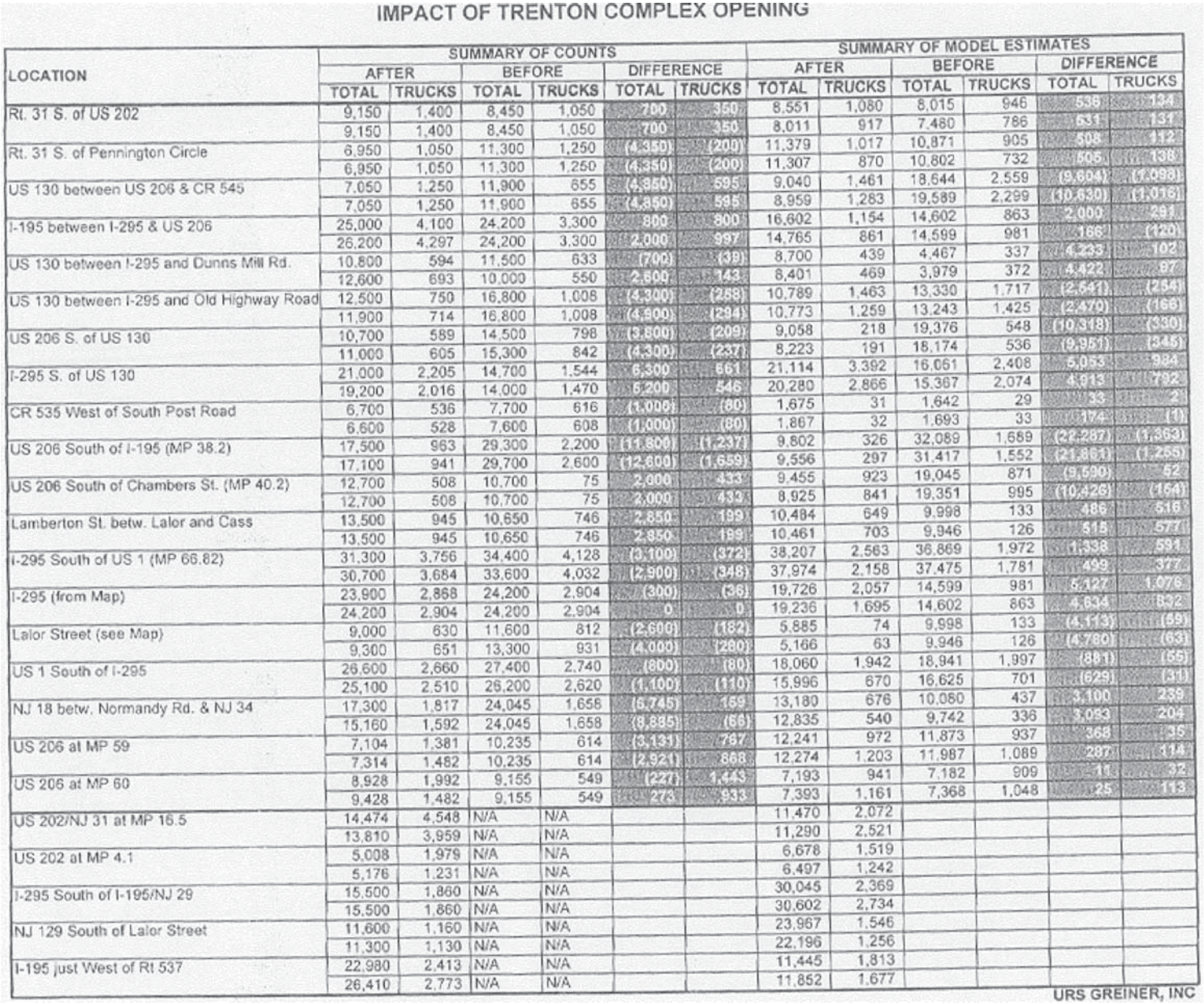
LOCATION		SUMMARY of COUNTS*						COUNTS FROM OTHER SOURCES **						SUMMARY of MODEL ESTIMATES					
		"Before"		"After"		Difference (Dec - Nov 93)		1992 AADT		1994 AADT		Difference		"Before"		"After"		Difference	
		Average aily Traffic	Trucks	Average aily Traffic	Trucks	Average aily Traffic	Trucks	Total	Trucks	Total	Trucks	Total	Trucks	Total	Trucks	Total	Trucks	Total	Trucks
1 HOLLAND TUNNEL	Total	88,883	5,462	87,160	5,294	(1,722)	(168)					0	0	59,199	5,975	58,503	5,927	(696)	(48)
2 LINCOLN TUNNEL	Total	108,764	4,854	111,062	4,410	2,298	(444)					0	0	101,772	762	102,579	761	807	(1)
3 G.W. BRIDGE	Total	260,726	21,946	247,283	20,612	(13,443)	(1,334)					0	0	233,980	30,485	230,383	29,171	(3,597)	(1,314)
4 TAPPAN ZEE BRIDGE (NYS Thruway)	Total	109,841	5,038	104,385	6,142	(6,457)	1,104	113,140	4,704	116,862	7,248	3,722	2,544	139,999	7,226	142,664	8,592	2,665	1,366
5 Spring Valley Toll Plaza (NYS Thruway)	Total	51,424	3,747	51,804	5,304	379	1,557	58,679	3,751	67,354	6,292	8,675	2,541	74,981	5,372	79,706	7,406	4,725	2,034
6 GSP ESSEX TOLL PLAZA	Total	150,717		138,551		(12,166)	0	148,141		146,784		(1,357)	0	131,528	0	128,617	0	(2,911)	0
7 GSP BERGEN TOLL PLAZA	Total	124,214		108,157		(16,058)	0	119,124		112,223		(6,901)	0	41,699	0	40,278	0	(1,421)	0
8 NJ TURNPIKE INT. 4-5	Total	48,651	6,627	41,066	6,456	(7,585)	(171)	53,506	6,244	55,044	7,540	1,538	1,296	43,578	8,351	44,001	8,776	423	425
9 NJ TURNPIKE INT. 7A-8	Total	90,942	16,256	81,104	16,006	(9,838)	(250)	94,002	14,977	98,246	16,795	4,244	1,818	85,125	14,887	85,754	15,358	629	471
10 NJ TURNPIKE INT. 12-13	Total	172,898	24,752	164,140	23,002	(8,758)	(1,750)	175,178	23,953	177,361	25,307	2,183	1,354	188,094	25,386	187,229	27,670	(865)	2,284
11 NJ TURNPIKE INT. 17-18E	Total	68,097	10,242	65,115	9,800	(2,982)	(442)	65,520	9,551	64,743	10,007	(777)	456	56,369	6,092	54,963	5,525	(1,406)	(567)
12 NJ TURNPIKE INT. 16W-18W	Total	58,288	10,929	64,305	10,465	(5,982)	(464)	70,180	10,397	71,589	10,928	1,409	531	109,070	18,377	107,996	17,659	(1,074)	(718)
13 NJ 17 MP 23.00 [2-1-01]	Total	73,654	8,470	71,453	8,217	(2,201)	(253)					0	0	39,638	5,769	37,397	2,403	(2,241)	(3,366)
14 NJ 17 MP 7.40 [2-1-20]	Total	96,359	11,081	96,225	9,623	(134)	(1,458)					0	0	69,819	8,165	68,685	7,954	(1,134)	(211)
15 NJ 23 MP 12.12 [2-1-05]	Total	58,972	6,782	62,202	3,732	3,230	(3,050)					0	0	59,691	3,249	58,031	2,383	(1,660)	(866)
16 I-80 MP 54.72 [2-1-11]	Total	127,105	14,617	117,486	12,923	(9,619)	(1,694)					0	0	160,934	15,586	150,083	11,808	(10,851)	(3,778)
17 NJ 31 MP 26.20 [5-1-25]	Total	16,369	1,882	15,989	959	(381)	(923)					0	0	11,885	1,280	11,915	1,308	30	28
18 US 202 MP 10.40 [5-1-05]	Total	21,760	2,502	21,135	1,585	(625)	(917)					0	0	22,163	4,249	22,961	4,586	798	337
19 US 1 MP 29.30 [4-1-13]	Total	78,428	9,019	80,165	8,017	1,737	(1,002)					0	0	74,364	4,983	70,910	6,319	(3,454)	1,336
20 RT 287 Between I-78 & I-80	Total	67,989	7,819	74,968	8,996	6,979	1,177			68,400		[illegible]	0	61,872	7,614	63,096	9,278	1,224	1,664
21 RT 287 South RT 78	Total	98,475	11,325	108,190	12,983	9,715	1,658					0	0	81,137	9,247	82,037	9,616	900	369
22 RT 95 West of RT 579	Total	54,055	6,216	53,844	6,461	(211)	245					0	0	30,016	5,147	29,925	5,450	(91)	303
23 RT 295 East of RT 31	Total	65,828	7,570	60,291	7,235	(5,537)	(335)					0	0	42,059	3,266	42,104	3,477	45	211
24 RT 31 South of RT 202	Total	16,233	681	16,040	1,743	(193)	1,062					0	0	15,495	1,732	16,805	1,943	1,310	211
25 RT 206 South of RT 514	Total	19,826	2,280	23,063	1,384	3,237	(896)					0	0	8,141	73	8,182	69	41	(4)

NOTE:

* - Traffic counts were performed during November 4-10, 1993 and December 7-13, 1993.

** - GSP Traffic counts were obtained from NJ HWY AUTHORITY (provided by Dianne Marsh) and NJ TPK COUNTS were from TPK AADT (provided by Tushar), other counts were obtained from 1997 Straight line diagram
Tappan Zee and Spring Valley counts were obtained from NYS Thruway Authority.

Figure 8.8. Impact of I-287 opening.



IMPACT OF TRENTON COMPLEX OPENING

LOCATION	SUMMARY OF COUNTS						SUMMARY OF MODEL ESTIMATES					
	AFTER		BEFORE		DIFFERENCE		AFTER		BEFORE		DIFFERENCE	
	TOTAL	TRUCKS	TOTAL	TRUCKS	TOTAL	TRUCKS	TOTAL	TRUCKS	TOTAL	TRUCKS	TOTAL	TRUCKS
Rt. 31 S. of US 202	9,150	1,400	8,450	1,050	700	350	8,551	1,080	8,015	946	536	134
	9,150	1,400	8,450	1,050	700	350	8,011	917	7,460	786	551	131
Rt. 31 S. of Pennington Circle	6,950	1,050	11,300	1,250	(4,350)	(200)	11,379	1,017	10,871	905	508	112
	6,950	1,050	11,300	1,250	(4,350)	(200)	11,307	870	10,802	732	505	138
US 130 between US 206 & CR 545	7,050	1,250	11,900	655	(4,850)	595	9,040	1,461	18,644	2,559	(9,604)	(1,098)
	7,050	1,250	11,900	655	(4,850)	595	8,959	1,283	19,589	2,299	(10,630)	(1,016)
I-195 between I-295 & US 206	25,000	4,100	24,200	3,300	800	800	16,602	1,154	14,602	863	2,000	291
	26,200	4,297	24,200	3,300	2,000	997	14,765	861	14,599	981	166	(120)
US 130 between I-295 and Dunns Mill Rd.	10,800	594	11,500	633	(700)	(39)	8,700	439	4,467	337	4,233	102
	12,600	693	10,000	550	2,600	143	8,401	469	3,979	372	4,422	97
US 130 between I-295 and Old Highway Road	12,500	750	16,800	1,008	(4,300)	(258)	10,789	1,463	13,330	1,717	(2,541)	(254)
	11,900	714	16,800	1,008	(4,900)	(294)	10,773	1,259	13,243	1,425	(2,470)	(166)
US 206 S. of US 130	10,700	589	14,500	798	(3,800)	(209)	9,058	218	19,376	548	(10,318)	(330)
	11,000	605	15,300	842	(4,300)	(237)	8,223	191	18,174	536	(9,951)	(345)
I-295 S. of US 130	21,000	2,205	14,700	1,544	6,300	661	21,114	3,392	16,061	2,408	5,053	984
	19,200	2,016	14,000	1,470	5,200	546	20,280	2,866	15,367	2,074	4,913	792
CR 535 West of South Post Road	6,700	536	7,700	616	(1,000)	(80)	1,675	31	1,642	29	33	2
	6,600	528	7,600	608	(1,000)	(80)	1,867	32	1,693	33	174	(1)
US 206 South of I-195 (MP 38.2)	17,500	963	29,300	2,200	(11,800)	(1,237)	9,802	326	32,089	1,689	(22,287)	(1,363)
	17,100	941	29,700	2,600	(12,600)	(1,659)	9,556	297	31,417	1,552	(21,861)	(1,255)
US 206 South of Chambers St. (MP 40.2)	12,700	508	10,700	75	2,000	433	9,455	923	19,045	871	(9,590)	52
	12,700	508	10,700	75	2,000	433	8,925	841	19,351	995	(10,426)	(154)
Lamberton St. betw. Lalor and Cass	13,500	945	10,650	746	2,850	199	10,484	649	9,998	133	486	516
	13,500	945	10,650	746	2,850	199	10,461	703	9,946	126	515	577
I-295 South of US 1 (MP 66.82)	31,300	3,756	34,400	4,128	(3,100)	(372)	38,207	2,563	36,869	1,972	1,338	591
	30,700	3,684	33,600	4,032	(2,900)	(348)	37,974	2,158	37,475	1,781	499	377
I-295 (from Map)	23,900	2,868	24,200	2,904	(300)	(36)	19,726	2,057	14,599	981	5,127	1,076
	24,200	2,904	24,200	2,904	0	0	19,236	1,695	14,602	863	4,634	832
Lalor Street (see Map)	9,000	630	11,600	812	(2,600)	(182)	5,885	74	9,998	133	(4,113)	(59)
	9,300	651	13,300	931	(4,000)	(280)	5,166	63	9,946	126	(4,780)	(63)
US 1 South of I-295	26,600	2,660	27,400	2,740	(800)	(80)	18,060	1,942	18,941	1,997	(881)	(55)
	25,100	2,510	26,200	2,620	(1,100)	(110)	15,996	670	16,625	701	(629)	(31)
NJ 18 betw. Normandy Rd. & NJ 34	17,300	1,817	24,045	1,658	(6,745)	159	13,180	676	10,080	437	3,100	239
	15,160	1,592	24,045	1,658	(8,885)	(66)	12,835	540	9,742	336	3,093	204
US 206 at MP 59	7,104	1,381	10,235	614	(3,131)	767	12,241	972	11,873	937	368	35
	7,314	1,482	10,235	614	(2,921)	868	12,274	1,203	11,987	1,089	287	114
US 206 at MP 60	8,928	1,992	9,155	549	(227)	1,443	7,193	941	7,182	909	11	32
	9,428	1,482	9,155	549	273	933	7,393	1,161	7,368	1,048	25	113
US 202/NJ 31 at MP 16.5	14,474	4,548	N/A	N/A			11,470	2,072				
	13,810	3,959	N/A	N/A			11,290	2,521				
US 202 at MP 4.1	5,008	1,979	N/A	N/A			6,678	1,519				
	5,176	1,231	N/A	N/A			6,497	1,242				
I-295 South of I-195/NJ 29	15,500	1,860	N/A	N/A			30,045	2,369				
	15,500	1,860	N/A	N/A			30,602	2,734				
NJ 129 South of Lalor Street	11,600	1,160	N/A	N/A			23,967	1,546				
	11,300	1,130	N/A	N/A			22,196	1,256				
I-195 just West of Rt 537	22,980	2,413	N/A	N/A			11,445	1,813				
	26,410	2,773	N/A	N/A			11,852	1,677				

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Figure 8.9. Impact of Trenton Complex opening.

heavy-duty trucks. (CARB defines a heavy-duty truck as a truck with a gross vehicle weight of 8,500 pounds or more.) A way was needed to improve the SCAG RTM to properly characterize truck traffic by route and time of day, and to identify the impacts of roadway conditions on route choice by different types of trucking operations. Accordingly, a new component of the model was developed that provided these additional capabilities. This component is called the SCAG Heavy-Duty Truck (HDT) Model.

Objective and Purpose of the Model

The HDT Model provides a methodology that can be integrated with the SCAG Regional Model to forecast HDT activity and associated VMT for the SCAG region. The main objectives of the HDT Model are as follows:

- To characterize truck activity in terms of truck trips linked to goods movement, intermodal facilities, interregional truck traffic, regional distribution traffic, and intraregional truck traffic;
- To understand and develop the relationships between truck trip generation and different types of economic activity and develop appropriate forecasts of future truck activity at the TAZ and facility level;
- To develop model outputs for HDTs including traffic volumes, VMT, speeds on links, transit times between specific O-D points, etc., to be used to compute mobility performance indicators; and
- To implement a simultaneous traffic assignment procedure using the TRANPLAN software system.

General Approach

Model Class

The SCAG Heavy Duty Truck Model is an example of the truck model class. Fully integrated with the SCAG Regional Transportation Model, the HDT Model estimates trip generation, distribution, and traffic assignment for HDTs. It employs truck trip generation rates, and uses a network of regional highway facilities for truck traffic assignment. The truck traffic assignment process is integrated with the assignment process for light-and-medium duty vehicles in the regional model, so that the effects of congestion on truck route choice are represented. This case study provides an overview of the HDT Model and describes how it was used to generate and distribute HDT trips. The assignment and VMT results for the HDT traffic component of the model are presented later in this case study.

The HDT Model is technically a metropolitan planning organization model. However, given the size of the SCAG region and the techniques employed in the model, it is considered a suitable case study for the statewide truck model class. A detailed description of the Truck Model is provided in Section 6.3.

Modes

The HDT Model is designed to develop forecasts of HDT in the following three GVW categories:

1. Light-heavy: 8,500 to 14,000 pounds GVW;
2. Medium-heavy: 14,000 to 33,000 pounds GVW; and
3. Heavy-heavy: over 33,000 pounds GVW.

Markets

The model is specifically designed to forecast truck movements for air quality conformity determinations in the six-county SCAG region. As such, it produces VMT estimates for the three truck weight classifications identified above. The HDT Model employs socioeconomic data by TAZ, with employment data broken down into further detail by SIC code to better estimate commodity flow demand that corresponds to truck travel demand. The industries or employment types used in this model are retail, wholesale, manufacturing, agriculture/mining/construction, transportation/utilities, government, and households.

Framework

The HDT Model is fully integrated within the SCAG Regional Model. As such, HDTs are assigned to the highway system together with passenger car trips. The result is a forecast of volumes, including truck volumes, on all links on the highway network.

Flow Units

The model forecasts truck volumes by truck type for each of four time periods: a.m. peak (6:00 a.m.-9:00 a.m.), midday (9:00 a.m.-3:00 p.m.), p.m. peak (3:00 p.m.-7:00 p.m.) and night (7:00 p.m.-6:00 a.m.). Though the model uses annual tons for the external trips, these data are converted to average daily traffic (ADT) before the trip assignment process.

Data

Forecasting Data

The HDT Model has two major components, internal and external. Internal truck trips begin and end inside the SCAG region while external truck trips have one trip end outside the region. Internal trucks are estimated using the socioeconomic data available at the TAZ level for the year 2000. The employment categories used for internal truck trip generation are retail, wholesale, manufacturing, agriculture/mining/construction, transportation/utilities, government, and households.

Model Development Data

The model coefficients and parameters are specifically developed for the HDT Model. While the internal truck trip generation involves deriving truck trip rates from truck surveys, the distribution model is based on gravity model parameters unique to this model that are calibrated to observed truck trip length distributions.

Conversion Data

Converting commodity flows to truck trips required developing commodity-specific estimates of the portion of tonnage carried in each truck weight class and the average truck payload for each weight class. These estimates were developed using data from Federal Truck Inventory and Use Survey (TIUS) data and various O-D surveys carried out at cordon points around the SCAG region.

Validation Data

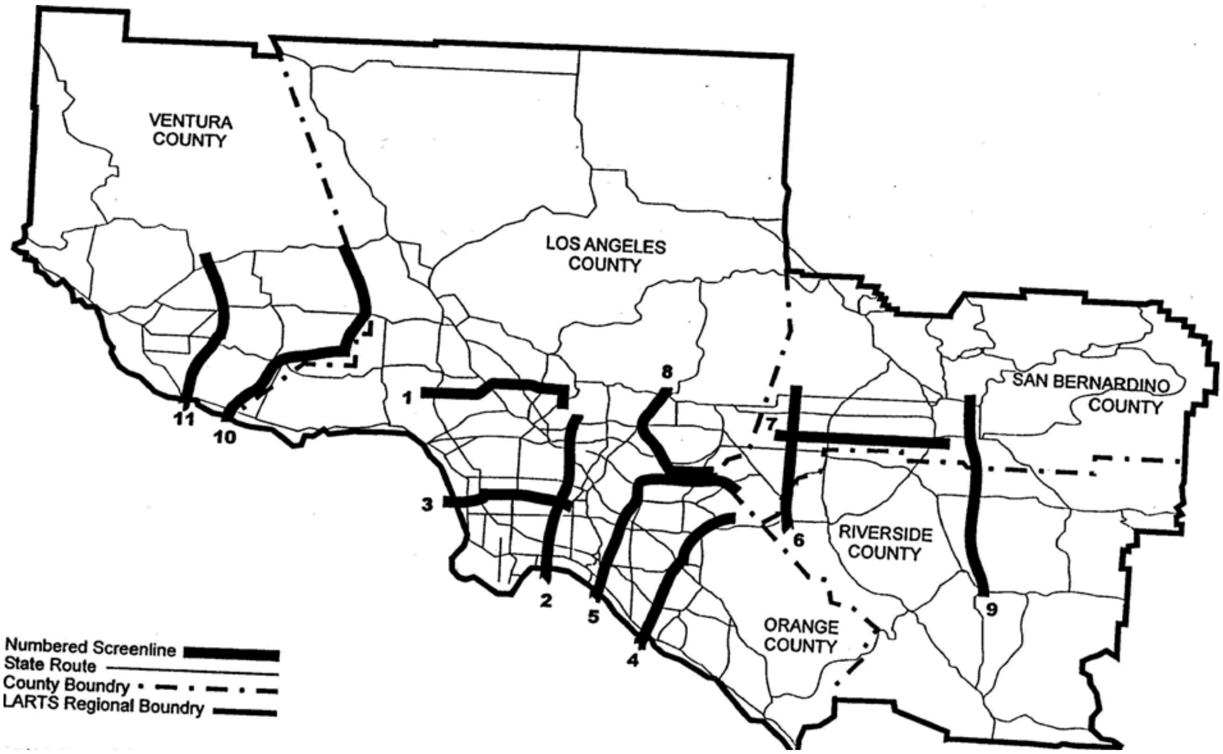
The SCAG HDT Model trip distribution results were validated against the survey data obtained from the truck trip diaries for the three classes of trucks. The truck trip length frequency distributions from the internal trip distribution model were plotted against the observed data by truck class for validation.

The California Department of Transportation's *1995 Annual Average Daily Truck Traffic on the California State Highway System* was used to validate the truck volumes on screenlines across the region. The screenlines map is shown in Figure 8.10. The truck volumes and VMT were validated against the observed truck count data by regional screenlines, subregional screenlines, and volume groups. The standards from *NCHRP Report 255: Highway Traffic Data for Urbanized Area Project Planning and Designs*, were used for deriving validation targets.

Model Development

Software

The TRANPLAN travel demand modeling package was used to build and operate the HDT Model.



Source: Califonia Department of Transportation.

Figure 8.10. Regional model screenlines.

Commodity Groups/Truck Types

As shown in Table 8.25, the internal truck model estimates trucks by gross vehicle weight and by eight employment categories. The external truck trip model was derived from the commodity flow database that consists of commodities at the two-digit STCC level listed in Table 8.15.

Trip Generation

The internal truck trip generation model uses a cross-classification methodology using one-digit employment categories by truck type. The trip rates were derived from a shipper-receiver survey that collected data on the number of truck trips generated by different land uses/industry types and related this to employment levels. Shipping and receiving rates per employee were determined from the surveys, which were used to calculate total trip ends by multiplying the rates with SCAG employment and household data. The distribution of trips by sector was compared against the survey results and data from other studies and necessary adjustments were made to the trip rates. The trip rates then were split into weight classes based on other studies.

Table 8.25 shows the various employment categories and the trip rates used for each category by truck type.

Trip Distribution

The trip generation model computes production and attractions at the TAZ level for the seven employment categories and for households by the three truck weight classes. Survey data from truck trip diaries collected generated friction factors used in the gravity model for the purpose of developing internal truck distribution functions in the distribution model. Adjustments then were made to calibrate truck movements in the distribution model based on K-factors. The final trip distribution yielded average internal truck trip lengths of 5.592 miles for light-heavy trucks, 12.827 miles for medium-heavy, and 23.914 miles for heavy-heavy trucks.

Commodity Trip Table

The SCAG HDT Model divides the external trips into three types: external-internal, internal-external and external-external. The external trip model is based on a commodity flow database and forecasts developed by DRI/McGraw Hill and Reebie Associates. This database contains commodity flows associated with imports and exports at the county-to-county level within California and at the state level for all other domestic and North American flows. The freight flows in the database are expressed in tonnage by three trucking modes: less-than-truckload (LTL) carriers, truckload (TL) carriers and private carriers. The external truck trips are generated and distributed using a combination of commodity flow data at the county level and two-digit employment data for allocating county data to TAZs. External to external truck trips were developed by adjusting the 2001 regional transportation plan 2000 truck tables.

TRUCKLOAD AND PRIVATE MODES

Commodity flows were allocated to the TAZs largely using the two-digit SIC employment data at that level. The simplest allocation process involved outbound flows of manufactured goods by TL and private truck modes. In this case, commodities were assumed to move from manufacturing facilities directly to their destination. Flows for a particular commodity out of a SCAG county were allocated to TAZs in that county based on the employment share in the producing SIC industry. For inbound flows of manufactured goods and farm goods by TL and private truck modes, some freight was

Table 8.25. Daily trip rates for internal truck trip generation.

Employment Category	Light-Heavy 8,5000-14,000 Pounds	Medium-Heavy 14,000-33,000 Pounds	Heavy-Heavy Over 33,000 Pounds
Households	0.0390	0.0087	0.0023
Agriculture/Mining/Construction	0.0513	0.0836	0.0569
Retail	0.0605	0.0962	0.0359
Government	0.0080	0.0022	0.0430
Manufacturing	0.0353	0.0575	0.0391
Transportation/Utility	0.2043	0.4570	0.1578
Wholesale	0.0393	0.0650	0.0633
Other	0.0091	0.0141	0.0030

Note: Rates are per household or per employee in each category.

Source: Southern California Association of Governments Heavy-Duty Truck Model.

assumed to move directly to manufacturing facilities for use in a production process, and the remainder to move to a warehouse for eventual retail distribution. The IMPLAN input-output (I-O) models were used to determine the portion of each commodity that falls into these two groups. These models produce I-O tables that can be used to determine the commodity inputs per unit output of each industry. The models first were used to characterize the portion of each commodity flowing into a county that goes to final demand by consumers and the portion that goes to industry. Flows to consumers were assumed to pass through distribution warehouses and were allocated to TAZs based on warehouse space in each TAZ.

LTL MODE

All LTL shipments, inbound and outbound, were assumed to move through an LTL distribution/consolidation facility. Because the number of LTL carriers making external trips is relatively small, these flows were disaggregated based on the exact locations of the LTL facilities. A list of these LTL carriers and facility locations was obtained from the 1995 SCAG interregional goods movement study.

Mode Split

Not applicable.

Flow Unit and Time Period Conversion

Commodity flows are converted from annual tonnage to truck trips by truck weight class by using the TIUS data and O-D surveys performed at cordon points around the SCAG region.

The California Department of Transportation's weigh-in-motion stations collect data from along the state highway system that are used for deriving truck time of day factors by truck class and by direction.

Assignment

Truck-specific time period factors, derived from weigh-in-motion truck data, were applied to assign daily truck activity to the four model time periods (a.m. peak, midday, p.m. peak, and night). Trucks were converted into PCEs during the assignment phase. The trip assignment process simultaneously loaded both HDTs and light-and-medium duty autos/trucks so that all vehicle types were accounted for in the traffic stream.

As shown in Table 8.26, truck PCEs were estimated for each link by the product of a grade factor and a congestion factor. The grade factors ranged from 1.2 to 3.6 for light-heavy, 1.5 to 4.5 for medium-heavy, and 2.0 to 6.0 for heavy-heavy trucks. The congestion factors ranged between 1.0 and 1.3.

Model Validation

The distribution of total trip ends by employment category was compared with other major truck studies to calibrate and validate the truck trip rates.

Trip Distribution

The comparison of truck trip length distributions from the model against the observed data from the truck surveys served as a criterion for trip distribution validation. These are shown in Figures 8.11, 8.12, and 8.13 for each of the three truck classes.

Mode Choice

Not applicable.

Modal Assignment

The HDT Model was validated against a number of specific parameters. The model estimated Year 2000 truck movements across 16 regional screenlines to within 12% of the corresponding truck traffic counts (all screenlines combined). All differences on individual screenlines were well within allowable tolerances established for regional modeling processes. The model estimated 22.4 million VMT by all trucks within the SCAG modeling region. This was within 2% of the VMT estimates from the HPMS.

The modal assignment validation results are summarized in Table 8.27.

POST MODEL ADJUSTMENT OF SPEED FOR HDTS

The SCAG RTM assumes the same speed for all vehicles traveling on the same roadway segment. For instance, both HDTs and passenger cars are loaded on the same segment of the roadway and the current model cannot distinguish between the lanes that permit HDT travel and those that do not. In order to reasonably represent the slower speeds that most trucks are traveling, a post model speed adjustment was made using available Freeway Performance Measurement Project (PeMs) data.

The SCAG RTM did not have a separate network for HDTs, unless a truck-only lane is present. Both HDTs and passenger cars are loaded on the same segment of the roadway, regardless of any truck-lane restrictions. Therefore, both HDTs and passenger cars have the same speed on the same output roadway segment.

Table 8.26. Truck PCE factors by GVW and grade.

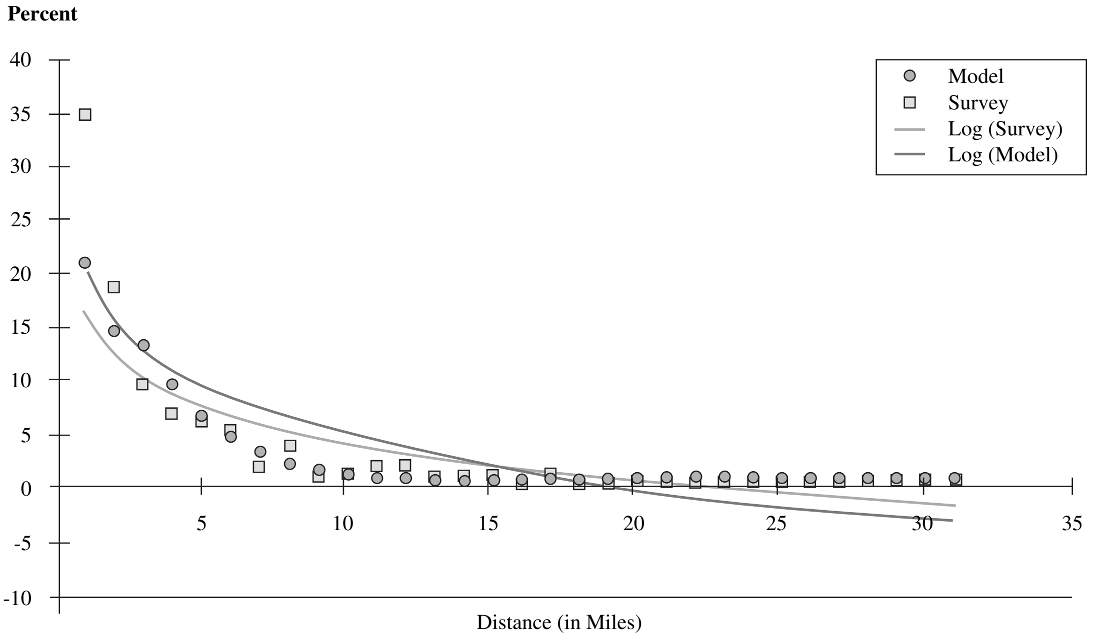
Heavy-Duty Vehicle Passenger Car Equivalent Values by Vehicle Type, Terrain, and Percent Trucks

				Percent Grade		
Percent Trucks		**Length (Miles)**	**0-2**	**3-4**	**5-6**	**>6**
Light-Heavy						
0	5	<1	1.2	2	3.6	3.6
0	5	1-2	1.2	2	3.6	3.6
0	5	>2	1.2	2	3.6	3.6
5	10	<1	1.2	2	3.6	3.6
5	10	1-2	1.2	2	3.6	3.6
5	10	>2	1.2	2	3.6	3.6
10	100	<1	1.2	2	3.6	3.6
10	100	1-2	1.2	2	3.6	3.6
10	100	>2	1.2	2	3.6	3.6
Medium-Heavy						
0	5	<1	1.5	2.5	4.5	4.5
0	5	1-2	1.5	2.5	4.5	4.5
0	5	>2	1.5	2.5	4.5	4.5
5	10	<1	1.5	2.5	4.5	4.5
5	10	1-2	1.5	2.5	4.5	4.5
5	10	>2	1.5	2.5	4.5	4.5
10	100	<1	1.5	2.5	4.5	4.5
10	100	1-2	1.5	2.5	4.5	4.5
10	100	>2	1.5	2.5	4.5	4.5
Heavy-Heavy						
0	5	<1	2	3.3	6	6
0	5	1-2	2	3.3	6	6
0	5	>2	2	3.3	6	6
5	10	<1	2	3.3	6	6
5	10	1-2	2	3.3	6	6
5	10	>2	2	3.3	6	6
10	100	<1	2	3.3	6	6
10	100	1-2	2	3.3	6	6
10	100	>2	2	3.3	6	6

Passenger Car Equivalent Value Adjustment Factors for Highway Congestion

Percent Trucks		**V/C Ratio**		**L-H**	**M-H**	**H-H**
0	5	0.0	0.5	1.0	1.0	1.0
0	5	0.5	1.0	1.0	1.0	1.2
0	5	1.0	1.5	1.1	1.2	1.3
0	5	1.5	2.0	1.0	1.2	1.2
0	5	2.0	99.0	1.0	1.2	1.3
5	10	0.0	0.5	1.0	1.0	1.0
5	10	0.5	1.0	1.0	1.0	1.2
5	10	1.0	1.5	1.2	1.3	1.3
5	10	1.5	2.0	1.0	1.2	1.3
5	10	2.0	99.0	1.0	1.2	1.3
10	100	0.0	0.5	1.0	1.0	1.0
10	100	0.5	1.0	1.0	1.0	1.2
10	100	1.0	1.5	1.2	1.3	1.3
10	100	1.5	2.0	1.0	1.2	1.3
10	100	2.0	99.0	1.0	1.2	1.3

Source: Southern California Association of Governments Heavy-Duty Truck Model.



Source: Southern California Association of Governments Heavy-Duty Truck Model.

Figure 8.11. Trip length frequency curves (light-heavy trucks).

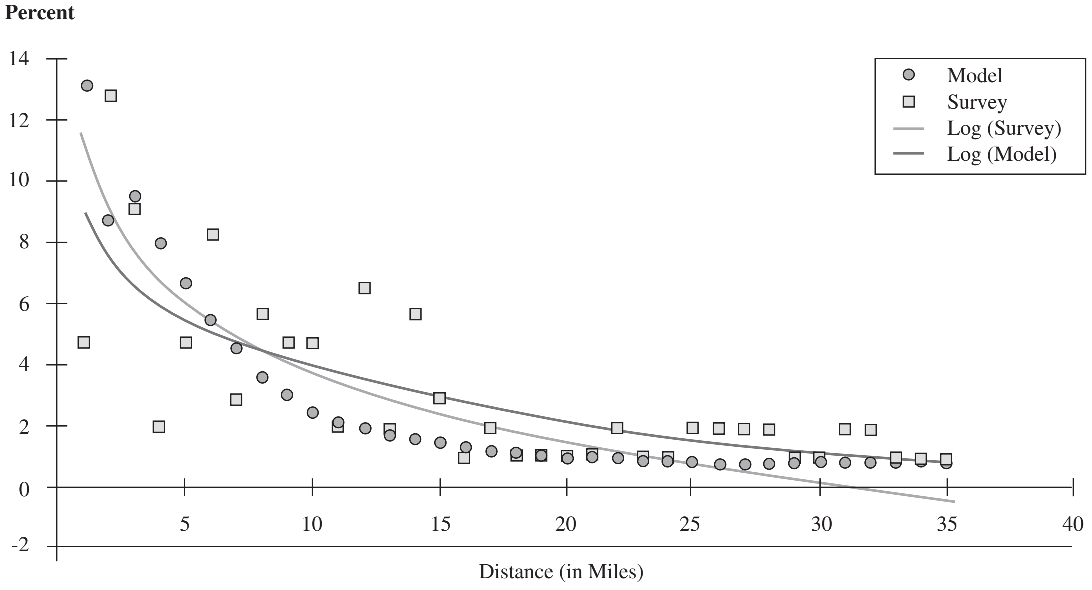
However, HDTs are assumed to travel slower than passenger cars because:

- HDTs can only travel on the outside lanes; their choice of travel is relatively limited.
- The speed on the outside lanes is slowed by vehicles entering and exiting the highway.
- HDTs accelerate and decelerate more slowly than passenger vehicles.

The following section describes how the relationship between HDT speed and average roadway speed was used to conduct post model speed adjustment for the HDT Model.

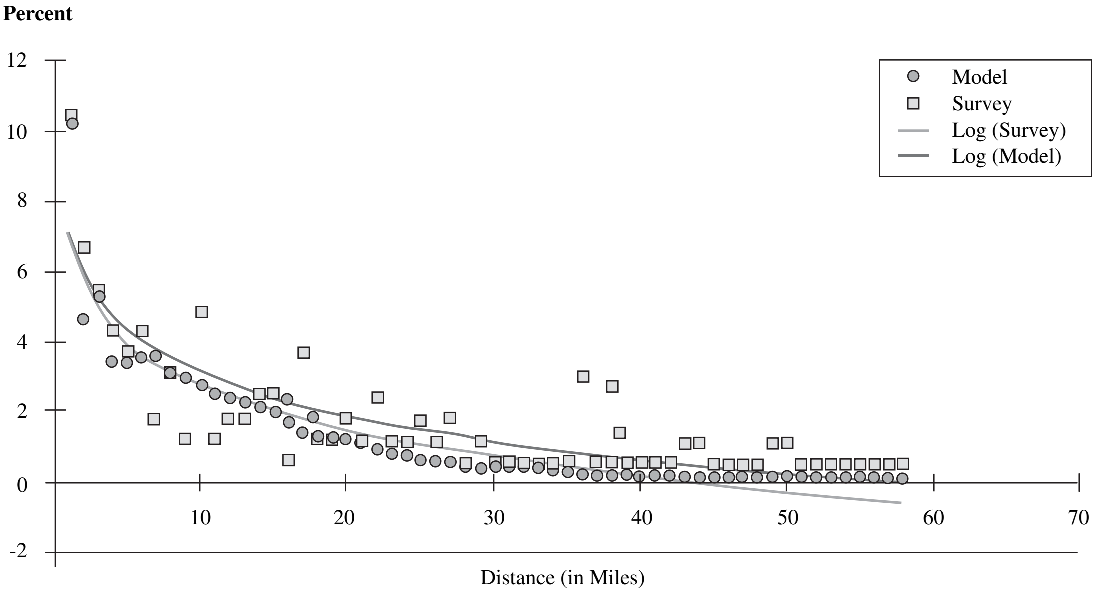
SPEED OF THE HDTS ON FREEWAYS

A total of 9,361 records were selected through the PeMs database. A detailed review of the database revealed some problems, such as detectors that lacked data or had observed



Source: Southern California Association of Governments Heavy-Duty Truck Model.

Figure 8.12. Trip length frequency curve (medium-heavy trucks).



Source: Southern California Association of Governments Heavy-Duty Truck Model.

Figure 8.13. Trip length frequency curves (heavy-heavy trucks).

speeds out of range of reasonably expected values. SAS statistical analysis software programs were used to screen and analyze the database.

Only 3,465 out of 9,361 records were suitable for the analysis. The dependent variable was the average speed of the outside two lanes. The independent variable was the average speed of all lanes at each detector's location. A simple linear model was used to build the relationship between the dependent and independent variables.

The *R*-Square value was 0.98. The t-statistic for the independent variable was 417.95. The equation of the result was:

Heavy-duty truck speed = 0.31 + 0.9657* average freeway speed

SPEED OF HDTS ON ARTERIALS

There is no reliable data to derive the speed of HDTs on arterials, although their speed is slower than that of passenger

Table 8.27. Comparison of truck volumes and counts on regional model screenlines.

Screenline	Count Volume (ADT)	Model Volume (ADT)	Difference (Model-counts)	Percent Difference	Allowable per NCHRP
1	61,870	73,778	11,908	19%	± 31%
2	106,041	118,760	12,719	12%	± 25%
3	59,381	59,610	229	0%	± 30%
4	65,344	61,901	(3,443)	-5%	± 29%
5	84,261	93,010	8,749	10%	± 23%
6	73,546	73,778	232	0%	± 28%
7	52,893	46,866	(6,027)	-11%	± 36%
8	84,400	82,117	(2,283)	-3%	± 26%
9	29,135	28,712	(423)	-1%	± 40%
10	20,495	23,118	2,623	13%	± 46%
11	15,762	14,879	(883)	-6%	± 52%
Total	**653,128**	**676,529**	**23,401**	**4%**	**N/A**

Source: Southern California Association of Governments Heavy-Duty Truck Model.

cars. SCAG subsequently conducted an arterial average speed study in fiscal year 2003-2004. For the HDT model as presented in this case study, validation, the ratio of speed of HDTs compared to passenger cars on arterials was assumed to be similar to the same relationship observed on freeways.

Model Application

The SCAG HDT Model was initially used to forecast truck volumes by truck class for the year 2020, as shown in Table 8.28.

Performance Measures and Evaluation

The SCAG HDT Model presents no special performance measures. The model is used to produce volume, speed, and air emission forecasts. While truck performance results for these measures specifically are not produced, since heavy duty trucks are maintained as a separate trip type, it would be possible to use the model to produce those standard performance measures outputs for only those truck trips.

8.8 Case Study – Indiana Commodity Transport Model

Background

Context

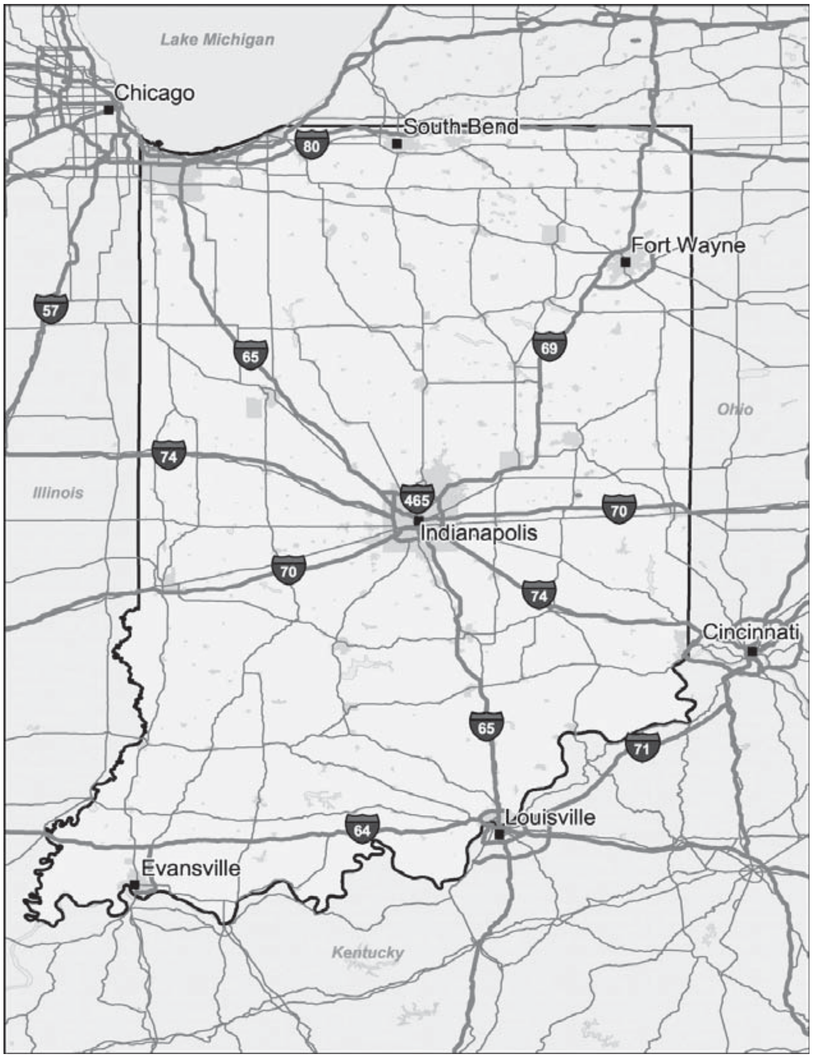
Indiana's transportation network, shown in Figure 8.14, moves a tremendous volume of goods each year. According to the FHWA Freight Analysis Profile for Indiana, in 1998 over 698 million tons of goods worth more than $398 billion were moved to, from, within, and through Indiana, traveling by highway, rail, water, and air.[21] This represents almost 5% of the freight tonnage and over 4% of the freight value moved in the United States. In the early 1990s, in order to better understand freight movements, the Indiana Department of Transportation (InDOT) sponsored a research project conducted by the Transportation Research Center of Indiana University. The goal of the project was to create a database that would include the flows of manufactured goods, major grains, and coal along the state's transport networks and the use of that data to develop a series of models to estimate the future flows of freight. If the research was successful, the results were to be included in InDOT's comprehensive Indiana Statewide Travel Demand Model.

The Indiana Commodity Transport Model was created in 1993 using the 1977 Bureau of Transportation Statistics CFS and was updated in 1997 using the 1993 CFS.[22] The 1993 CFS showed that in that year about $179 billion of goods weighing 286 million tons originated in Indiana. These goods accounted for about 3% of the value and weight of total U.S. shipments. Major commodities originating in Indiana by value included transportation equipment, metal products, food, electrical machinery, and chemicals. Major commodities by weight included petroleum or coal products, minerals, farm products, and metal products. About three-quarters of these commodities (by value and weight) moved by truck, with lesser amounts moving by rail (7% by value and 15% by

Table 8.28. Comparison of 2020 and 1995 forecast truck volumes on regional model screenlines.

Screenline	2020 Model Volume (ADT)	1995 Model Volume (ADT)	Difference (2020-1995)	Allowable per NCHRP
1	120,690	73,778	46,912	63%
2	196,468	118,760	77,708	65%
3	111,695	59,610	52,085	87%
4	79,241	61,901	17,340	28%
5	144,770	93,010	51,760	56%
6	80,250	73,778	6,472	9%
7	83,769	46,866	36,903	79%
8	141,051	82,117	58,934	71%
9	88,972	28,712	60,260	210%
10	30,501	23,118	7,383	32%
11	20,676	14,879	5,797	39%
Total	**1,098,083**	**676,529**	**421,554**	**62%**

Source: Southern California Association of Governments Heavy-Duty Truck Model.



Source: ESRI data and maps 2002, prepared by Cambridge Systematics, Inc.

Figure 8.14. State of Indiana.

weight) and by parcel post, U.S. Postal service, and courier services (7% by value). The CFS also shows that in 1993 about 28% of Indiana's shipments by value and 56% of its shipments by weight were bound for destinations within the state. For shipments to other states, the main destinations by value were Michigan, Illinois, Ohio, California, and Kentucky. By weight, the major destinations were Michigan, Ohio, Kentucky, and Louisiana.

Objective and Purpose of the Model

InDOT's primary objective in supporting the research project was the creation of a model or forecasting tool capable of estimating future flows of commodities on Indiana's rail and highway networks, from which a general transportation model for the state could be developed.

General Approach

Model Class

The Indiana Commodity Transport Model is a four-step commodity flow class of model based on the traditional four-step transportation planning model commonly used for passenger and total truck forecasting applications. A detailed description of the four-step commodity class of model is provided in Section 6.4.

Modes

Following the modal definition in the CFS, the Indiana Commodity Transport Model considers nine single mode categories, as shown in Table 8.29. The model does not count traffic passing through Indiana or traffic originating outside

Table 8.29. Modal categories.

Single Modes	Multiple Modes
Parcel/Courier	Private Truck and For-Hire
U.S. Postal Service	Truck and Air
Private Truck	Truck and Rail
For-Hire Truck	Truck and Water
Air	Truck and Pipeline
Rail	Rail and Water
Inland Water	Inland Water and Great Lakes
Great Lakes	Inland Water and Deep Sea
Deep Sea Water	

the United States. Truck as the primary or part of a multiple mode of freight shipments was used by about 77% of shipments originating in Indiana in terms of value. Rail accounted, solely or with other modes, for about 7% of the traffic based on value and 15% based on weight. Air freight (excluding parcels) and truck-air accounted for 2% of shipments based on value and less than 0.1% based on weight.

Following the CFS, the Indiana model considers eight multiple mode categories. However, the 1993 CFS data indicated that intermodal traffic in Indiana was insignificant, representing only about one-quarter of 1% based on tonnage but over 3.2% based on value.

Markets

The main component of commercial vehicle traffic included in this model was interregional freight shipments to, from, and within Indiana, although the model was not limited to Indiana traffic only, since a significant portion of the commodity traffic in Indiana does not have an origin or destination in the state. The study includes not only the 92 counties of Indiana but several major terminals outside the state including all of the remaining contiguous 47 states as well as additional nodes for the states bordering Indiana, for a total of 145 nodes or centers of freight activity.

Framework

The Indiana Commodity Transport Model was developed as a research project to prove the concepts presently being introduced into Indiana's Statewide model. The model structure follows the basic four-step transportation planning model structure typical of passenger models. Trip generation and trip distribution components utilize tons of commodities rather than persons and the mode split step distributes tons to the various modes or mode combinations available for shipments. These tonnage trip tables are then converted to trucks or rail cars and assigned to the appropriate networks to produce vehicle flows. The model components are written in several different software programs and are manually linked together.

Flow Units

The Indiana model focuses primarily on daily interstate and intercounty commercial transport flows, mainly large trucks and rail cars moving on the regional transportation system between regions in Indiana and the rest of North America. The model does not address goods movement associated with the service transport sector (such as, commercial laundry vehicles, plumbers, lawn care vehicles), nor does it consider movements by household moving vans.

Data

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

The Indiana model was calibrated and validated to 1993 base year data. Forecasts were made for future years, 1998, 2005, and 2015. Future year input data was primarily composed of population and employment forecasts from Woods & Poole.

EXTERNAL MARKETS

Much of the commodity traffic in Indiana has neither an origin nor a destination in the state, but instead represents goods or materials passing through the state. This through traffic may contribute little to the state's economy, but it adds to urban congestion, air pollution, rail traffic, and wear and tear on highways. To address the impact of through traffic, the commodity flow model includes, in addition to the 92 counties of Indiana, nine other nodes or terminals representing portions of the adjacent states of Ohio, Illinois, Kentucky, and Michigan and the single zones for the remaining 43 continental states and the District of Columbia. Base year models for all 145 zones relied on data from the 1993 CFS and were supplemented with information from the 1977 Census of Transportation. Forecasts of future year socioeconomic data used to generate external trip-making levels were based on 1992 projections by Woods & Poole.

Modal Networks

FREIGHT MODAL NETWORKS

The highway network for the Indiana Commodity Transport Model includes all major facilities within a 200-mile radius of Indianapolis and, for roads outside Indiana, the FHWA's 1992 digital highway network, which covers only major interstate highways connecting the lower 48 states. To provide even greater detail in order to match the county-level zone system within Indiana, roadway detail at the State Roadway Inventory level was included. The resulting network consists of 34,154 links and 31,557 nodes, as shown in Figure 8.15.

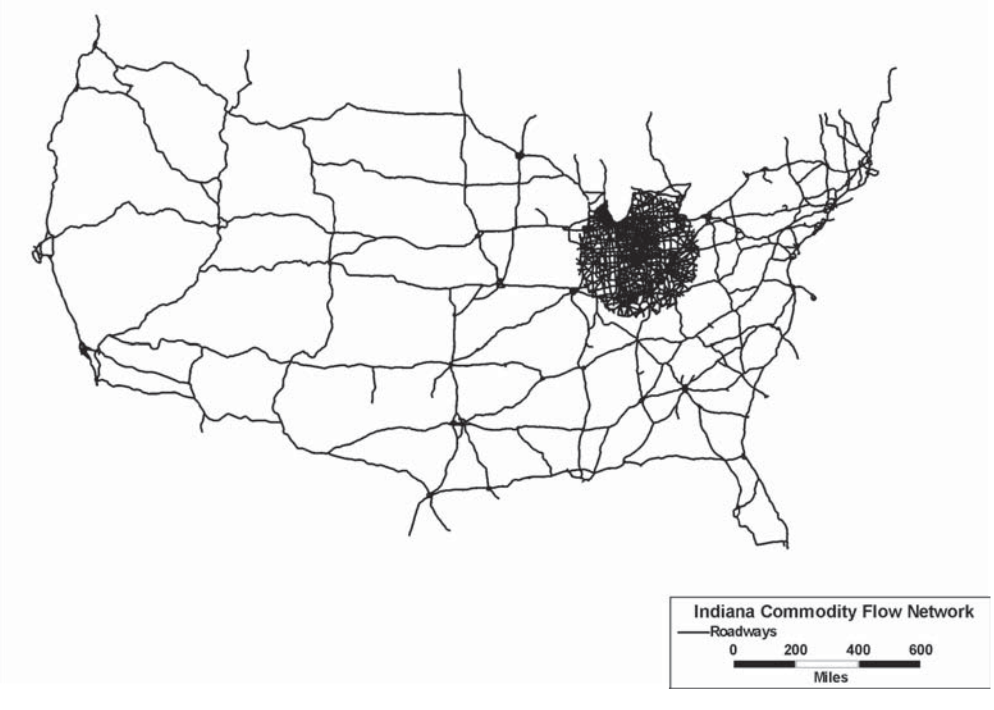
INTERMODAL TERMINAL DATA

Very little data on intermodal freight transported through terminals was available from the 1993 CFS and the Bureau of Transportation Statistics' Carload Waybill Sample for railroads, the main sources used for the Indiana study. These data are considered proprietary in many cases and therefore were not reported or included in the model.

Model Development Data

The 1993 CFS that forms the basis for this model is shipper-based and therefore only includes data for U.S. shippers. Data on imports to Indiana are not included, although some estimates were made to account for this gap in the data. Other components, such as vehicle movements associated with the service transport sector and movements by household moving vans, also were not included.

The main data source for the development of the original trip production and attraction models was the 1977 Census of Transportation and the Commodity Flow Survey. This source was chosen because no other comprehensive data were available at the time the model development began. The 1993 Census of Transportation and CFS was underway at the beginning of the project but results were not available until late in the development phase; ultimately, the 1993 data were used to update and validate the traffic distribution models that describe the flows into, through, within, and out of Indiana. In addition, the model development made use of various years of County Business Patterns, U.S. Census Bureau data, and Carload Waybill Sample data.



Source: W.R. Black, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment*, Phase 2, Bloomington, Indiana: Transportation Research Center, Indiana University, 1997.

Figure 8.15. Highway network for the Indiana Commodity Transport Model.

Little data was available from CFS regarding the destinations of individual commodity groups for Indiana shipments. However, destination data for all shipments were available and indicated that the major destination in terms of both value and weight was Indiana itself, which is common among most states. Destinations in terms of value for shipments out of state were Michigan, Illinois, Ohio, California, and Kentucky. In terms of tonnage, the major destinations out of state were Illinois, Michigan, Ohio, Kentucky, and Louisiana.

Conversion Data

Commodity density factors by commodity were developed for rail from the Waybill Sample, adjusted for destination (inbound or outbound). This process yielded tons by commodity per carload. These factors were used to develop density factors for trucks by multiplying by 0.40, the relative difference in loads between rail cars and trucks.

To convert annual tons to daily trucks, factors based on data within the Highway Capacity Manual Special Report 209 were used. A daily to annual factor of 306 days was derived for weekday traffic. Multiplying the estimated weekday traffic by 0.44 yielded an approximation for weekend truck traffic. Table 8.30 shows the payload factors used for converting tonnage to truck volumes.

Validation Data

The 1993 CFS data were used to validate estimated commodity flow tables to, from, and within the 145 zones within the model. Assigned truck volumes from the model were compared against InDOT traffic counts from 1991 to 1994. No route segment-specific data on rail flows were available for comparison of assigned rail volumes. A visual examination of rail flows was made to assess their reasonableness.

Model Development

Software

Most of the model components, including network creation and traffic assignment, were developed and operate within the GIS-based TransCAD planning software. Other independent estimation procedures also were utilized, such as multivariate analysis and entropy-based gravity model algorithms using specially developed FORTRAN programs.

Commodity Groups/Truck Types

For this study, all two-digit categories of the STCC were examined in terms of their importance to Indiana's economy. A set of 18 commodity groups was identified. One

Table 8.30. Traffic density factors for rail cars and motor carriers by commodity.

Commodity STCC	Import Rail Traffic	Export Rail Traffic	Weighted Rail Density (Tons)	Weighted Truck Density (Tons)
01	94.90	96.20	96.13	38.44
11	100.60	99.10	100.42	40.17
14	97.10	97.40	97.20	38.88
20	77.35	80.36	79.52	31.81
22	25.00	15.00	18.33	7.33
23	N/A	N/A	*10.00	*4.00
24	73.88	55.50	72.27	28.91
25	N/A	15.00	15.00	6.00
26	64.82	50.64	62.10	24.84
28	85.11	90.11	87.58	35.03
29	63.20	77.16	65.90	26.36
32	86.70	77.10	81.15	32.46
33	87.48	85.21	85.82	34.33
34	28.40	16.16	19.76	7.90
35	68.75	21.70	28.42	11.37
36	18.80	16.25	16.69	6.68
37	19.93	23.40	22.50	9.00
40	75.40	82.60	78.47	31.39
**50	92.85	14.88	86.56	34.62

* Estimated Values

** STCC 50 represents STCC 21, 27, 30, 31, 38 and 39.

additional group of five commodities was aggregated to a single category called STCC 50. As used in the Indiana Commodity Transport Model, STCC 50 includes all durable and nondurable manufactured commodities not separately processed. It differs from the definition of STCC 50 as secondary traffic to warehousing and distribution centers as used in TRANSEARCH and the Freight Analysis Framework. In addition, movements by the U.S. Postal Service and overnight express mail operations also were included in the analysis.

Based on the CFS, commodity flows originating in Indiana in 1993 were valued at $178.7 billion and exceeded 280 million tons. By weight, they consisted primarily of petroleum and coal products (21.9%), nonmetallic minerals (20.1%), farm products (14.0%), primary metal products (9.8%), stone, clay and glass products (7.7%), food and kindred products (7.4%), and chemicals and allied products (4.2%). The major commodity groups in Indiana in 1993 are shown in Table 8.31.

Trip Generation

Traffic production models are based on the assumption that employment in a particular sector is an accurate indicator of that sector's production. In these models, the key variable is employment. In some cases, population also is used to represent the consumer market to account for locally consumed goods.

Traffic attraction models are based on the assumption that the flows of manufactured goods to a particular market are a function of the demand for that product in two markets: personal consumers and industrial consumers. In the former market, population is the key variable. In the case of industrial consumers, employment is again key.

At the time the Indiana Commodity Transport Model was being developed, data from the 1993 CFS was unavailable. Most of the model's components were therefore developed using the 1977 dataset. Population estimates derived from U.S. Census Bureau figures from 1977 and employment data derived from 1977 County Business Patterns were used to develop models based on these 1977 production and attraction levels of manufactured goods. Models of nonmanufactured goods (coal, nonmetallic minerals, farm products, and waste) were developed using the 1993 CFS and Census Bureau data. Table 8.32 shows these models along with an indicator of their accuracy. Table 8.33 describes the model variables.

Trip Distribution

The Indiana Commodity Transport Model uses a standard gravity model or entropy model to distribute annual freight tonnage between origins and destinations in the United States

Table 8.31. Major commodity groups in Indiana (1993).

Description	STCC Code	Value (Millions of Dollars)	Tons (Thousands)
Farm Products	01	$5,794	39,902
Coal	11	281	10,759
Nonmetallic Minerals	14	463	57,341
Food and Kindred Products	20	16,958	21,039
Basic Textiles	22	275	93
Apparel	23	7,795	553
Lumber and Wood Products	24	3,235	4,131
Furniture and Fixtures	25	3,120	734
Pulp and Paper Products	26	3,194	2,814
Chemicals and Allied Products	28	11,474	11,957
Petroleum and Coal Products	29	9,008	62,500
Stone, Clay and Glass Products	32	2,748	21,972
Primary Metal Products	33	17,485	27,881
Fabricated Metal Products	34	10,363	4,572
Machinery (except Electrical)	35	9,504	1,023
Electrical Machinery	36	15,914	1,909
Transportation Equipment	37	34,401	6,731
Waste and Scrap Material	40	703	4,474
Other Manufactured Products[a]	50	14,811	2,421

Source: Bureau of Transportation Statistics, 1993 Commodity Flow Survey.

[a] Category 50 includes STCC 21, STCC 27, STCC 30, STCC 31, STCC 38, and STCC 39.

Table 8.32. Traffic generation models.

Model Number	Model Equation	Adjusted R Squared
(1)	Prod01 = 1445 –.523 Agser +.0048 Cash	0.562
(2)	Attr01 = .819 Prod01	0.660
(3)	Prod11 = 7.6 Coal	0.650
(4)	Attr11 = 3.1 Coal + 5.3 Min	0.657
(5)	Prod14 = .078 Man	0.658
(6)	Attr14 = .997 Prod14	0.977
(7)	Prod20 = .282 Food	0.965
(8)	Attr20 = .832 Pop + .162 Food	0.965
(9)	Prod22 = .016 Tex	0.931
(10)	Attr22 = .003 App + .0001 All	0.743
(11)	Prod23 = .004 App	0.919
(12)	Attr23 = .002 App + .011 Pop	0.926
(13)	Prod24 = .668 Lum	0.808
(14)	Attr24 = .728 Prod24	0.805
(15)	Prod25 = .017 Furn	0.906
(16)	Attr25 = .033 Pop + .002 Furn	0.960
(17)	Prod26 = .103 Pulp + .056 Lum	0.886
(18)	Attr26 = .085 Pulp + .002 Furn	0.953
(19)	Prod28 = .150 Chem + 1.164 Pet	0.758
(20)	Attr28 = .077 Chem + .455 Pet + .683 Pop	0.851
(21)	Prod 29 = 6.857 Pet	0.945
(22)	Attr29 = 4.007 Pet + 1.881 Pop	0.938
(23)	Prod32 = 2.882 Pop	0.851
(24)	Attr32 = 2.914 Pop	0.871
(25)	Prod33 = .085 Met	0.982
(26)	Attr33 = .093 Met + .061 Fab	0.923
(27)	Prod34 = .013 Met + .034 Fab	0.927
(28)	Attr34 = .035 Fab	0.861
(29)	Prod35 = .013 Mac	0.883
(30)	Attr35 = .010 Mac	0.878
(31)	Prod36 = .004 Met + .004 Fab + .003 Elec	0.826
(32)	Attr36 = .005 Fab + .034 Pop	0.915
(33)	Prod37 = .040 Tran	0.753
(34)	Attr37 = .027 Tran	0.837
(35)	Prod40 = .00048 Pop	0.704
(36)	Attr40 = .0067 Man	0.791
(37)	Prod50 = 1.097 Attr50	0.858
(38)	Attr50 = .245 Pop	0.857

Source: W.R. Black, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment, Phase 2,* Bloomington, Indiana: Transportation Research Center, Indiana University, 1997.

for the year 1993. The cost or impedance factor for the gravity formulation was based on the straight-line distance between zones. The model has the general form:

$$S_{jk} = A_j B_k O_j D_k \exp(-\beta c_{jk})$$

where

S_{jk} = the amount of a given commodity shipped from origin j to destination k;

O_j = the amount of a given commodity available for shipment at origin j;

D_k = the amount of a given commodity demanded by destination k; and

c_{jk} = a measure of the cost or impedance of moving from j to k.

In addition,

$$A_j = [\Sigma B_k D_k \exp(\beta c_{jk})]^{-1}$$

and

$$B_k = [\Sigma A_j O_j \exp(\beta c_{jk})]^{-1}$$

Table 8.33. List of employment variables used in trip generation equations.

Variable Name	Description	SIC Code
Agser	Employment in Agricultural Services	07
All	Total Employment	N/A
App	Employment in Apparel and Other Textile Products	23
Cash	Gross Cash Receipts (in $1,000s) from Farming	N/A
Chem	Employment in Chemicals and Allied Products	28
Coal	Employment in Coal Mining	11
Elec	Employment in Electrical and Electrical Equipment	36
Fab	Employment in Fabricated Metal Products	34
Food	Employment in Food and Kindred Products	20
Furn	Employment in Furniture and Fixtures	25
Lum	Employment in Lumber and Wood Products	24
Mac	Employment in Industrial Machinery and Equipment	35
Man	Employment in Manufacturing	02 and 03
Met	Employment in Primary Metal Industries	33
Min	Employment in Nonmetallic Minerals, except Fuels	14
Pet	Employment in Petroleum and Coal Products	29
Pop	Total Population	N/A
Pulp	Employment in Paper and Allied Products	26
Tex	Employment in Textile Mill Products	22
Tran	Employment in Transportation Equipment	37

Source: W.R. Black, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment, Phase 2,* Bloomington, Indiana: Transportation Research Center, Indiana University, 1997.

The development of the model also used actual data for Indiana to refine or calibrate the estimates of county-to-county flows. These refinements were meant to ensure that:

1. Total flows from all states within the gravity model were equal to actual traffic productions by manufacturing category for those states.
2. Total flows to and from Indiana, by commodity, as generated by the model, were equal to actual flows reported in the commodity census.
3. Total flows generated by each state were equal to national totals.

Table 8.34 shows the average shipping distance per ton of commodity for estimated and actual conditions for Indiana and the rest of the United States.

Commodity Trip Table

Not applicable for the Indiana model. Commodity tables, the CFS, and Carload Waybill Samples were not used directly but supported the development of model parameters.

Mode Split

A computer model was written to distribute traffic flows generated by the gravity model among the various modes available for movement. As shown in Table 8.29, the modal split model (NEWMODE) considered nine individual modes and eight multiple mode categories. Each of the 17 modes was further divided into nine distance-based categories: less than 50 miles, 50 to 99 miles, 100 to 249 miles, 250 to 499 miles, 500 to 749 miles, 750 to 999 miles, 1,000 to 1,499 miles, 1,500 to 1,999 miles, and 2,000 miles or more. Base year weights or probabilities were developed using the 1993 CFS for each of the market-segmented modes and applied to future year trip tables to create future year trips by mode. The model allocated future flows based on current mode splits in each of those distance classes.

Flow Unit and Time Period Conversion

Commodity density factors by commodity were developed for rail from the Carload Waybill Sample, adjusted for destination (inbound or outbound). This process yielded tons by commodity per rail carload. As shown in Table 8.35, these factors were used to develop density factors for trucks by multiplying by 0.40, the relative difference in loads between rail cars and trucks.

To convert annual tons to daily trucks, factors based on data within the Highway Capacity Manual Special Report 209 were used. A daily to annual factor of 306 days was derived for weekday traffic. Multiplying the estimated weekday traffic by 0.44 yielded an approximation for weekend truck traffic.

Table 8.34. Traffic distribution model results (average shipper distance per ton of commodity).

Commodity STCC	U.S. Average		Indiana Average	
	Actual	Modeled	Actual	Modeled
(1)	434	434	435	432
(11)	432	432	85	436
(14)	87	116	44	122
(20)	315	311	333	311
(22)	458	445	236	489
(23)	658	420	391	397
(24)	182	190	220	222
(25)	591	592	794	563
(26)	464	313	313	314
(28)	434	345	280	294
(29)	152	153	89	140
(32)	105	202	124	189
(33)	365	365	356	361
(34)	359	358	342	345
(35)	559	500	472	473
(36)	649	505	481	483
(37)	560	487	449	446
(40)	211	211	181	243
(50)	560	507	426	465

Source: W.R. Black, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment, Phase 2,* Bloomington, Indiana: Transportation Research Center, Indiana University, 1997.

Table 8.35. Traffic density factors for rail cars and motor carriers by commodity.

Commodity STCC	Rail Traffic		Weighted Rail Density (Tons)	Weighted Truck Density (Tons)
	Import	Export		
01	94.90	96.20	96.13	38.44
11	100.60	99.10	100.42	40.17
14	97.10	97.40	97.20	38.88
20	77.35	80.36	79.52	31.81
22	25.00	15.00	18.33	7.33
23	N/A	N/A	10.00[a]	4.00[a]
24	73.88	55.50	72.27	28.91
25	N/A	15.00	15.00	6.00
26	64.82	50.64	62.10	24.84
28	85.11	90.11	87.58	35.03
29	63.20	77.16	65.90	26.36
32	86.70	77.10	81.15	32.46
33	87.48	85.21	85.82	34.33
34	28.40	16.16	19.76	7.90
35	68.75	21.70	28.42	11.37
36	18.80	16.25	16.69	6.68
37	19.93	23.40	22.50	9.00
40	75.40	82.60	78.47	31.39
50[b]	92.85	14.88	86.56	34.62

Assignment

The daily truck trip table was assigned to the highway network using a FORTRAN program that used an "all or nothing" assignment procedure based on the travel time between zones. Based on initial results, adjusted speeds were developed based on the following formula to account for the over-assignment of vehicles to interstate links compared to other roadways:

$$\text{New Speed} = \text{Old Speed} + (2 \times \sqrt{(65\text{-Old Speed})})$$

Rail assignment procedures were somewhat different because rail carriers tend to consider the use of mainline trackage as an equal or more important variable than the directness of the route. For this reason, a new "cost of movement" variable was developed for rail that incorporated a distance minimizing component as well as a component related to the magnitude of volume of the rail-line. This measure lessens the length of line segments by dividing the segment by its traffic density and takes the form:

$$I = (L(1/(D+1)))$$

where

I = the index of spatial separation;
L = the length of the line segment of the network; and,
D = the traffic density of the line in millions of gross ton-miles per year.

Model Validation

Trip Generation

No data was available to validate the trip generation model.

Trip Distribution

No data was available to validate the trip distribution model.

Mode Choice

No data was available to validate the mode choice model.

Modal Assignment

TRUCK ASSIGNMENT

The 21 categories of goods were aggregated to create total flow trip tables assigned to the roadway network using an all or nothing assignment procedure. The resulting truck volumes were then compared against actual traffic count data on Indiana's highways from 1991 to 1994. Adjustments were made to account for inherent inconsistencies between the modeled flows and the target flows. For example, the lack of intracounty traffic being assigned by the model to the roadways will consistently give low estimates because the traffic count data includes these flows. The overall model explained 48% of the variation in total commercial traffic using the flows assigned at 40 rural locations.

RAIL ASSIGNMENT

No route segment-specific data on rail flows was available to which the assigned values could be compared. A visual examination of rail flows was made to assess their reasonableness.

Model Application

The Indiana Commodity Transport Model has not been applied to date, although the 1998 year trip tables crated by the model are being used as the basis for the development of InDOT's freight truck trip table in an update of the Indiana Statewide Travel Demand Model, now under development.

Performance Measures and Evaluation

No performance measures were developed for this research model.

8.9 Case Study – Florida Intermodal Statewide Highway Freight Model (FISHFM)

Background

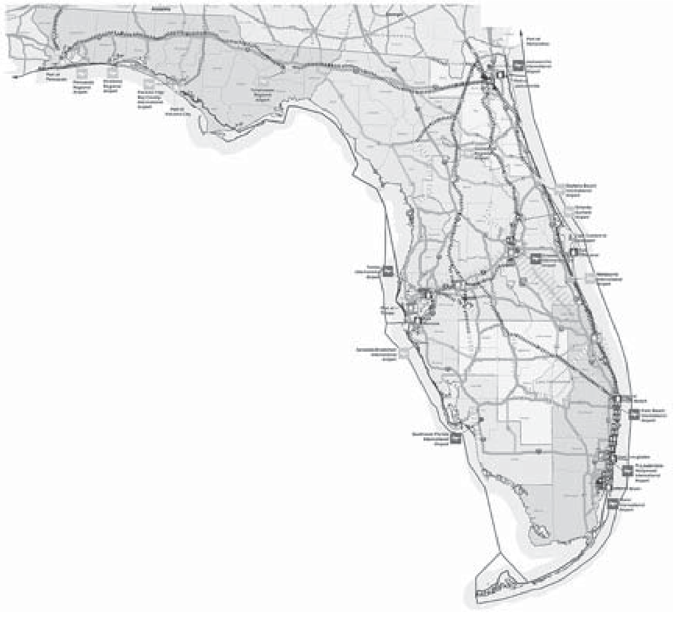
Context

In 2001, the State of Florida had a gross state product of nearly $500 billion, or 5% of the gross domestic product of the United States.[23] If Florida were a separate country, its economy would be the 12th largest in the world, larger than that of India, South Korea, Netherlands, and Australia.[24] The U.S. Census Bureau's CFS shows that in 1997 $214 billion of goods shipments representing 397 million tons originated in Florida. The CFS also indicates that of those shipments 73% by value and 78% by weight moved by truck. In 1997, Florida's seaports and airports handled $64 billion of exports and imports, with trucks the predominant mode of transport to and from these facilities.[25] A study by Cambridge Systematics, Inc. for the Florida Chamber of Commerce, *Transportation Cornerstone Florida*, concluded that the key to the state's economic growth and competitiveness is an efficient intermodal transportation system. Transportation costs, including trucking, currently constitute 5% of the price of goods both nationally and in Florida.

The Florida Department of Transportation (FDOT), recognizing the importance of intermodal freight in the state's economy, has advanced the freight planning process by sponsoring the Florida Freight Stakeholders Task Force and initiating a Strategic Intermodal System (SIS) Plan. A map of the SIS is shown in Figure 8.16. *Transportation Cornerstone Florida* calls for focused investment on trade corridors and international gateways and greater attention to freight mobility and economic development in the planning process.

Objective and Purpose of the Model

FISHFM was designed to support the project-related work of FDOT and Florida's metropolitan planning organizations, which are required by Federal law to consider factors of freight mobility. The purpose of the model was to identify deficiencies and needs and to test solutions on major freight corridors throughout the state. These freight corridors suffer from considerable congestion as they pass through metropolitan areas. For example, I-95 in South Florida is not only a major international freight corridor, it is also the main thoroughfare for local travel in major metropolitan areas, including Miami, Daytona and Jacksonville. I-4 in Central Florida is heavily used by both truckers and tourists and is the site of a growing high-technology industry. In addition, the local highway connections between major freight corridors and intermodal terminals —warehouses, seaports, and airports— are often the weakest link in the intermodal highway chain. The truck freight model will be integrated with MPO transportation models to ensure that needs and deficiencies at the local level that impact efficient freight transportation can easily be identified.



Source: Strategic Intermodal System Plan, Florida Department of Transportation, April 2004.

Figure 8.16. Florida's Strategic Intermodal System.

Many truck trips in Florida begin or end at intermodal terminals, either as long-distance movements or as short-haul connections between intermodal terminals. Because rail, air, and water serve as important components of the freight system, the model determines how freight traffic is allocated and routed among all freight modes in order to produce truck forecasts. While a primary purpose of the model is to forecast truck volumes on highways, the data and forecasts of other freight modes are important as well.

General Approach

Model Class

The FISHFM is a four-step commodity forecasting model. Florida has a statewide highway model in which total truck trips are forecasted based on total employment and are assigned together with auto trips. An existing four-step model for passenger auto and total truck traffic provided the state zone structure, highway network, and employment data that served as the structure for developing the commodity model. The four-step commodity forecasting model is described in detail in Section 6.4.

Modes

Even though the primary purpose of the FISHFM was to analyze freight truck traffic, the model development recognized that over 80% of the freight by tonnage serving Florida's major commercial airports, deepwater ports, and rail container terminals is transported by truck. These intermodal facilities generate significant truck volumes at concentrated locations. The model development further recognized that the rail, water, and air freight systems are important competitors to truck freight. Understanding the demands of other modes was deemed a critical component of the model development.

A primary purpose of FISHFM was to forecast truck volumes on highways. However, the data and forecasts of other freight modes also were determined to be valuable as FDOT prepares to implement a Statewide Intermodal Systems Plan and responds to its Transportation Land Use Study Committee's recommendation that the Florida Intrastate Highway System (FIHS) be expanded to a Florida Intermodal Transportation System (FITS) covering all modes.

Markets

Trucking in Florida consists of very different markets: long-haul interstate/international, intrastate, private/for-hire, truckload/less-than-truckload, local/metropolitan delivery, and drayage (truck shipment between ports, airports, and rail terminals). These markets have different needs, use different vehicles (combination vehicles versus panel trucks) and are sensitive to different variables. Based on the data available to support the development of the model and the role of MPOs in planning for local/metropolitan delivery, the markets selected for inclusion in FISHFM were interregional freight shipments within Florida, drayage movement to and from intermodal terminals, and interstate freight shipments of all kinds. In order to properly account for the various characteristics influencing the interstate shipment of freight, the model had to cover all of North America, although at a level of zone and network detail more geographically aggregated than that for Florida alone.

Framework

Florida's Model Task Force decided that the structure of the FISHFM should follow the basic framework of the four-step Florida Standard Urban Transportation Model Structure (FSUTMS) passenger process. This requires that tons of commodities be generated and distributed and that a mode split component be used to determine which tons are shipped by truck and other modes. Truck trips identified in the mode split process then are assigned to the statewide highway network. All model components operate as part of the FSUTMS software. Following the FSTUMS approach results in a model that is easily understood by users and ensures compatibility with FSUTMS and the statewide passenger model.

TRUCK TYPES

The FISHFM focuses primarily on long-distance commodity freight movements. It captures large trucks moving on the FIHS, the shipment of commodities between regions in Florida, and the shipment of freight between Florida and the rest of North America. These truck trips currently represent about 25% of the total truck trips in Florida, but 45% of the total truck vehicle-miles traveled within the state. These freight movements are surveyed as part of Reebie Associates' TRANSEARCH database. The FISHFM does not address local delivery or service trucks, which primarily serve regional markets and are best modeled at the regional or urban area level as part of the MPO planning process. As such, FISHFM does not attempt to model the two-axle trucks not commonly used in commodity freight shipments.

Data

Forecasting Data

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

The forecasting data include population and employment, used as input to the trip generation step of a freight demand estimation model. Base year values for these data are used to calibrate the trip generation (production and attraction) equations. Forecast values for these data are then used in the generation (production and attraction) equations to predict the number of freight trips that will be generated in future years.

Population serves as an input variable in the trip generation (attraction) equations. Population is one of the key variables that determine regionwide consumption of goods originating from other areas of Florida and nationwide. Base year data were collected from the U.S. Census Bureau's 1998 U.S. Census of population, Florida MPOs, local planning departments, and FSUTMS data (ZDATA1) sets. Future year data were forecast from Florida's Long-Term Economic Forecast, Florida Population Studies-population projections for Florida counties, MPO forecasts, and FSUTMS data (ZDATA1) forecasts.

Employment by commodity sector serves as an independent variable in trip generation (production and attraction) equations for freight tonnage produced and attracted by commodity group. Employment data by industry code are the principal explanatory variables in the trip generation equations. Base year data were collected from the Regional Economic Information System (employment by standard industrial classification, or SIC), County Business Patterns (SIC employment by county), SIC employees by TAZ, Florida MPOs, local planning departments, FSUTMS data (ZDATA2) sets, and the Florida Department of Labor. Future year data were estimated using the Florida Long-Term Economic Forecast.

FORECAST GROWTH OF EXTERNAL MARKETS

While population and employment were chosen to be the forecasting data for freight shipments to and from Florida TAZs, the data were not available or suitable to forecast freight shipments for the zones located outside Florida. For these zones, freight forecasts were developed by factoring existing flows using the growth rates by industry and state provided by the Bureau of Economic Analysis's BEA Projections to 2045.

Modal Networks

FREIGHT MODAL NETWORKS

While the FISHFM is a multimodal commodity model, the assignments were only to be made to a highway network. Information from the other modal networks, such as distances, travel times, or costs, was inferred from the highway network. The highway network for Florida was the existing Statewide Model highway network to ensure compatibility with that model. The highway network outside Florida was drawn from the NHPN, as shown in Figure 8.17.

Figure 8.17. Highway network for Florida Intermodal Statewide Highway Freight Model.

INTERMODAL TERMINAL DATA (SEAPORTS, RAIL YARDS, AIRPORTS)

The location of the intermodal terminals (X Y coordinate or zip code) and the activity (ton shipments from/to for both base year and forecast year) at the major ports and intermodal terminals by commodity were obtained to locate these facilities in FISHFM as special generators. The locations were obtained from the 1999 National Transportation Atlas Databases for the U.S. and Florida, the Strategic Investment Plan to Implement the Intermodal Access Needs of Florida's Seaports (Part II, U.S. and Florida seaports), Federal Aviation Administration Forecasts for the fiscal years 2000-2011, the North America Airport Traffic Report, the Port Facilities Inventory (U.S. and Florida water ports), the U.S. Maritime Administration's Office of Intermodal Development, and published reports from port operators.

Model Development Data

The TRANSEARCH commodity flow database as purchased for Florida was chosen to represent the survey of existing freight flows. The STCC codes in that database were used to develop commodity groups for the model, the existing mode shares were chosen, flows were treated as revealed-preference surveys, the total tonnage originating in a zone was chosen to be the production of freight, and the total of tonnage destined for a zone was chosen to represent the attraction of freight to that zone. The average trip length between zones was used for the pattern of trip distribution.

Conversion Data

VALUES PER TON

The TRANSEARCH data used for the model is in the STCC code. The dollar value per ton by commodity can be obtained from the Commodity Flow Survey records for Florida. However, the 1997 CFS uses a different system, the SCTG. To allow the direct use of the value information by STCC commodity the 1993 CFS, which also used the STCC system, was used to develop values per ton which were adjusted to 1998 dollars using the Consumer Price Index for those years.

DAILY VEHICLES FROM LOAD WEIGHTS AND DAYS OF OPERATION

Commodity flow data are given in terms of tons per year. Because transportation planning functions require model output in the form of vehicles (trucks) per day, it is necessary to determine the amount of goods carried in a vehicle and the number of vehicle operation days in a year. Payloads in tons per day were obtained from the U.S. Census Bureau's VIUS.

Validation Data

Validation data consisted of the truck counts by vehicle class. Classification truck counts on highways are needed to separate truck traffic from passenger car traffic. Truck counts by vehicle class were used for the validation of the model-estimated truck volume. These data are available from the 1999 AADT Report for Florida and Truck Weight Study Data for the U.S. These truck counts include all trucks, not just freight trucks. The FAF's loaded highway network was used to estimate the %age of freight trucks observed in truck counts.

Model Development

Software

FISHFM was designed to run using TRANPLAN software and FSUTMS scripts.

Two FORTRAN programs were written specifically to run FISHFM components. The freight trip generation program, FGEN, generates production and attraction files representing the number of tons of goods generated in each zone by commodity group. The mode split program, FMODESP, allocates commodities to modes, and converts annual tons of truck commodities to daily truck trips. All other components of the FISHFM run using the TRANPLAN program within the FSUTMS structure.

Commodity Groups

In FISHFM, commodity groups serve a function similar to that of trip purposes in passenger travel demand models. The shipments within a commodity group have similar characteristics. A total of 14 commodity groups were defined for the FISHFM, as shown in Table 8.36.

Trip Generation

The FISHFM estimates the total freight tonnage by all modes—truck, carload rail, intermodal rail, water, and air—

Table 8.36. Commodity groups.

Code	Description	Standard Transportation Commodity Codes
1	Agricultural	1, 7, 8, 9
2	Nonmetallic Minerals	10, 13, 14, 19
3	Coal	11
4	Food	20
5	Nondurable Manufacturing	21, 22, 23, 25, 27
6	Lumber	24
7	Chemicals	28
8	Paper	26
9	Petroleum Products	29
10	Other Durable Manufacturing	30, 31, 33-39
11	Clay/Concrete/Glass	32
12	Waste	40
13	Miscellaneous Freight	41-47, 5020, 5030
14	Warehousing	5010

produced (originating) and attracted (terminating) in Florida. Production and attraction equations for the 14 commodity groups were based on population and employment relationships that were identified by statistical regressions with the TRANSEARCH freight database. The trip generation equations were produced by a linear regression of observed county production and attraction tonnage by commodity group as the dependent variable and the employment by industry and/or population variable for that county as the independent variable, as shown in Tables 8.37 and 8.38. The regression assumed a zero-intercept (that is, no freight productions or attractions if the independent variable is also zero). A variety of independent variables were tested to determine the best fit. The choice of independent variable was guided by the employment by SIC in the industry associated with the STCC commodity for the production equations and with the industries determined by an I-O model to be the principal consumers of the commodity for the attraction equations. Productions and attractions of freight tonnage at ports and airports are treated as special generators.

The trip generation equations were programmed into FGEN for inclusion in the FSUTMS package.

Trip Distribution

FISHFM uses a standard gravity model for the distribution of freight tonnage between zones. The average trip lengths for

Table 8.37. Trip production equations.

Code	Name	Coefficient	Variable (Employment)
Commodity Groups			
1	Agricultural	45.597	SIC07
2	Nonmetallic Minerals	6,977.771	SUM(SIC10-14)
3	Coal		No Production Employment
4	Food	245.464	SIC20
5	Nondurable Manufacturing	90.120	SUM(SIC21,22,23,25,27)
6	Lumber	241.464	SIC24
7	Chemicals	678.583	SIC28
8	Paper	190.814	SIC26
9	Petroleum Products	795.117	SIC29
10	Other Durable Manufacturing	212.202	SUM(SIC30,31,33-39)
11	Clay, Concrete, Glass	1498.501	SIC32
12	Waste	0.500	TOTEMP
13	Miscellaneous Freight	0.599	TOTEMP
14	Warehousing	314.852	SIC50 + SIC51

Table 8.38. Trip attraction equations.

Code	Name	Coefficient	Variable	Coefficient	Variable
Commodity Groups					
1	Agricultural	23.537	SIC20		
2	Nonmetallic Minerals	1461.302	SIC28		
3	Coal	178.639	SIC49		
4	Food	109.51	SIC51		
5	Nondurable Manufacturing	24.698	SIC51		
6	Lumber	147.624	SIC25	0.448	Pop
7	Chemicals	83.247	SIC51		
8	Paper	23.924	SIC51		
9	Petroleum Products	0.228	Pop		
10	Other Durable Manufacturing	46.762	SIC 50		
11	Clay, Concrete, Glass	2.964	Pop		
12	Waste	68.089	SIC33		
13	Miscellaneous Freight	2.886	SUM (SIC42,44,45)		
14	Warehousing	2.926	Pop		

each commodity group were calculated from TRANSEARCH. That average trip length was used as the coefficient of TRANPLAN's gravity model deterrence function. The deterrence function calculates friction factors using an exponential decay function of the impedance variable. Distance in miles was used to determine the impedance variable that produced the best fit to the observed trip distributions. A trip length frequency distribution was prepared for both the estimated and the actual trip tables. For all commodity groups except minerals and coal the R^2 was above 0.646. For petroleum and nondurable manufactured goods the R^2 was above 0.95. The coincidence ratio of the actual and estimated trip length frequency distributions also showed the close correspondence between the estimated and actual tables. The average trip distance and deterrence coefficient by commodity group are shown in Table 8.39.

The model trip length frequency distributions of all 14 commodity groups are reasonable matches to the observed trip length frequencies from the Reebie database. For example, Figure 8.18 presents trip length frequency distributions for the food commodity group.

Since the trip distribution used the standard TRANPLAN gravity model program, no special programs were needed to operate with FSUTMS.

Table 8.39. Average trip distance and deterrence coefficient by commodity group.

CG Group	Description	Average Distance	Deterrence Coefficient
1	Agricultural	1,260	0.00079
2	Nonmetallic Minerals	332	0.00301
3	Coal	764	0.00131
4	Food	681	0.00147
5	Nondurable Manufacturing	528	0.00189
6	Lumber	606	0.00165
7	Chemicals	790	0.00127
8	Paper	406	0.00246
9	Petroleum Products	768	0.00130
10	Other Durable Manufacturing	712	0.00140
11	Clay/Concrete/Glass	244	0.00410
12	Waste	1,034	0.00097
13	Miscellaneous Freight	748	0.00134
14	Warehousing	250	0.00400

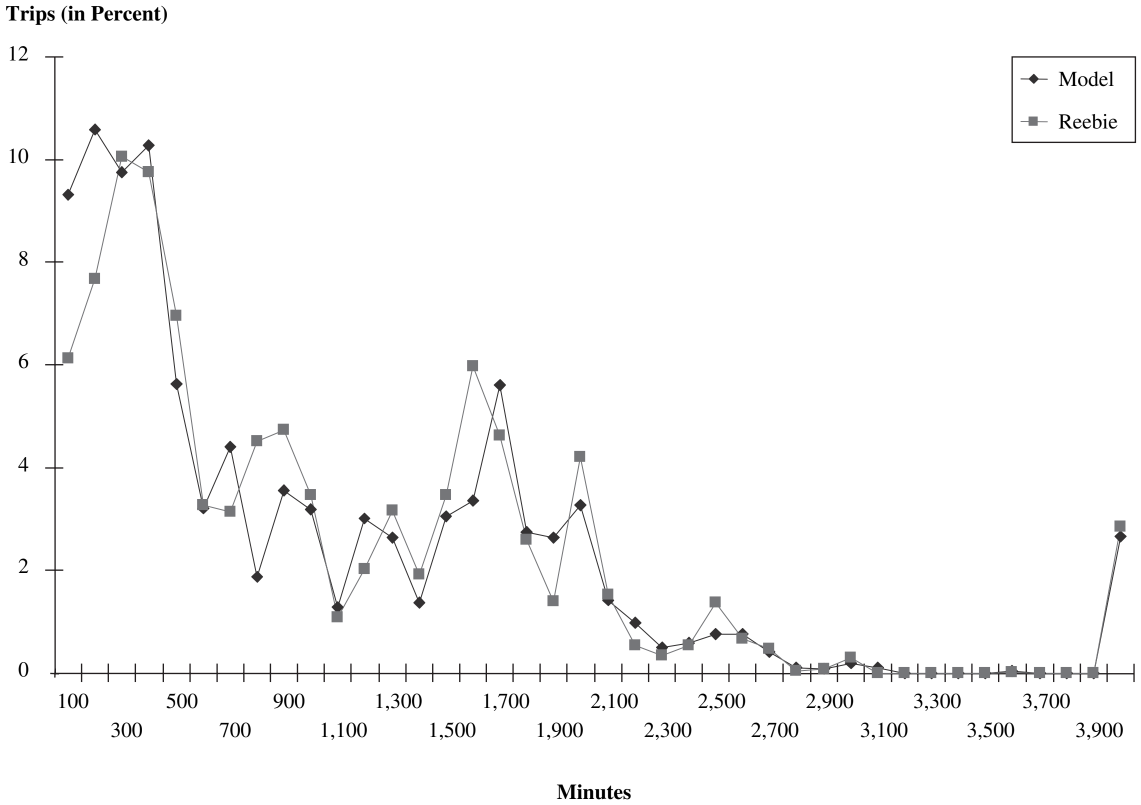


Figure 8.18. Reebie versus model TLF distribution.

Mode Split/Daily Truck Conversion

FISHFM was developed to estimate annual tons shipped by truck, bulk/carload rail, container/intermodal rail, air, and water. The mode split model is in the form of an incremental logit mode choice model. This model pivots from the base mode shares as identified in the TRANSEARCH database. The base water and air mode splits are assumed to remain unchanged. For all O-D pairs, the mode share for each other mode (truck, carload rail, and intermodal rail) for each commodity is the base year mode share as adjusted by an incremental logit model. The coefficients of the utility equation were calculated using ALOGIT and the TRANSEARCH data as a revealed-preference survey.

The mode split model is an incremental logit model, as shown below.

$$S_i' = \frac{S_i * \text{Exp}(\Delta U_i)}{\sum_{I=1}^{J} * \text{Exp}(\Delta U_j)}$$

where

S_i' = New share of mode i;

S_i = Original share of mode i;

ΔU_i = Utility of mode i in the choice set J ($j = 1,2,3, \ldots, J$);

= Modal Constant$_i$ + $b^v \times$ (Explanatory Variable$_i^v$; and

b^v = Coefficient for Explanatory Variable (e.g., travel time).

The explanatory variables applied in the model were the natural log of travel time multiplied by commodity value per ton and travel cost. For the travel time variable, the highway uncongested (free-flow speed) skim file, as created by TRANPLAN, was used. The highway cost is \$0.0575 per mile traveled. The carload rail cost is \$12 + \$0.025 per mile. The intermodal rail cost is \$26 + \$0.028 per mile. The highway time is INT((distance/50 + 8)/18) * 8 + distance/50, which represents travel at 50 mph and an eight-hour rest period after every 10 hours of travel, in accordance with the hours of service regulations. The carload rail time is 60 hours plus distance/20 mph. The intermodal rail time is 24 hours + distance/22.75 mph.

The coefficients of the utility equation are given in Table 8.40. For commodity groups 2, 3, and 13 (minerals, coal, and waste, respectively) no truck tonnage is given in the base year, the truck mode split is 0% for all alternatives, and no coefficients are given. For commodity groups 12 and 14 (clay/concrete and warehousing, respectively), all tonnage is by truck in the base year, the truck mode split is 100% for all alternatives, and no coefficients are given. While the utility constants for carload rail and intermodal rail differ, the utility coefficients for time and cost are the same for both carload and intermodal rail.

FISHFM develops daily truck assignments. It is therefore necessary to convert the annual truck table of tonnages to daily truck trips. The table of annual shipments of tonnage by

Table 8.40. Mode choice model utility coefficients.

Commodity Group	Value per Ton	Intermodal Constant	Carload Constant	Time	Cost
1	$171.49	-2.05	-0.69	-0.00757	-0.00417
2	$24.33	No Truck			
3	$27.01	No Truck			
4	$684.14	-1.85	-0.15	-0.00194	-0.00189
5	$7,175.17	2.86	3.92	-0.00069	0.0281
6	$276.15	-0.68	-2.47	-0.00473	-0.00388
7	$865.91	-3.37	-0.96	-0.00092	-0.00861
8	$1,041.00	-0.45	-1.75	-0.00126	-0.00240
9	$175.93	3.00	9.16	0.000217	0.0868
10	$5,143.68	-0.48	1.88	-0.00048	0.0145
11	$103.62	-1.57	1.72	-0.02075	0.0164
12	$4,612.67	All Truck			
13	$7,264.31	No Truck			
14	$1,618.00	All Truck			

truck between the origins and destinations is converted into truck trips using payload factors established from the Florida data in VIUS. These factors are specific to each commodity group and vary by the distance traveled between zones. The factors include the percentage of mileage that a truck travels empty, based on VIUS.

During the model validation process, truck conversion factors were modified by smoothing the values. The smoothing method was used to fit values to a growth function as a calibration parameter so that the average truck load increased as distance increased. The growth function is defined as follows:

$$\text{Payload Factor} = \exp\left(b_o + (b_1 * \text{Distance})\right)$$

This modification ensured a better fit with observed truck flows. The calibrated tons per daily truck by commodity group are shown in Table 8.41.

In order to implement the mode split component and the conversion to daily truck trips in FSUTMS, a special program known as FMODESP was written in FORTRAN.

Table 8.41. Calibrated tons per daily truck by commodity group.

	Miles				
Commodity Group	Less Than 50	50 to 100	100 to 200	200 to 500	Greater Than 500
Agricultural	13.59	16.04	18.92	22.32	26.34
Nonmetallic Minerals	19.35	20.92	22.63	24.46	26.45
Coal	19.35	20.92	22.63	24.46	26.45
Food	12.19	14.92	18.28	22.38	27.40
Non-durable Manufacturing	3.94	5.79	8.51	12.51	18.38
Lumber	10.80	14.12	18.46	24.14	31.57
Chemicals	10.93	13.29	16.15	19.63	23.87
Paper	15.53	17.99	20.85	24.16	27.99
Petroleum Products	24.58	24.99	25.40	25.82	26.24
Other Durable Manufacturing	6.32	8.92	12.58	17.76	25.07
Clay/Concrete/Glass	19.57	21.29	23.16	25.20	27.41
Waste	12.45	14.99	18.06	21.76	26.21
Miscellaneous Freight	7.79	10.49	14.13	19.02	25.62
Warehousing	8.25	9.93	11.95	14.38	17.30

Table 8.42. Ratio of estimated volume-to-count by facility type.

Area Type	Facility Type	Number of Links with Counts	Estimated Volume	Truck Count	Volume/ Count Ratio
10	10	228	714,290	712,350	1.00
10	20	2	395	410	0.96
10	60	12	24,373	16,662	1.46
Total		**242**	**739,058**	**729,422**	**1.01**

Assignment

The daily truck trip table is assigned to the highway network, which includes the Florida Intrastate Highway System plus major arterials and collectors and the skeletal network developed from the National Highway Planning Network outside Florida. The North American network was connected to the Florida Statewide Model network at nodes shared by external station connectors in the Statewide Model network, as shown in Figure 8.17. The freight trucks are assigned based on free flow paths and preloaded to the network prior to any assigning of general vehicle trips.

Model Validation

Model validation was completed with the same data used in developing the models. During the model validation process, the need to calibrate the model was studied and identified for each model step, including trip generation, trip distribution, mode split/truck conversion, and truck assignment. Validation of the assignment of daily freight trucks was compared against observed truck counts.

Trip Assignment

The truck volumes loaded in the model were validated against the truck counts on major corridors, across the screen lines and external stations. Estimates such as VMT, vehicle-hours traveled by truck, and RMSE statistics were reviewed and compared with existing statewide freight models and urban freight/truck models. The model was validated on corridors, screen lines, area types and facility types as well.

The volume-over-count ratios by facility type are presented in Table 8.42. The overall volume-to-count ratio is a perfect match for interstate freeways (FT 10) with a ratio of 1.00. The highest is for toll roads (FT 60), at 1.46. The lowest is for other freeway types (FT 20), at 0.96 where the values of volumes and counts are low. The overall ratio of 1.01 indicates that the model performs extremely well relative to these performance measures. Table 8.43 shows the volume over count ratios for major interstate freeways (I-75, I-95, and I-10) at the Florida state line. Other major statewide screenline volume-over-count ratios are presented in Table 8.44. The majority of estimates were within 10% of the observed screenline volumes. The RMSE summary is shown in Table 8.45. The overall RMSE is well below the maximum desirable percent RMSE established for urban passenger models by FDOT.

Model Application

The FISHFM is still under development and is being converted to a new statewide model zone structure and network. It is being considered for use in a variety of applications including:

- Existing and forecast productions and attractions of annual freight tonnage for each TAZ in Florida for 14 specific commodities;
- The existing and forecast O-D table of annual freight tonnage moving between TAZs and the external zones covering North America, for 14 specific commodities;
- The existing and forecast table of annual freight tonnage by mode and by commodity derived from the total O-D table;

Table 8.43. Florida state line volume/count ratio.

Interstate Freeway	Model Volume	Observed Count	Volume/Count
I-75	10,175	9,600	1.06
I-95	4,125	4,350	0.95
I-10	4,062	4,450	0.91
Total	**18,362**	**18,400**	**1.00**

Table 8.44. Major statewide screenline volume/count ratio.

Screenline	Model Volume	Observed Count	Volume/Count
North Central Statewide	26,559	30,016	0.88
Southeast Statewide	24,724	24,696	1.00

Table 8.45. RMSE summary for intercity freeways.

All Volume Groups	34.83%
Volume Group Great Than 5,000 Trucks	17.60%
Volume Group Less Than 5,000 Trucks	37.98%

- The existing and forecast table of daily truck trips derived from the O-D table of annual tonnage by truck for 14 specific commodities; and
- The existing and forecast daily volumes of trucks moving on the Florida highway system through assignment of the truck table to the highway network.

Performance Measures and Evaluation

Not developed in FISHFM.

8.10 Case Study – Cross-Cascades Corridor Analysis Project

Background

Context

Washington State depends heavily on trade for its economic well-being. Home to just 2% of the nation's population, the state accounts for 7% of the nation's exports. As a result, Washington's economy is directly linked to its ability to move freight through its many ports.

A number of organizations are responsible for freight mobility in Washington, most notably the Freight Mobility Advisory Committee (FMAC) and the Washington State Department of Transportation (WSDOT). The FMAC, created in 1996 by the Legislative Transportation Committee, is a 23-member body whose purpose is to advise the Washington State Legislature on freight issues. WSDOT's freight mandate was established in 1998, when the Legislature directed the agency to focus on five primary goals, one of which was freight mobility. The Legislature sought to ensure reliable freight movement and transportation investments that supported Washington's strategic trade advantage. In January 2001, the WSDOT reached an agreement with MPOs across the state to develop a new planning and forecasting model that would integrate economic, land use, and transportation decisions and produce interregional forecasts across the full length of the Cross-Cascades Corridor, from Seattle to Spokane, across all modes.

The Cross-Cascades Corridor analysis focused on transportation systems and the Washington economy, and provided a tool for forecasting passenger and freight transportation demand from population and employment forecasts and to use the transportation forecast demand to modify those population and employment forecasts in an iterative process. As shown in Figure 8.19, this project covered two east-west highways (I-90 and SR 2), two railroad lines (the Burlington Northern Santa Fe routes across Stampede Pass and Stevens Pass), and the airways between Seattle and Spokane. This modeling effort could signal a new approach to corridor and statewide modeling across the state.

Objective and Purpose of the Model

The purpose of the Cross-Cascades Corridor analysis was to examine interregional passenger and freight travel between Seattle and Spokane and to construct a forecasting tool that could be used in future corridor studies. WSDOT sought a tool that would:

- Produce interregional passenger and freight forecasts and analysis;
- Integrate output from other models;
- Be transferable and expandable to other corridors;
- Provide six-year and 20-year forecasts;
- Consider alternative modes of travel; and
- Offer visual appeal and a user-friendly format.

Today, WSDOT uses the Cross-Cascades model to test how corridor transportation system changes can affect mode choice, route choice, and travel time performance, and to forecast demands and analyze issues statewide. The model can be interfaced with urban models used in metropolitan

Source: ESRI 2002, prepared by Cambridge Systematics, Inc.

Figure 8.19. Washington state counties and roadways.

areas. For MPO planning purposes, the Cross-Cascades model provides accurate external trips that pass through the metropolitan areas along the corridor. For regional planning purposes, the model provides detailed analysis of statewide freight activity.

General Approach

Model Class

The Cross-Cascades model is an economic class of model. The modeling approach selected in this case is known generally as a spatial I-O model. It distributes household and economic activity across zones, and uses links and nodes of a transportation network to connect the zones and model the transportation system before calculating transportation flows on the network. The location of households and economic activities can be thought of as the land use component of the model.

The basic methodology allows the model to produce forecasts of:

- Traffic volume assignments;
- Mode split;
- Population (household); and
- Employment.

A detailed description of the economic activity class of model is provided in Section 6.5.

Modes

The modes available to make freight trips and shipments include:

- Air freight;
- Rail freight;
- Heavy truck freight; and
- Medium truck freight.

As an integrated passenger and freight model the following passenger modes also are included:

- Air passenger;
- Amtrak (rail passenger);
- Coach (bus passenger);
- Private auto; and
- Work auto.

Markets

The Cross-Cascades model is intended to provide an analysis of general transportation and investment demand in the corridor and to prove the concept of an integrated spatial I-O model. While all passenger and freight activity is calculated for 10 economic sectors and four ranges of household income, the level of geographic detail is limited. The model uses 61 zones, 54 in Washington, 1 in Idaho, and 6 external. Washington and Idaho zones were generally organized by county boundaries. Seven counties within the corridor were further subdivided into 2 to 4 zones, primarily in the Puget Sound area.

Framework

The modeling approach is known as a "spatial input-output model" because it considers not only the level of transportation and economic activities, but also their interaction and spatial distribution across the state. The approach combines the disciplines of land use analysis, economic analysis, and transportation planning process, as shown in Figure 8.20.

Flow Units

The Cross-Cascades Corridor model produces average weekday passenger and freight vehicle volumes on the corridor's transportation system. The model also produces mode splits for freight by highway, rail, and water. The intermediate results of the model produce economic activity (expressed in dollars) which can be converted to tonnage or vehicles.

Data

Forecasting Data

Household Data

County-level 1998 household data were developed from county population and household size statistics from the Washington State Population Survey. County-level households were split into smaller subcounty zones using 1990 U.S. Census tract household data. Total households by zone were divided into four income groups based on data from the 1990 Census.

Employment Data

County-level 1998 employment data by major industry sector were developed from covered employment data and adjusted by industry to reflect total employment. The MEPLAN model requires employment by workplace location. BEA data could not be used directly because they are based on place of residence. Hence, BEA data on total employment by industry and Labor Market Economic Analysis (LMEA) studies of covered and noncovered employment were used instead. Total employment by industry by county was allocated to subcounty, with zones based on 1990 Census data.

MEPLAN Model Coefficient

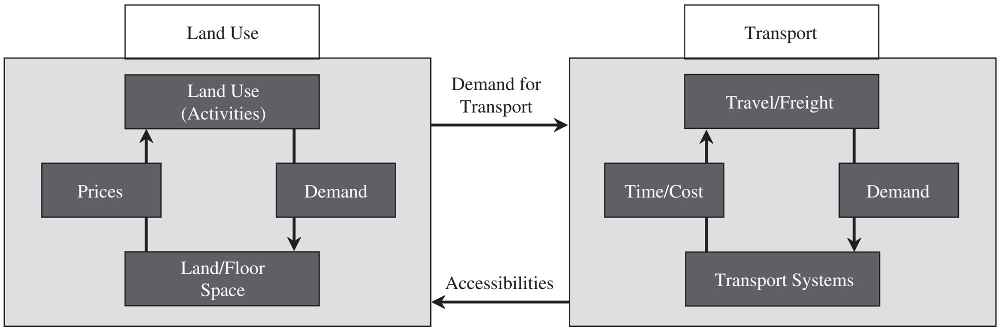
Washington State's economic activity reflects through the MEPLAN model coefficient. The model coefficient in MEPLAN is defined as the amount of each type of employee and household activity required to produce a single unit of economic activity for a certain industrial or household sector. These coefficients translate the industry and household numbers to trips on the transport network.

The data is provided for an internal zone structure that includes:

- Twenty-five subcounty zones within the corridor (24 in Washington and one in Idaho); and
- Thirty other county-level zones in Washington.

The external markets for the Cross-Cascades model consist of the following six external zones:

1. Western Canada;
2. Canada, East of Cascades;
3. Northern Idaho, Montana, and East;



Source: Cross-Cascades Corridor Analysis Project Sumary Report, Washington State Department of Transportation, 2001.

Figure 8.20. The Cross-Cascades Corridor spatial input-output approach.

4. Eastern Oregon, Southern Idaho, and Southwest;
5. West Oregon, California; and
6. Non-United States

As shown in Figure 8.21, three of the external zones are in the United States, two are in Canada, and one is overseas. All trip types considered in the model's internal zones are also forecast for these external zones. The model developers chose not to include eastern portions of North America based on their understanding of study area trade patterns.

Modal Networks

FREIGHT MODAL NETWORKS

The transportation network in the Cross-Cascades Corridor model includes all Washington highways of statewide significance, the Burlington Northern Santa Fe (BNSF) rail lines across Stevens Pass and Stampede Pass, and the airways connecting Seattle, Wenatchee, Yakima, Moses Lake, the Tri-Cities area, and Spokane. Each of these networks also includes connections to external zones. The road network within the corridor was modeled in more detail than the remainder of the state. Highways and rail lines are described in terms of links and nodes. Each link has assigned attributes of length, speed, capacity, and toll charges, if applicable. Centroid connectors link the zones to the transport network, while special links interface between highway, rail, air, and transit routes.

Source: External Zones, Cross-Cascades Corridor Analysis Project Summary Report. Washington State Department of Transportation, 2001.

Figure 8.21. External zones.

- The highway network data are derived primarily from the WSDOT Travel Delay Methodology and the nodes as defined in the WSDOT's EMME/2 transportation network.[26] Rail, air, and transit networks are based on national or carrier-specific data. The Cross-Cascades model used a variety of sources for additional data including: travel delay methodology highway link AADT (and truck percentage); synthesized highway O-D from Washington traffic counts; Washington State Freight Rail Study 1996 rail ton-miles/mile by rail segment; and MPO congested travel times between their external zones.

INTERMODAL TERMINAL DATA

Truck, rail, and air freight terminals are explicitly coded and included in the assignment and path identification process. The use of multimodal paths through intermodal connectors between the various model systems allows the inclusion of terminal transfer costs (parking and freight handling, see costs). Nodes in the transportation component of the Cross-Cascades model include attributes of geographic location and connections for not only highway and rail nodes but also nodes with special identifier codes for airports, truck terminals, and ports.

Model Development Data

Data sources utilized for freight model development and calibration are shown below. Calibrations are primarily focused on trip length and mode split data.

- 1997 Reebie TRANSEARCH O-D flows (tons);
- 1997 U.S. CFS Washington State Internal-External (I-E)/Interstate (I-I) tons and trip lengths;
- 1995 Eastern Washington Intermodal Transportation Study (EWITS) Internal-External Truck tons;
- 1996 Washington Freight Rail Study through (E-E)/E-I tons; and
- Washington Airport Activity Statistics Cargo tonnage enplaned/deplaned.

Other types of calibration data include O-D trip tables, link volumes, and elasticity.

Conversion Data

The model converts annual tonnage to trucks trips using load factors expressed as tons per vehicle. Heavy truck load factors were derived from the EWITS and FAST Trucks weight classification by commodity combined with Reebie Associates commodities and flow. Light and medium truck load factors were derived by assuming an average cargo volume of 100, 60, and 15 cubic yards for heavy, medium, and light trucks, respectively.

Validation Data

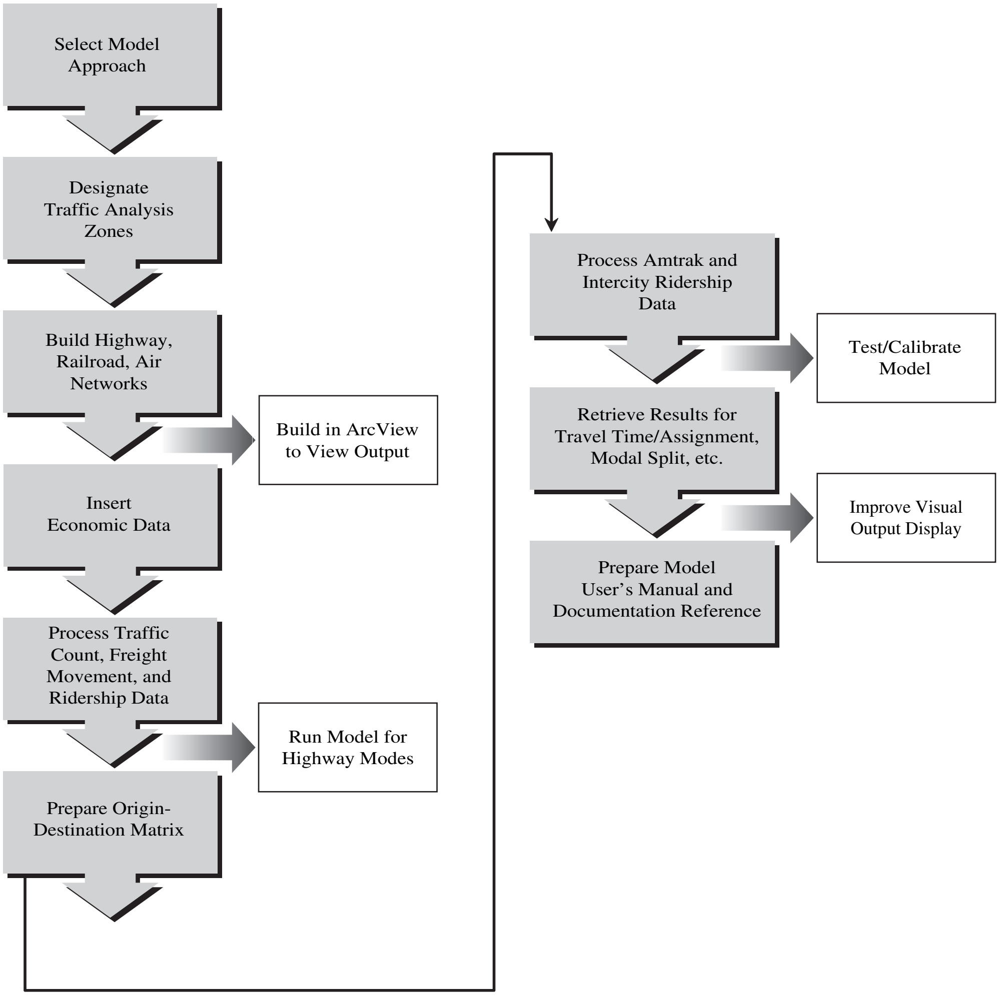
Only minimal calibration and validation were possible within the Cross-Cascades project scope. Thus, the objective of the calibration/validation process, particularly as applied to a real-world example of the Cross-Cascades Corridor, was to make initial model runs and understand the major issues of the model that would point to recommended next steps regarding available target data, model parameters, and shortcomings in model assumptions and structure.

Model Development

The model development effort, shown in Figure 8.22, was initiated in January 2001 by WSDOT and MPO modelers for both the Cross-Cascades and I-15 corridors. This approach is generally known as a spatial I-O model. It distributes household and economic activity across zones, and uses links and nodes of a transportation network to connect the zones and model the transportation system before calculating transportation flows on the network. The model components that forecast the location of households and economic activity are similar to the land use component of integrated transportation and land use models used in urban passenger modeling.

Software

MEPLAN software, developed and distributed by ME&P of Cambridge, England, is used to run the model.[27] MEPLAN



Source: Cross-Cascades Corridor Analysis Project Summary Report, Washington State Department of Transportation, 2001.

Figure 8.22. Cross-Cascades Corridor model development review process.

is based on the concept that, at any geographic level, land use and transport affect one another. The location of households in turn create demands for industrial land, retail floorspace, and housing. The relationship of the supply of land to the demand for development influences prices for space in each location, and that pattern of prices in turn influences where people choose to live and work. In addition the mobility and access provided by transportation also affects the demand and location of residents, employers, and new developments.

The three major components of MEPLAN are as follows:

1. The land use model component, processing economic and household data, including the I-O table and generating output data;
2. The transport assignment model, containing transportation network and flow information; and
3. The interface model, relating land use and economic volumes.

Key outputs generated by MEPLAN include:

- Land use and economic outputs, in terms of zonal characteristics (employment and households);
- Transportation volumes including O-D transportation flow volumes, network link volumes, congested travel times, network data, and other statistics; and
- Interface model including disutility (costs) of transportation between zone and pairs, flow volumes, and evaluation statistics.

Output of the model includes:

- Average daily traffic volumes for the average weekday for the corridor;
- Mode splits between highway, rail, intercity bus, and air for the corridor; and
- Future employment allocation by industry and zone.

Commodity Groups/Truck Types

Exogenous production is production related to sales exported outside of the economic model area. Exogenous production is one of the inputs in the MEPLAN model, and is shown by industry in Washington State in Table 8.46.

Trip Generation

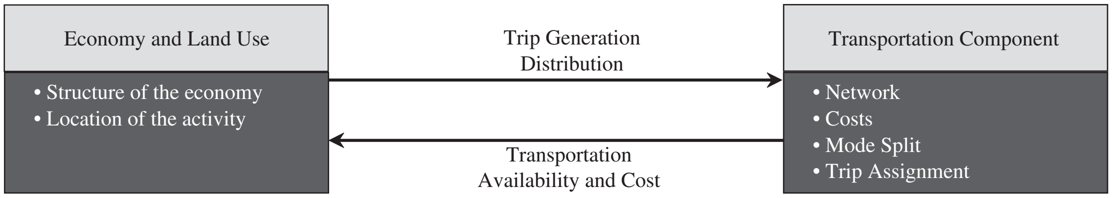
The Cross-Cascades Corridor (see Figure 8.23) model as implemented in MEPLAN, uses an I-O structure of the economy to simulate economic transactions that generate transportation activity. A spatial input/output model identifies economic relationships between origins and destinations. For future years, the spatial allocation of economic activity, and thus trip flows, is influenced by the attributes of the transport network in previous years.

Together, the land use/economic components and the location of the transportation network affect transportation flows. Transportation cost, including the cost of congestion created by increasing travel demands, also influences the location of households and businesses.

Table 8.46. Exogenous production by factor.

Groups	Total	Exogenous	Percent Exogenous
Agriculture	122,398	97,432	80%
Mining	3,380	282	8%
Construction	155,869	42,289	27%
Manufacturing	407,455	185,695	46%
TCPU	145,334	59,150	41%
Wholesale Trade	163,227	15,759	10%
Retail Trade	506,920	28,023	6%
FIRE	143,288	47,205	33%
Services	761,001	233,870	31%
Government	501,340	229,043	46%
$0-15,000 Household Income	640,496	340,219	53%
$30,000-50,000 Household Income	544,471	127,394	23%
$50,000+ Household Income	595,022	54,754	9%
Imports		1,660	

Source: Cross-Cascades Corridor Study Model Development Peer Review Session, June 1, 2001.



Source: Special Input-Outputs, Cross-Cascades Corridor Analysis Project, Summary Report, Washington State Department of Transportation, 2001.

Figure 8.23. Trip generation and distribution structure.

The model is driven by exogenous economic activity generated by exports and non-wage-based household income. It uses an iterative process to forecast the study area economy and transportation demands. By making alternative assumptions about economic growth, the transportation network or travel demands, the model can evaluate the economic/land use and transport impact of various policy choices.

Trade-to-trip ratios translate economic activity and household units into transportation flows in the form of trips and tons of freight. The rates were developed primarily using Nationwide Personal Transportation Survey (NPTS) travel data and Reebie Associates freight data and are provided as inputs to the model.

INDUSTRY-BASED TRANSPORT FLOWS

Trip rates for industry transport flows used Reebie Associates and East Washington Intermodal Transportation Study flow data for through trips combined with Washington State employment levels by industry. The following assumptions were made as supported by Table 8.47.

- STCC commodities one to nine were produced by Agriculture Forestry and Fishing industries;
- STCC commodities 10 to 14 were produced by the Mining industry;
- STCC commodities 19 to 41 were produced by Manufacturing;
- STCC commodities 42 to 50 were produced by Transportation Communications and Public Utilities;
- Wholesale and retail goods production was assumed to be 464 tons per employee (the average of the above industries);
- External to internal truck trips were assumed to generate 2,116 tons/$1.0 million of imports as forecast by MEPLAN; and
- Through truck tips assumed to generate 322 tons/$1.0 million of IMPLAN imports.

Using these classifications and the combined TRANSEARCH/EWITS data for intrastate and internal-external traffic, tons of each value to weight transport flow category were defined for these four industries. These tons were divided by the Washington Labor Market Economic Analysis employment in each industry to generate tons produced per employee.

A key feature of MEPLAN is the ability of the transport model to provide feedback to the land use model. The transport model generates travel disutility (costs) for each zone pair that in turn influences business and household location decisions. In future year iterations of the model, a nested logit model is used to determine the location of business and housing changes in response to these travel costs.

Table 8.47. Freight trip rates 1995 U.S. National Personal Transportation Survey.

	Agriculture	Mining	Manufacturing	Transportation Communications, Public Utilities
1997 I-E/I-I Tons	1	2	3	4
Value/Weight Low	9,265,423	10,820,524	77,089,686	35,423,068
Medium	203,008	0	49,939,463	3,877,568
High	0	0	5,586,221	43,346,426
1998 Employees	122,398	3,380	407,455	145,334
Tons/Employee	77.36	3,201.40	325.45	270.73

Source: Federal Highway Administration, 1995 Nationwide Personal Transportation Survey.

Trip Distribution

Under the Cross-Cascades Corridor model structure, trip generation, and distribution are handled together as described above.

Commodity Trip Table

Not applicable. Commodity tables, TRANSEARCH and others were used indirectly to support the development of model parameters.

Mode Split

The freight transport flows defined by the model include:

- Three freight flows (low, medium, and high value-to-weight); and
- Two external truck trip types (external-external and external-internal).

Modes available to make these freight trips and shipments include:

- Air freight;
- Rail freight;
- Heavy truck freight; and
- Medium truck freight.

In addition the passenger component of the model includes

- Four personal passenger trip categories (commuter, shopping, visit friends and relatives, and recreation/other); and
- Two business passenger trip categories (services and business promotion).

The modes available for these passenger trips include:

- Air passenger;
- Amtrak (rail passenger);
- Coach (bus passenger);
- Private auto; and
- Work auto.

Transportation volumes for each mode and link were determined by first calculating the desired flows that result from the economic transactions and then assigning them to modes and routes. In the Cross-Cascades model, mode choice is calculated based on monetary values of time, distance, and cost. The mode split disutility function structure and coefficients are defined with cost functions. Costs (disutility) are related to mode choice through a nested logit function with linear utility. The function distributes trips stochastically rather than assigning all trips to the least cost route.

There are two types of cost functions: passenger and freight. In this section freight cost functions will be discussed.

FREIGHT COST FUNCTIONS

Freight costs were assumed to consist of a distance-based charge (paid by the shipper to the carrier), a time cost, and a terminal handling fee. A range of distance (per ton-mile) costs was assumed as follows:

- $18.80/hour for passenger drivers; and
- $16.50/hour for commercial drivers.

Terminal handling costs use the distance-based rates and assume a $75 fee for a local (20-mile) medium truck trip. This results in a terminal handling cost of $20.50 for medium trucks. The handling cost is increased by 25% for heavy trucks. Rail handling fees are calculated assuming that medium truck and rail trips are competitive for distances over 250 miles. The handling costs used in the model are shown in Table 8.48.

Table 8.48. Freight rate function.

Mode	Terminal Cost	Distance Rate Range (including terminal cost)	Dollars/Ton-Mile Assumed
Work Drive			
Light Truck	$0	$0.04-$0.10/ton-mile $1.25-2.50/mile	$0.10
Medium Truck	$20.50		$0.08
Heavy Truck	$25.63		$0.10
Rail Freight	$37.50	$0.02-$0.04/ton-mile $2.20-2.73/mile	$0.03
Air Freight	$70.00	$4.90-7.50/ton-mile	$3.00

Flow Unit and Time Period Conversion

Truck load factors are used to convert tons to truck trips as shown in Table 8.49.

Assignment

The Cross-Cascades model handles mode and route choice simultaneously in a manner that distributes trips stochastically rather than assigning all trips to the least cost route. Freight and passenger trips also are handled simultaneously.

Model Validation

A formal process was adopted for calibration of the Cross-Cascades model. Various data items were identified as targets and an algorithmic process was used to adjust parameters to attempt to meet those targets. This process identified parameter values, and provided a framework for investigating lack-of-fit and guidance in changes to the model assumptions and model structure.

A set of targets of historical observations for the Cross-Cascades Corridor were collected for calibration. The targets are generally transportation demand-related, describing the volume of travel by different modes over different distances or origin-destination pairs. The collected targets span the following types of data:

- Trip length distributions;
- Mode splits;
- O-D trip tables;
- Demand elasticity; and
- Road or station counts.

MEPLAN calibration software was used to calibrate the model. The base year Cross-Cascades Corridor MEPLAN model calibration efforts were intended to match passenger and freight targets of average trip lengths by flow and mode, and by mode split by flow. Passenger targets were derived from a weighting of ATS (trips greater than 100 miles) and NPTS data (all trips) for Washington State, while freight targets relied on the Washington State Reebie Associates freight data.

Model Application

The model has not yet been applied.

Performance Measures and Evaluation

The model was tested by running four hypothetical scenarios designed to demonstrate its various capabilities and outputs. The results of the scenarios form initial validation of the predictive capability of the model. The scenario results are useful primarily for demonstration purposes until additional base year calibration can be completed.

In testing the model each of the scenarios was evaluated by comparing impact on:

- Employment by zone;
- Household by zone; and
- Traffic volumes on I-90 and SR 2.

The conclusion of the scenario testing found that the model is working and responds to the proposed scenario policy questions in its predictions of future economic and travel activity.

However, like most of the states, the nature of freight in the state of Washington is complex, and the Cross-Cascades Corridor model might not cover all the issues. In freight models, logistics and fares of freight travel, intermodal connections, and port activities need to be considered carefully. More direct representation of the various freight movements, rather than average cost and shipment size, can be made by using a statistical distribution to more accurately reflect actual freight diversity.

Table 8.49. Truck load factors.

User Mode	Flow	Tons/Vehicle
Light Truck	Mid value-to-weight	3.60
	High value-to-weight	3.41
Medium Truck	Low value-to-weight	15.50
	Mid value-to-weight	14.41
	High value-to-weight	13.64
Heavy Truck	Low value-to-weight	25.92
	Mid value-to-weight	24.02
Freight Truck	Low value-to-weight	75.95
	Mid value-to-weight	68.23

8.11 Case Study – Oregon Statewide Passenger and Freight Forecasting Model

Background

Context

Goods movement by truck is a vital component of Oregon's economy. On an average weekday, approximately 780,000 tons of goods worth $486 million are transported on Oregon state highways. Goods from Washington State make up the largest inbound shipments, reflecting the geographic proximity of Portland to Seattle and Spokane. Goods from California also make up a large share of inbound shipments. Together, Washington and California account for over three-quarters of all inbound truck shipments to Oregon, while the Mountain Pacific, Midwest, and Southern regions of the United States make up approximately 11%.

As shown in Table 8.50, truck traffic in Oregon is expected to grow significantly over the next 20 years. The Oregon Department of Transportation (ODOT) is aware of the crucial role freight transportation plays in the state's economy. In 1995, ODOT initiated the Oregon Model Improvement Program (OMIP) to address the relationship between transportation, land use, and economics. Under OMIP, all Oregon cities, counties, MPOs, and state agencies work together using state-of-the-art transportation modeling tools for application in statewide, urban, and small city model areas.

The area covered by the Oregon model is shown in Figure 8.24.

In 1998, ODOT formed the Oregon Freight Advisory Committee (OFAC). In 2001, the Oregon State Legislature formalized OFAC by passing House Bill 3364. This legislation called for the director of ODOT to appoint members to the committee to advise the director and Oregon Transportation Commission on issues, policies, and programs that impact multimodal freight mobility in Oregon. This included identifying high-priority freight mobility projects for consideration in Transportation Improvement Programs.

Objective and Purpose of the Model

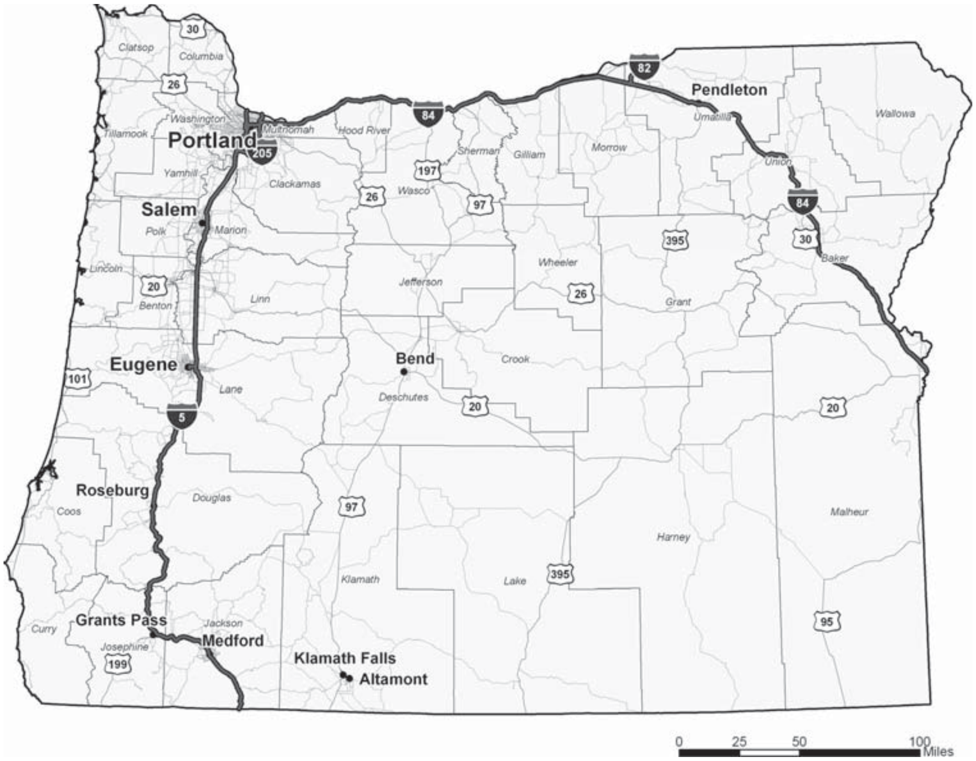
In 1996, the State of Oregon, through ODOT, established the Transportation and Land Use Model Integration Program (TLUMIP) to prepare legislation and guidelines for travel demand and land use planning. The program developed and refined an interactive statewide transportation and land use model for use in transportation planning and policy analysis at varying scales of geography. The model covered the entire State of Oregon, and it complemented all MPO models. It simulated land use and travel behavior mathematically, relying on various data sources. In early 1999, ODOT began developing the second generation statewide model. The second Transportation and Land Use Model Integration Program (TLUMIP2) integrates both passenger travel and freight movements, simultaneously modeling land use, economic activity, transportation supply, and travel demand.

The new Oregon Statewide Model can be used to 1) analyze and support land use and transportation decision-making; and 2) make periodic, long-term economic, demographic, passenger, and commodity flow forecasts at the statewide and substate levels. Specifically, it can be used to analyze the potential effects of transportation and land use policies, plans, programs, and projects on travel behavior and location choices. The model produces outputs that can be used in other analysis packages for assessing transportation system performance.

Table 8.50. Freight shipments to, from, and within Oregon (1998, 2010, and 2020).

	Tons (Millions)			Value (Billions of Dollars)		
Oregon	**1998**	**2010**	**2020**	**1998**	**2010**	**2020**
State Total	291	428	557	201	411	704
By Mode						
Air	<1	<1	1	15	42	85
Highway	220	323	420	165	330	555
Other	2	3	4	<1	<1	<1
Rail	53	81	109	18	34	55
Water	16	20	24	3	5	8

Source: U.S. Highway Administration Office of Operations, Freight News, November 2002.



Source: ESRI 2002, prepared by Cambridge Systematics, Inc.

Figure 8.24. Oregon Statewide Model.

The second generation model includes several important characteristics not found in the first generation. This new model:

- Operates at a single geographic scale, using traffic analysis zones within the urban areas and larger zones outside;
- Fully integrates the economic, land use, and transportation model elements;
- Is dynamic;
- Is a hybrid equilibrium (for economic and transportation markets) and disequilibrium (for activity and location markets) formulation; and
- Is an activity-based travel model.

As of this writing, the second generation Oregon Statewide Model has not been validated or applied, but is described in the following sections of this case study.

General Approach

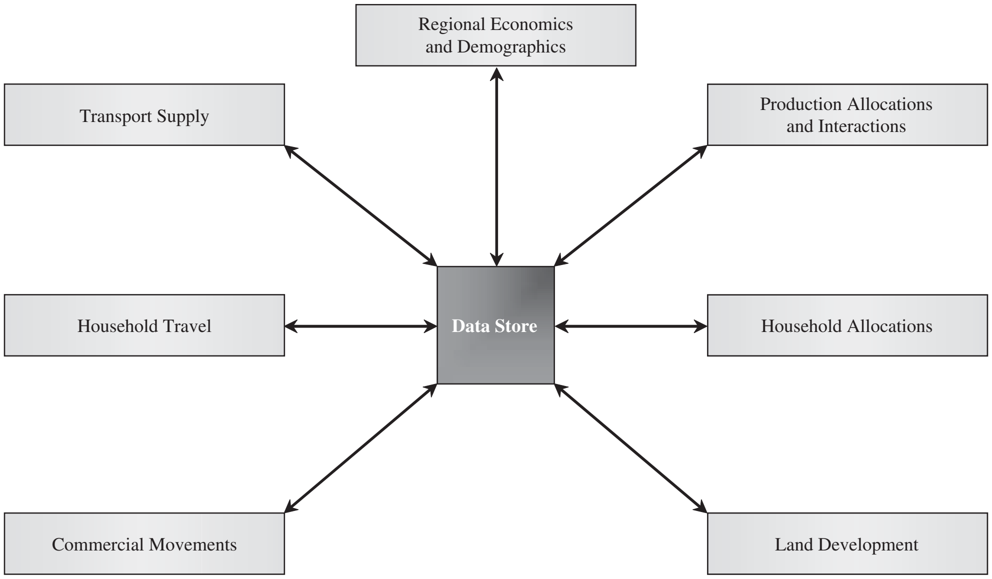
Model Class

The Oregon Statewide Model is an economic class of model designed for forecasting both passenger and freight movements. In contrast to four-step commodity models, economic class models develop modal facility flows by assigning modal O-D tables of commodity flows to modal networks. The zonal employment or economic activity is not directly supplied to the model but is created by applying an economic/land use model. The O-D table, produced by applying commodity trip generation and distribution steps to the resulting employment O-D table, is split to freight modes based on existing shares or a diversion method. A detailed description of the economic activity class of model is provided in Section 6.5.

As shown in Figure 8.25, the Oregon model contains a set of seven separate but highly connected modules: regional economics and demographics; production allocations and interactions; household allocations; land development; commercial movements; household travel; and transportation supply.

REGIONAL ECONOMICS AND DEMOGRAPHICS

The regional economics and demographics module provides productions in each economic sector, imports and exports by economic sector, employment by labor category, and in-migration and payroll by sector for each year. The production sectors in the model follow conventional industry breakdowns. Besides the production sectors, Oregon's model has four sectors for final demand: exports, consumption, investment, and government (state and local).



Source: J.D. Hunt and others, *Design of a Statewide Land Use Transportation Interaction Model for Oregon*, 2001.

Figure 8.25. Modules in the Oregon Statewide Model.

PRODUCTION ALLOCATIONS AND INTERACTIONS

The production allocations and interactions model determines the distribution of production activity among zones, the consumption of space by these production activities, the flows of goods and services and labor from the location (zone) of production to the location (zone) of consumption, and the exchange prices for goods and services, labor, and space each year. The model also uses the concept of exchange locations, the places where commodities transfer between seller and buyer.

HOUSEHOLD ALLOCATIONS

During the allocation of production activities, households stay in the zones in which they were placed by the household allocation module the previous year. The labor flows produced by these households are allocated to the exchange locations as part of the allocation of production activities. Similarly, the flows of commodities consumed by the households are allocated from the exchange locations.

LAND DEVELOPMENT

The land development module determines the changes in space from one year to the next. The supply of space in a particular year is fixed, and the other modules operating for the year take into account this fixed supply. These other components determine a price for each category of space in each zone, and the primary task of the land development module is to adjust the quantity of space over time in response to changes in price. This is done in a highly disaggregate manner, one grid cell at a time.

COMMERCIAL MOVEMENTS

The commercial movement module is used to determine the growth of truck movements during a particular workday in each year. It synthesizes a fully disaggregated list of individual truck movements. For each truck movement, the synthesized data are the vehicle type (light single-unit, heavy single-unit, articulated), starting link, ending link, starting time, commodity carried and transsshipment organization. Shipment sizes are chosen to be consistent with the CFS. A value to weight ratio is necessary to calculate the weight of each shipment. The aggregate flows in the activity interaction matrices are first translated into discrete shipments by commodity, then combined into truck tours. O-D patterns for empty vehicles are derived from the patterns for loaded vehicles.

HOUSEHOLD TRAVEL

The household travel module establishes a list of the specific individual trips made by members of households during a particular representative workday for each year, providing starting link, end link, starting time, tour mode, vehicle occupancy, utility attribute coefficients, and non-network-related utility components. The process starts by assigning each household member an activity pattern for the day. The activity pattern is a listing of the sequence of activities undertaken by the household member as a series of tours made out from the home or work place.

TRANSPORT SUPPLY

The transportation supply module is a hybrid of macroscopic and microscopic techniques. Equilibrium travel times are found by loading a conventional trip table to a network. These equilibrium travel times then are used in a microscopic assignment, which works at the level of individual vehicles, determining the network loadings from synthesized demands of the household travel and commercial movements.

The goods and services shipments flows are determined as part of the spatial distributions of activities and population, following the path from the production locations to the exchange locations and then to the consumption locations. Mode split and assignment are accomplished together as a simultaneous loading to a multimodal network. The multimodal network represents the supply of various combinations of available goods and services.

Apart from the model modules, the principal components of the software system for running the model are data store, process control, user interface, and calibrator.

- The **data store** is the database in which all the information input and output from the modules is stored. All information flowing between modules passes through the data store.
- The **process controller** commands the operational sequence of each of the modules in order to facilitate model run. In a given year, the economic and demographic module is run first, followed by the production allocation and interactions module, and so on following a clockwise circuit as shown in Figure 8.25.
- The **user interface** includes a graphic interface for facilitating both input and output. With the graphic interface, inputs are written to the data store and specified outputs from the data store are presented in graphical or map format as appropriate.
- The **calibrator** facilitates the estimation of specified model parameters given various observations of systems behaviors, considering the fit of the model across modules.

Modes

The Oregon model assigns modal O-D tables of commodity flows to modal networks. The O-D table, produced by applying commodity trip generation and distribution steps to the resulting employment O-D table, is split to freight modes based on existing shares or a diversion method. The modes are two-axle truck, 3+-axle truck, rail, auto and van, water and air cargo.

Markets

The model covers the State of Oregon and extends about 50 miles beyond the state boundaries to the south, east, and north. Each major mode has a separate network. The road network for goods and services matches MPO networks. The freight rail network matches track alignments within Oregon.

Framework

This is a statewide passenger and freight forecasting model. Both passenger and freight vehicles are forecast and assigned simultaneously.

Flow Units

The model estimates O-D table of commodity flows and then converts to freight trucks before assignment.

Data

Forecasting Data

The state and the MPOs develop and maintain the databases needed to produce future year forecasts to support travel demand modeling, land use allocation models, and policy analysis as required under Federal guides and the statewide planning program. These databases and forecasts support statewide planning for intrastate freight and passenger movements and distribution of population and employment growth. The forecasts are sufficiently detailed to provide control totals to city and county planning agencies for use in developing and applying land use allocation models, and travel demand and freight models.

This model operates at three geographic levels: statewide, substate, and urban. The statewide model assesses broad policy options and intercity travel and provides the basis for the substate model. The regional substate model offers a finer level of analysis along the major transportation corridors. Finally, the urban model handles the high-resolution analysis of the local impacts of policy decisions and investments.

The regional economics and demographics module provides productions in each economic sector, imports and exports by economic sectors, employment by labor category, and in-migration and payroll by sector for each year. This module uses United States gross domestic product, employment, and population as exogenous inputs. The regional economic and demographic module determines the total production activity in all the economic sectors other than the households sector over the entire model area each year. The production sectors in the model are listed in Table 8.51.

Besides the production sectors, the Oregon Statewide Model has four sectors for final demand: exports, consumption, investment, and government (state and local). Table 8.52 shows commodity categories included in the model.

BASE AND FORECAST YEAR SOCIOECONOMIC DATA

State DOT and MPOs maintain base year and the future year forecast data. These data are used for travel demand

Table 8.51. Production sectors included in the Oregon model.

Agriculture in Office Space	Production in the Agricultural Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Agriculture in Agricultural Space	Production in the Agricultural Industrial Sector that is located in Agricultural Development Space and consumes Agricultural Labor
Forest in Office Space	Production in the Agricultural Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Forest in Forest Space	Production in the Agricultural Industrial Sector that is located in Forest Development Space and consumes Agricultural, Unskilled and Other Labor
Light Industry in Office Space	Production in the Light Industry Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Light Industry in Light Industrial Space	Production in the Light Industry Industrial Sector that is located in Light Industrial Development Space and consumes assembly and Fabrication, Semiskilled Manual and Other Labor
Heavy Industry in Office Space	Production in the Heavy Industry Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Heavy Industry in Heavy Industrial Space	Production in the Heavy Industry Industrial Sector that is located in Heavy Industrial Development Space and consumes Assembly and Fabrication, Semiskilled Manual and Other Labor
Wholesale in Office Space	Production in the Wholesale Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Wholesale Industry in Warehouse Space	Production in the Warehouse Industrial Sector that is located in Warehouse Development Space and consumes Semiskilled Manual, Unskilled Manual and Other Labor
Retail in Office Space	Production in the Retail Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Retail in Retail Space	Production in the Retail Industrial Sector that is located in Retail Development Space and consumes Retail and Other Labor
Hotel and Accommodation	All production in the Hotel and Accommodation Sector that is located in Hotel Development Space and consumes all categories of Labor
Construction	All production in the Construction Sector that is located at construction sites and consumes all categories of Labor
Health Care in Office Space	Production in the Health Care Industrial Sector that is located in Office Development Space and consumes Managerial, Professional, Clerical and Health Care Labor
Health Care in Hospital Space	Production in the Health Care Industrial Sector that is located in Hospital Development Space and consumes all categories of Labor
Health Care in Institutional Space	Production in the Health Care Industrial Sector that is located in Institutional Development Space and consumes all categories of Labor
Transportation Handling in Office Space	Production in the Transportation Handling Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Transportation Handling in Depot Space	Production in the Transportation Handling Industrial Sector that is located in Depot Development Space and consumes Semiskilled Manual, Unskilled Manual and Other Labor
Other Services in Office Space	Production in the Agricultural Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Other Services in Light Industrial Space	Production in the Other Services Industrial Sector that is located in Light Industrial Development Space and consumes Assembly and Fabrication, Semiskilled Manual, Unskilled Manual Labor and Other Labor
Other Services in Retail Space	Production in the Other Services Industrial Sector that is located in Retail Development Space and consumes Retail Labor
Grade School Education in Office Space	Production in the Grade School Education Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Grade School Education in Grade School Space	Production in the Grade School Education Industrial Sector that is located in Grade School Development Space and consumes Grade School Teaching Labor
Post-Secondary Education	Production in the Post-Secondary Education Sector that is located in Institutional Development Space and consumes all categories of Labor
Government in Office Space	Production in the Government Industrial Sector that is located in Office Development Space and consumes Managerial, Professional and Clerical Labor
Government in Government Support Space	Production in the Government Industrial Sector that is located in Government Support Development Space and consumes all categories of Labor
Government in Institutional Space	Production in the Government Industrial Sector that is located in Institutional Development Space and consumes all categories of Labor

Source: J.D. Hunt and others, *Design of a Statewide Land Use Transportation Interaction Model for Oregon*, 2001.

Table 8.52. Commodity categories included in the Oregon Statewide Model.

Farm Products	Forest Products
Fresh Fish or Marine Products	Metallic Ores
Coal	Crude Petroleum, Natural Gas or Gasoline
Nonmetallic Minerals	Ordnance or Accessories
Food or Kindred Products	Tobacco Products, Excluding Insecticides
Textile Mill Products	Apparel or Other Finished Textile Products or Knit Apparel
Lumber or Wood Products, Excluding Furniture	Furniture or Fixtures
Pulp, Paper or Allied Products	Printed Matter
Chemical or Allied Products	Petroleum or Coal Products
Rubber or Miscellaneous Plastic Products	Leather or Leather Products
Clay, Concrete, Glass or Stone Products	Primary Metal Products, Including Galvanized
Fabricated Metal Products	Machinery, Excluding Electrical
Electrical Machinery, Equipment or Supplies	Transportation Equipment
Instruments, Photographic Goods, Optical Goods, Watches or Clocks	Miscellaneous Products or Manufacturing
Waste or Scrap Materials Not Identified by Producing Industry	Other (Miscellaneous) Freight Shipments
Containers, Carriers or Devices, Shipping, Returned Empty	Waste Hazardous Materials or Waste Hazardous Substances
Construction Services	Pipeline Transportation Services
Transportation and Storage Services	Radio and Television Broadcasting Services
Postal Services	Utilities Services
Wholesale Margins	Retail Margins
Other Finance, Insurance and Real Estate Services	Business Services
Education Services	Health Services
Amusement and Recreation Services	Accommodation Services
Food Services	Other Personal and Miscellaneous Services
Managerial Labor	Professional Labor
Grade-school Teaching Labor	Clerical Labor
Assembly and Fabrication Labor	Agricultural Labor
Semi-skilled Manual Labor	Unskilled Manual Labor
Retail Labor	Health Care Labor
Post-secondary Teaching Labor	Other Labor

modeling, land use allocation models, and policy analysis as required under Federal guides and the statewide planning program. These databases are forecasts that support statewide planning for interstate freight and passenger movements and distribution of population and employment growth.

EXTERNAL MARKETS

Goods from Washington State make up the largest inbound shipments, reflecting the geographic proximity of Portland to Seattle and Spokane. Goods from California also make up a large share of inbound shipments. Together, Washington and California account for over three-quarters of all inbound truck shipments to Oregon.

Modal Networks

FREIGHT MODAL NETWORKS

The model covers the State of Oregon and extends about 50 miles beyond the state boundaries to the south, east, and north. This coverage area is made up of internal zones. Other regions of the United States are considered external zones.

The internal zones are the locations of production, consumption, and exchange. They are largely based on Census tracts and are nested into counties. The internal zones inside Oregon contain grid cells, while the internal zones outside Oregon do not. Zones are consistent with MPO internal zones.

With about 3,000 zones spread across the state, the model uses finer spatial disaggregation than most integrated land use-transportation models. Internal zones are further divided into grid cells and link tributary areas. Grid cells are the smallest units, and they nest completely into both of the other two.

A grid cell is a square of land small enough to include a single type of developed space (one category of building floor space). Cells are typically 30m × 30m in and near built up areas and 300m × 300m or even larger in less densely populated spaces. A total of about 14.5 million grid cells cover the entire model area.

The zones are connected to the transportation network using centroid connectors, as in a conventional travel forecasting model. Link tributary areas are grid cells that feed a particular link and are contained within a single zone. It is possible for a single link to have more than one tributary area if it is located on or near the boundary of more than one zone.

Different parts of the model use different systems of spatial aggregations, depending upon the needs for spatial precision. Units of time vary throughout the model. Land use allocation and economic activity are stepped over time in one-year increments. Thus, activity allocation will tend toward equilibrium but is not in equilibrium in any given year.

Each major mode has a separate network. The road network (for goods and services) matches MPO networks within urban areas and is similarly detailed in rural areas. The freight rail network matches track alignments within Oregon. External areas in both networks are shown skeletally, becoming sparser as the distance from Oregon increases.

The model is dynamic in two distinct ways: 1) it calculates changes in activities over time (years), and 2) traffic is assigned microscopically by time period. The activity allocation aspects of the model give a disequilibrium treatment of land markets and activity allocations while allowing an equilibrium treatment of transportation and commodity markets. The regional economic structure and land use are done using relations similar to those in TRANUS (used in TLUMIP1), an aggregate integrated land use-transport model. Oregon's model is intentionally strong in statewide freight forecasting so that it can reliably evaluate the effects of economic policy changes and future population and economic growth.

Model Development Data

The model consists of seven modules, one of which addresses regional economics and demographics. This module provides productions in each economic sector, imports and exports by economic sector, employment by labor category, and in-migration and payroll by sector for each year.

Conversion Data

The model estimates yearly flow of commodities among TAZs, which it converts to daily weekday freight movements. The commercial movement module is used to determine the growth of truck movements during a particular workday in each year. It synthesizes a fully disaggregated list of individual truck movements. Shipment sizes are chosen to be consistent with the CFS.

Validation Data

The entire model was run and then compared with the weighted observed data to obtain a goodness-of-fit measure.

Model Development

The activity location and transportation network interface produces the trip O-D matrices of demands and possible exogenous trips. The transportation model transforms these demands into actual trips and assigns them to the networks systematically.

The first step in the modeling process is to find all possible paths, after which the process starts an iterative cycle. Both money and generalized costs along each path are calculated initially. A weighted arithmetic average cost over all paths is calculated for monetary costs, but composite costs are aggregated from a path level to a mode level through a logarithmic average. Similarly, aggregated costs over all modes are estimated to obtain the average monetary and composite cost of travel from an origin to a destination for a given user category.

The next two steps in the modeling process are trip generation and trip distribution. Trip generation transforms the potential travel demand into actual trips. It estimates the number of trips from an origin to a destination by a particular transport category, which is a function of the corresponding composite cost.

Trips for each category are split to modes by means of a Multinomial Nested Logit (MNL) model in which the utility function is determined by the composite cost of travel by mode. Mode choice is made over all modes available to each category. Trips by mode assigned to the different paths connect origins and destinations by that mode. Since each path implies a particular sequence of operators and transfers, trips are simultaneously assigned to operators, as well as to links of the network. There is an option in the model to check the empty returning vehicles.

Software

The Oregon Statewide Model has it roots in TRANUS, an integrated land use and transportation model that can be applied at an urban or regional scale.[28] TRANUS has two purposes: 1) to simulate the probable effects of applying particular land use and transport policies and projects, and 2) to evaluate these effects from social, economic, financial, and energy points of view.

TRANUS has two main components: land use and transportation. The relation between the two over time is shown in Figure 8.26. Because land use and transportation influence one another, a change in the transportation system, such as a new road, a mass transit system or change in rate charges, will have an immediate effect on travel demand.

Trip Generation

The TRANUS model converts demand into actual trips and assigns them to various supply options of routes. The sequence of the model is shown in Figure 8.27. First, it generates a set of paths connecting origin and destination of trips by each transport mode (freight, private auto, public transport, etc.). Again, freight might be subdivided into light, medium, and heavy trucks.

Second, TRANUS transforms the potential travel demand calculated by the activity/transport interface into actual trips at particular time of the day (peak, off-peak, 24 hours, etc.). Trips for each category are distributed to modes by means of a MNL logit model in which the utility function is determined by the composite cost of travel by mode. Next, a mode is chosen from among the modes available to each category.

Third, TRANUS assigns trips by mode to the different paths connecting origins to destinations by that mode. Trips are simultaneously assigned to operators and to links of the network. This also is carried out by a MNL model. The combination of the MNL model split and assignment models is equivalent to the two-level hierarchical modal split model. Both models are nested through composite costs.

Trip Distribution

The goods and services shipments flows are determined as part of the spatial distributions of activities and population, following the path from the production locations to the exchange locations and then to the consumption locations. There is no separate trip distribution step like the four-step modeling procedure.

Commodity Trip Table

Not applicable. Commodity tables were not used directly but were used to support the development of model parameters.

Mode Split

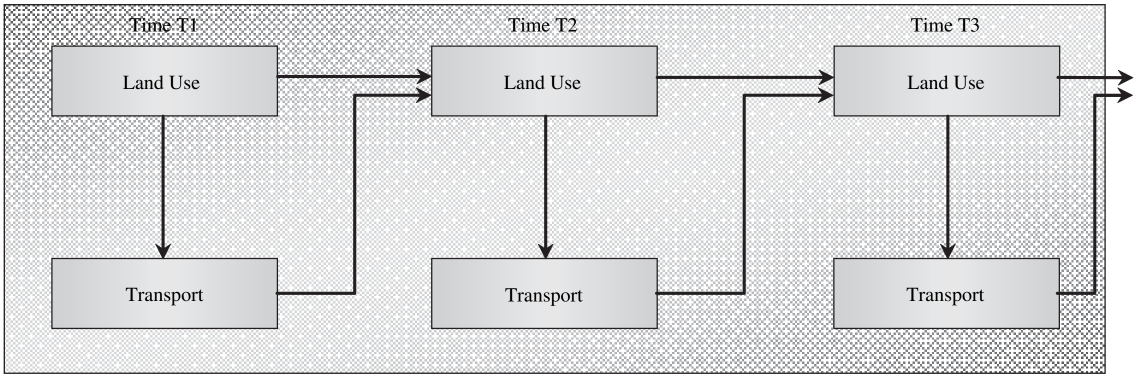
Mode split and assignment are accomplished together as a simultaneous loading to a multimodal network. The multimode network represents the supply of various combinations of available goods and services transportation. The mode alternatives are: two-axle truck, 3+-axle truck, rail, auto and van, water, and air cargo.

Utility is the measure of spatial separation throughout the Oregon Model. Utility separates persons from their activity sites, separates points of production from points of consumption, and separates vehicles from their origins and destinations. Utility is part of several choice processes with many alternatives, such as modes or locations. Thus, in general:

$Ui, a = f\,(\mathrm{ai}, \mathrm{Xa})$

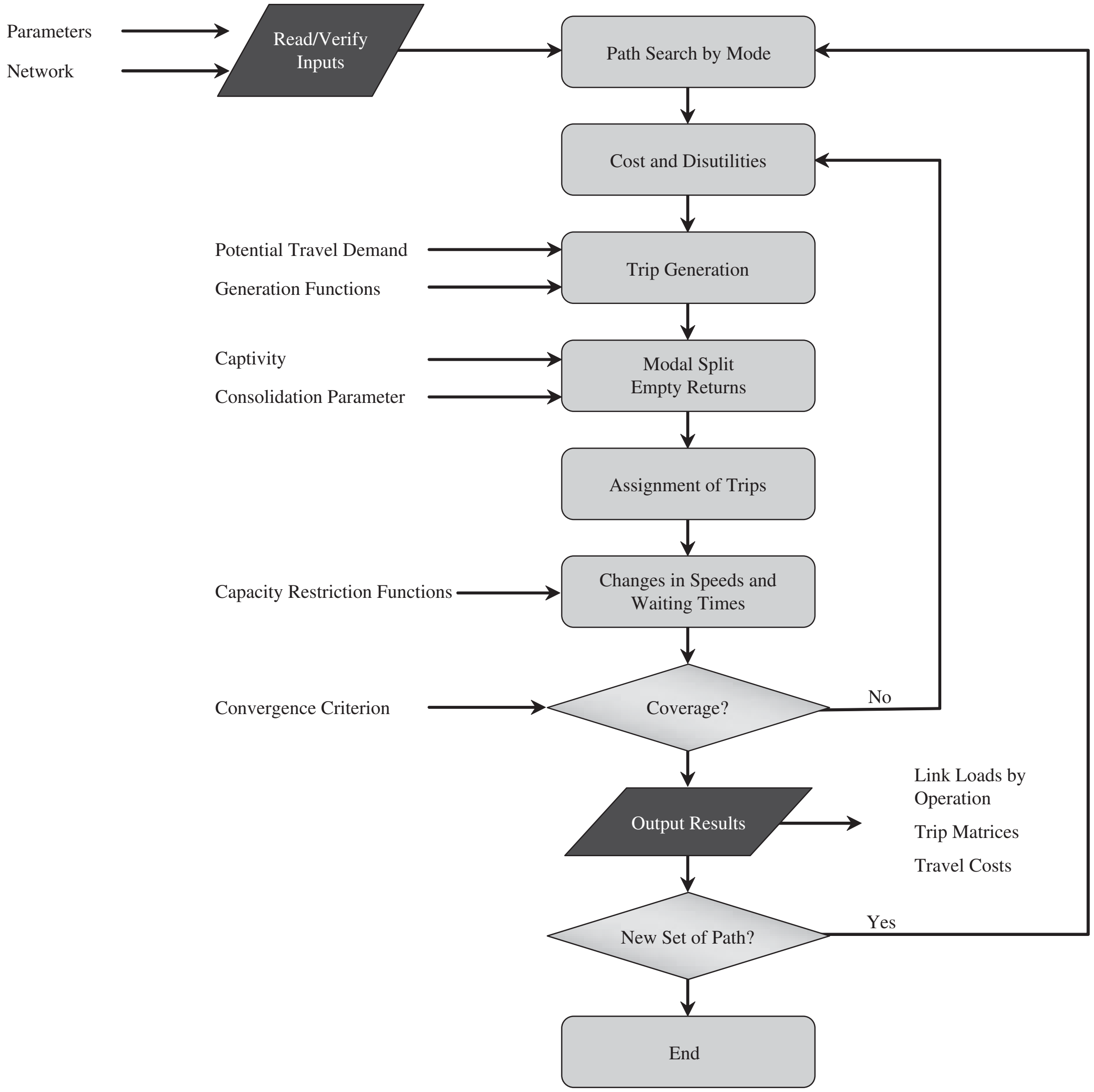
where

i = index representing individuals,
a = index representing alternatives,
Ui, a = utility determined for alternative a for individual i,



Source: Modelistica Systems and Planning, Caracas, Venezuela.

Figure 8.26. Dynamic relations in the land use-transport system.



Source: Modelistica Systems and Planning, Caracas, Venezuela.

Figure 8.27. Calculation sequence of the transport model.

ai = vector of utility function coefficients indicating sensitivities of individual *i* to attributes of alternative, and

Xa = vector of attribute values for alternative *a*.

The model has six manifestations of utility described in Table 8.53.

Flow Unit and Time Period Conversion

The commercial movement module is used to determine the growth of freight movements during a representative workday in each year. In fact, the model steps through time in a series of one-year steps that allow the entire system to evolve. The representation for year $t + 1$ is influenced in part by the conditions determined for year *t*. These yearly freight movements then are converted to a representative weekday.

Assignment

The transportation supply module is a hybrid of macroscopic and microscopic techniques. A standard equilibrium assignment is made using congested travel times and the resulting origin to destination travel times also are saved. These equilibrium travel times are then used in a microscopic assignment, which works at the level of individual vehicles, determining the network loadings from synthesized demands of the household travel and commercial movements.

Table 8.53. Utility definitions in the Oregon Statewide Model.

Utility	Format	Attribute Value Xa	Sensitivity Values ai
Rutlity (Representative)	Allocations of aggregate quantities.	Average, zonal, or typical.	Typical values for the category of aggregate quantity being allocated.
Zutility (Zonal)	Agent-based microsimulations of individual household and person decisions.	Average, zonal, or typical.	Specific values assigned to the household or person.
Iutility (Interchange)	Network path selection for aggregate, zone-to-zone trip flow assignment.	Specific link values.	Aggregate values assigned to the flow being assigned.
Lutility (Link)	Network path selection for individual trip.	Specific link values.	Typical values assigned to the trip-making agent.
Cutility (Cell)	Microsimulations of land development decisions.	Specific grid cell values.	Typical values assigned to the developers as a single category.

Model Validation

Model calibration establishes mathematical equations that replicate observed behavior. Model validation is the process of comparing model outputs against data to determine how well the model simulates aggregate measurements of behavior. Although the model has not yet been fully validated, the following data are going to be used for the validation of the model.

- IMPLAN[29] survey;
- Oregon household travel survey;
- State employment records;
- Highway and local road inventories;
- County assessment records;
- Land sales records;
- Metro (Regional Inventory System) data;
- Statewide zoning; and
- U.S. Census Bureau data.

The study team and peer review panel together developed several criteria for assessing model performance:

- Match production by sector and zone;
- Match number of trips and average trip distances by trip purpose;
- Minimize zone-specific constants by sector;
- Network flows to match counts by mode of transportation, with emphasis on inter-urban routes;
- Match increments of land to changes in land price; and
- Match Central Transportation Planning Package distribution for commuting flows.

Each criterion has it own target number. The network volume must be within plus or minus a certain percentage of the observed volume. Some targets are more important than others.

First, submodels and individual relationships within the various modules were calibrated separately from the overall modeling system and then the entire model was calibrated. The entire model was run and then compared with the weighted observed data to obtain a goodness-of-fit measure. Certain parameters were adjusted and the model was rerun to determine the effect of the adjustments. Finally, during the application of the model, the long-range results of the alternatives were evaluated to ensure that reasonable results were being obtained.

Trip Generation

The second generation Oregon Statewide model has not been validated. The trip generation step is also not validated.

Trip Distribution

Validation data for trip generation step are not available in the Oregon Statewide model documentation.

Mode Choice

Validation data for mode choice step are not available in the Oregon Statewide model documentation.

Modal Assignment

Submodels and individual relationships within the various modules are calibrated first, separate from the overall modeling system, and then the entire model is calibrated. The calibrator facilitates the calibration of the entire model by running the model and comparing its outputs with a selection of weighted observed data to provide a goodness-of-fit measure. However, the validation statistics are not available in the documentation.

Model Application

As of this writing, the second generation Oregon model has not been applied for any projects. However, the model will be used to analyze and support land use and transportation decision-making; and to make periodic, long-term economic, demographic, passenger, and commodity flow forecasts at the statewide and substate levels.

Performance Measures and Evaluation

Performance measures were not developed for the Oregon model. However, the model outputs can be used in other analysis packages for assessing transportation system performance.

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Acronyms

AADT	Annual Average Daily Traffic
AAS	Airport Activity Statistics
ADT	Average Daily Traffic
AGF	Annual Growth Factor
ARIMA	Autoregressive Integrated Moving Average
ASM	Annual Survey of Manufacturers
ATS	American Travel Survey
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BNSF	Burlington Northern Santa Fe
CARB	California Air Resources Board
CFD	Commodity Flow Database
CFS	Commodity Flow Survey
DVRPC	Delaware Valley Regional Planning Commission
E-E	External-External
E-I	External-Internal
EWITS	Eastern Washington Intermodal Transportation Study
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FAFD	Freight Analysis Framework Database
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FIHS	Florida Intrastate Highway System
FIPS	Federal Information Processing System
FISHFM	Florida Intermodal Statewide Highway Freight Model
FITS	Florida Intermodal Transportation System
FMAC	Freight Mobility Advisory Committee (Washington State)
FSUTMS	Florida Standard Urban Transportation Model Structure
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GVW	Gross Vehicle Weight
HCM	Highway Capacity Manual
HDT	Heavy-duty Truck
HERS	Highway Economic Requirements System
HPMS	Highway Performance Monitoring System
IDAS	Intelligent Transportation Systems Deployment Analysis System
InDOT	Indiana Department of Transportation
I-O	Input-Output
IRC	Interregional Corridor System (Minnesota)
ITS	Intelligent Transportation System
LMEA	Labor Market Economic Analysis
LOS	Level of Service
LTL	Less-than-truckload
Mn/DOT	Minnesota Department of Transportation
MNL	Multinomial Nested Logit
MORPC	Mid-Ohio Regional Planning Commission
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NCHRP	National Cooperative Highway Research Program
NHN	National Highway Network
NHPN	National Highway Planning Network
NHS	National Highway System
NJDOT	New Jersey Department of Transportation
NN	National Network
NPTS	Nationwide Personal Transportation Survey
NTAD	National Transportation Atlas Database

NYDOT	New York Department of Transportation
O-D	Origin-Destination
ODOT	Ohio Department of Transportation/Oregon Department of Transportation
OFAC	Oregon Freight Advisory Committee
OMIP	Oregon Model Improvement Program
PCE	Passenger Car Equivalent
PeMs	Performance Measurement Project
RMSE	Root Mean Square Errors
RTM	Regional Transportation Model (Southern California Association of Governments)
SCAG	Southern California Association of Governments
SCTG	Standard Classification of Transported Goods
SIC	Standard Industrial Classification
SIS	Strategic Intermodal System (Florida)
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Classification
STIP	Statewide Transportation Improvement Program
TAZ	Traffic Analysis Zone
TEA-21	Transportation Equity Act for the 21st Century
TEU	Twenty-foot Equivalent Unit
TIUS	Truck Inventory and Use Survey
TL	Truck Load
TLUMIP	Transportation and Land Use Model Integration Program (Oregon)
V/C	Volume to Capacity
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle-Miles Traveled
WSDOT	Washington State Department of Transportation

APPENDIX A

Commodity Classifications

Table A.1. Correspondence between SIC and NAICS categories.

SIC		NAICS	
Code	Description	Code	Description
01	Agricultural Production- Crops	11	Agriculture, Forestry, Fishing and Hunting
02	Agricultural Production- Livestock	11	Agriculture, Forestry, Fishing and Hunting
07	Agricultural Services	11	Agriculture, Forestry, Fishing and Hunting
07	Agricultural Services	54	Professional, Scientific, and Technical Services
07	Agricultural Services	56	Administrative and Support and Waste Management
07	Agricultural Services	81	Other Services (except Public Administration)
07	Agricultural Services	311	Food Manufacturing
08	Forestry	11	Agriculture, Forestry, Fishing and Hunting
09	Fishing, Hunting, and Trapping	11	Agriculture, Forestry, Fishing and Hunting
10	Metal Mining	21	Mining
10	Metal Mining	54	Professional, Scientific, and Technical Services
12	Coal Mining	21	Mining
13	Oil and Gas Extraction	21	Mining
13	Oil and Gas Extraction	54	Professional, Scientific, and Technical Services
14	Nonmetallic Minerals, except Fuels	21	Mining
14	Nonmetallic Minerals, except Fuels	54	Professional, Scientific, and Technical Services
15	General Building Contractors	23	Construction
16	Heavy Construction Contractors	23	Construction
17	Special Trade Contractors	23	Construction
17	Special Trade Contractors	56	Administrative and Support and Waste Management
20	Food and Kindred Products	11	Agriculture, Forestry, Fishing and Hunting
20	Food and Kindred Products	311	Food Manufacturing
20	Food and Kindred Products	312	Beverage and Tobacco Product Manufacturing
21	Tobacco Manufactures	312	Beverage and Tobacco Product Manufacturing
22	Textile Mill Products	313	Textile Mills
22	Textile Mill Products	314	Textile Product Mills
22	Textile Mill Products	315	Apparel Manufacturing
23	Apparel and Other Textile Products	313	Textile Mills
23	Apparel and Other Textile Products	314	Textile Product Mills
23	Apparel and Other Textile Products	315	Apparel Manufacturing
23	Apparel and Other Textile Products	323	Printing and Related Support Activities
23	Apparel and Other Textile Products	336	Transportation Equipment Manufacturing
23	Apparel and Other Textile Products	339	Miscellaneous Manufacturing
24	Lumber and Wood Products	11	Agriculture, Forestry, Fishing and Hunting
24	Lumber and Wood Products	321	Wood Product Manufacturing
24	Lumber and Wood Products	333	Machinery Manufacturing
24	Lumber and Wood Products	337	Furniture and Related Product Manufacturing
24	Lumber and Wood Products	339	Miscellaneous Manufacturing
25	Furniture and Fixtures	336	Transportation Equipment Manufacturing
25	Furniture and Fixtures	337	Furniture and Related Product Manufacturing
25	Furniture and Fixtures	339	Miscellaneous Manufacturing
26	Paper and Allied Products	322	Paper Manufacturing
26	Paper and Allied Products	326	Plastics and Rubber Products Manufacturing
27	Printing and Publishing	51	Information
27	Printing and Publishing	323	Printing and Related Support Activities
28	Chemicals and Allied Products	21	Mining
28	Chemicals and Allied Products	311	Food Manufacturing

(continued on next page)

Table A.1. (Continued).

SIC		NAICS	
Code	Description	Code	Description
28	Chemicals and Allied Products	325	Chemical Manufacturing
28	Chemicals and Allied Products	331	Primary Metal Manufacturing
29	Petroleum and Coal Products	324	Petroleum and Coal Products Manufacturing
30	Rubber and Miscellaneous Plastics Products	313	Textile Mills
30	Rubber and Miscellaneous Plastics Products	315	Apparel Manufacturing
30	Rubber and Miscellaneous Plastics Products	316	Leather and Allied Product Manufacturing
30	Rubber and Miscellaneous Plastics Products	325	Chemical Manufacturing
30	Rubber and Miscellaneous Plastics Products	326	Plastics and Rubber Products Manufacturing
30	Rubber and Miscellaneous Plastics Products	337	Furniture and Related Product Manufacturing
30	Rubber and Miscellaneous Plastics Products	339	Miscellaneous Manufacturing
31	Leather and Leather Products	315	Apparel Manufacturing
31	Leather and Leather Products	316	Leather and Allied Product Manufacturing
31	Leather and Leather Products	321	Wood Product Manufacturing
31	Leather and Leather Products	339	Miscellaneous Manufacturing
32	Stone, Clay, Glass, and Concrete Products	21	Mining
32	Stone, Clay, Glass, and Concrete Products	327	Nonmetallic Mineral Product Manufacturing
32	Stone, Clay, Glass, and Concrete Products	332	Fabricated Metal Product Manufacturing
32	Stone, Clay, Glass, and Concrete Products	336	Transportation Equipment Manufacturing
33	Primary Metal Industries	324	Petroleum and Coal Products Manufacturing
33	Primary Metal Industries	331	Primary Metal Manufacturing
33	Primary Metal Industries	332	Fabricated Metal Product Manufacturing
33	Primary Metal Industries	335	Electrical Equipment, Appliance, and Component Manufacturing
34	Fabricated Metal Products	322	Paper Manufacturing
34	Fabricated Metal Products	332	Fabricated Metal Product Manufacturing
34	Fabricated Metal Products	333	Machinery Manufacturing
34	Fabricated Metal Products	334	Computer and Electronic Product Manufacturing
34	Fabricated Metal Products	336	Transportation Equipment Manufacturing
34	Fabricated Metal Products	337	Furniture and Related Product Manufacturing
34	Fabricated Metal Products	339	Miscellaneous Manufacturing
35	Industrial Machinery and Equipment	314	Textile Product Mills
35	Industrial Machinery and Equipment	332	Fabricated Metal Product Manufacturing
35	Industrial Machinery and Equipment	333	Machinery Manufacturing
35	Industrial Machinery and Equipment	334	Computer and Electronic Product Manufacturing
35	Industrial Machinery and Equipment	335	Electrical Equipment, Appliance, and Component Manufacturing
35	Industrial Machinery and Equipment	336	Transportation Equipment Manufacturing
35	Industrial Machinery and Equipment	339	Miscellaneous Manufacturing
36	Electrical and Electronic Equipment	51	Information
36	Electrical and Electronic Equipment	332	Fabricated Metal Product Manufacturing
36	Electrical and Electronic Equipment	333	Machinery Manufacturing
36	Electrical and Electronic Equipment	334	Computer and Electronic Product Manufacturing
36	Electrical and Electronic Equipment	335	Electrical Equipment, Appliance, and Component Manufacturing
36	Electrical and Electronic Equipment	336	Transportation Equipment Manufacturing
36	Electrical and Electronic Equipment	339	Miscellaneous Manufacturing
36	Electrical and Electronic Equipment		
37	Transportation Equipment	54	Professional, Scientific, and Technical Services
37	Transportation Equipment	81	Other Services (except Public Administration)
37	Transportation Equipment	332	Fabricated Metal Product Manufacturing
37	Transportation Equipment	333	Machinery Manufacturing

Table A.1. (Continued).

SIC		NAICS	
Code	Description	Code	Description
37	Transportation Equipment	336	Transportation Equipment Manufacturing
37	Transportation Equipment	488	Support Activities for Transportation
38	Instruments and Related Products	322	Paper Manufacturing
38	Instruments and Related Products	325	Chemical Manufacturing
38	Instruments and Related Products	332	Fabricated Metal Product Manufacturing
38	Instruments and Related Products	333	Machinery Manufacturing
38	Instruments and Related Products	334	Computer and Electronic Product Manufacturing
38	Instruments and Related Products	339	Miscellaneous Manufacturing
39	Miscellaneous Manufacturing Industries	316	Leather and Allied Product Manufacturing
39	Miscellaneous Manufacturing Industries	325	Chemical Manufacturing
39	Miscellaneous Manufacturing Industries	326	Plastics and Rubber Products Manufacturing
39	Miscellaneous Manufacturing Industries	332	Fabricated Metal Product Manufacturing
39	Miscellaneous Manufacturing Industries	333	Machinery Manufacturing
39	Miscellaneous Manufacturing Industries	334	Computer and Electronic Product Manufacturing
39	Miscellaneous Manufacturing Industries	335	Electrical Equipment, Appliance, and Component Manufacturing
39	Miscellaneous Manufacturing Industries	336	Transportation Equipment Manufacturing
39	Miscellaneous Manufacturing Industries	337	Furniture and Related Product Manufacturing
39	Miscellaneous Manufacturing Industries	339	Miscellaneous Manufacturing
41	Local and Interurban Passenger Transit	62	Health Care and Social Assistance
41	Local and Interurban Passenger Transit	485	Transit and Ground Passenger Transportation
41	Local and Interurban Passenger Transit	487	Scenic and Sightseeing Transportation
41	Local and Interurban Passenger Transit	488	Support Activities for Transportation
42	Motor Freight Transportation and Warehousing	53	Real Estate and Rental and Leasing
42	Motor Freight Transportation and Warehousing	56	Administrative and Support and Waste Management
42	Motor Freight Transportation and Warehousing	484	Truck Transportation
42	Motor Freight Transportation and Warehousing	488	Support Activities for Transportation
42	Motor Freight Transportation and Warehousing	48-49	Transportation and Warehousing
43	U.S. Postal service	48-49	Transportation and Warehousing
44	Water Transportation	53	Real Estate and Rental and Leasing
44	Water Transportation	71	Arts, Entertainment, and Recreation
44	Water Transportation	483	Water Transportation
44	Water Transportation	487	Scenic and Sightseeing Transportation
44	Water Transportation	488	Support Activities for Transportation
45	Transportation by Air	56	Administrative and Support and Waste Management
45	Transportation by Air	62	Health Care and Social Assistance
45	Transportation by Air	481	Air Transportation
45	Transportation by Air	487	Scenic and Sightseeing Transportation
45	Transportation by Air	488	Support Activities for Transportation
45	Transportation by Air	48-49	Transportation and Warehousing
46	Pipelines, except Natural Gas	486	Pipeline Transportation
47	Transportation Services	53	Real Estate and Rental and Leasing
47	Transportation Services	54	Professional, Scientific, and Technical Services
47	Transportation Services	56	Administrative and Support and Waste Management
47	Transportation Services	72	Accommodation and Food Services
47	Transportation Services	487	Scenic and Sightseeing Transportation

(continued on next page)

Table A.1. (Continued).

SIC		NAICS	
Code	Description	Code	Description
47	Transportation Services	488	Support Activities for Transportation
48	Communications	51	Information
48	Communications	485	Transit and Ground Passenger Transportation
49	Electric, Gas, and Sanitary Services	22	Utilities
49	Electric, Gas, and Sanitary Services	56	Administrative and Support and Waste Management
49	Electric, Gas, and Sanitary Services	486	Pipeline Transportation
49	Electric, Gas, and Sanitary Services	488	Support Activities for Transportation
50	Wholesale Trade--Durable Goods	42	Wholesale Trade
50	Wholesale Trade--Durable Goods	441	Motor Vehicle and Parts Dealers
50	Wholesale Trade--Durable Goods	442	Furniture and Home Furnishings Stores
50	Wholesale Trade--Durable Goods	443	Electronics and Appliance Stores
50	Wholesale Trade--Durable Goods	444	Building Material and Garden Equipment and Suppliers
50	Wholesale Trade--Durable Goods	446	Health and Personal Care Stores
50	Wholesale Trade--Durable Goods	453	Miscellaneous Store Retailers
51	Wholesale Trade--Nondurable Goods	42	Wholesale Trade
51	Wholesale Trade--Nondurable Goods	54	Professional, Scientific, and Technical Services
51	Wholesale Trade--Nondurable Goods	311	Food Manufacturing
51	Wholesale Trade--Nondurable Goods	312	Beverage and Tobacco Product Manufacturing
51	Wholesale Trade--Nondurable Goods	313	Textile Mills
51	Wholesale Trade--Nondurable Goods	444	Building Material and Garden Equipment and Suppliers
51	Wholesale Trade--Nondurable Goods	453	Miscellaneous Store Retailers
51	Wholesale Trade--Nondurable Goods	454	Nonstore Retailers
52	Building Materials, Hardware, Garden Supply, and Mobile Home Dealers	444	Building Material and Garden Equipment and Suppliers
52	Building Materials, Hardware, Garden Supply, and Mobile Home Dealers	453	Miscellaneous Store Retailers
53	General Merchandise Stores	452	General Merchandise Stores
54	Food Stores	72	Accommodation and Food Services
54	Food Stores	311	Food Manufacturing
54	Food Stores	445	Food and Beverage Stores
54	Food Stores	446	Health and Personal Care Stores
54	Food Stores	447	Gasoline Stations
54	Food Stores	452	General Merchandise Stores
54	Food Stores	454	Nonstore Retailers
55	Automotive Dealers and Gasoline Service Stations	441	Motor Vehicle and Parts Dealers
55	Automotive Dealers and Gasoline Service Stations	447	Gasoline Stations
55	Automotive Dealers and Gasoline Service Stations	452	General Merchandise Stores
56	Apparel and Accessory Stores	315	Apparel Manufacturing
56	Apparel and Accessory Stores	448	Clothing and Clothing Accessories Stores
57	Furniture, Home Furnishings and Equipment Stores	314	Textile Product Mills
57	Furniture, Home Furnishings and Equipment Stores	337	Furniture and Related Product Manufacturing
57	Furniture, Home Furnishings and Equipment Stores	441	Motor Vehicle and Parts Dealers

Table A.1. (Continued).

SIC		NAICS	
Code	Description	Code	Description
57	Furniture, Home Furnishings and Equipment Stores	442	Furniture and Home Furnishings Stores
57	Furniture, Home Furnishings and Equipment Stores	443	Electronics and Appliance Stores
57	Furniture, Home Furnishings and Equipment Stores	451	Sporting Goods, Hobby, Book, and Music Stores
57	Furniture, Home Furnishings and Equipment Stores		
58	Eating and Drinking Places	71	Arts, Entertainment, and Recreation
58	Eating and Drinking Places	72	Accommodation and Food Services
59	Miscellaneous Retail	52	Finance and Insurance
59	Miscellaneous Retail	72	Accommodation and Food Services
59	Miscellaneous Retail	339	Miscellaneous Manufacturing
59	Miscellaneous Retail	443	Electronics and Appliance Stores
59	Miscellaneous Retail	445	Food and Beverage Stores
59	Miscellaneous Retail	446	Health and Personal Care Stores
59	Miscellaneous Retail	448	Clothing and Clothing Accessories Stores
59	Miscellaneous Retail	451	Sporting Goods, Hobby, Book, and Music Stores
59	Miscellaneous Retail	453	Miscellaneous Store Retailers
59	Miscellaneous Retail	454	Nonstore Retailers
60	Depository Institutions	52	Finance and Insurance
61	Nondepository Credit Institutions	52	Finance and Insurance
61	Nondepository Credit Institutions	53	Real Estate and Rental and Leasing
62	Security, Commodity Brokers, and Services	52	Finance and Insurance
63	Insurance Carriers	52	Finance and Insurance
64	Insurance Agents, Brokers, and Service	52	Finance and Insurance
65	Real Estate	23	Construction
65	Real Estate	53	Real Estate and Rental and Leasing
65	Real Estate	54	Professional, Scientific, and Technical Services
65	Real Estate	71	Arts, Entertainment, and Recreation
65	Real Estate	81	Other Services (except Public Administration)
67	Holding and Other Investment Offices	52	Finance and Insurance
67	Holding and Other Investment Offices	53	Real Estate and Rental and Leasing
67	Holding and Other Investment Offices	55	Management of Companies and Enterprises
67	Holding and Other Investment Offices	81	Other Services (except Public Administration)
70	Hotels, Rooming Houses, Camps, and Other Lodging Places	72	Accommodation and Food Services
72	Personal Services	53	Real Estate and Rental and Leasing
72	Personal Services	54	Professional, Scientific, and Technical Services
72	Personal Services	56	Administrative and Support and Waste Management
72	Personal Services	61	Educational Services
72	Personal Services	81	Other Services (except Public Administration)
73	Business Services	23	Construction
73	Business Services	42	Wholesale Trade
73	Business Services	51	Information
73	Business Services	52	Finance and Insurance
73	Business Services	53	Real Estate and Rental and Leasing
73	Business Services	54	Professional, Scientific, and Technical Services
73	Business Services	56	Administrative and Support and Waste Management

(continued on next page)

Table A.1. (Continued).

SIC		NAICS	
Code	Description	Code	Description
73	Business Services	71	Arts, Entertainment, and Recreation
73	Business Services	81	Other Services (except Public Administration)
73	Business Services	313	Textile Mills
73	Business Services	314	Textile Product Mills
73	Business Services	323	Printing and Related Support Activities
73	Business Services	325	Chemical Manufacturing
73	Business Services	334	Computer and Electronic Product Manufacturing
73	Business Services	443	Electronics and Appliance Stores
73	Business Services	48-49	Transportation and Warehousing
75	Automotive Repair, Services, and Parking	53	Real Estate and Rental and Leasing
75	Automotive Repair, Services, and Parking	81	Other Services (except Public Administration)
75	Automotive Repair, Services, and Parking	326	Plastics and Rubber Products Manufacturing
75	Automotive Repair, Services, and Parking	488	Support Activities for Transportation
76	Miscellaneous Repair Services	11	Agriculture, Forestry, Fishing and Hunting
76	Miscellaneous Repair Services	23	Construction
76	Miscellaneous Repair Services	56	Administrative and Support and Waste Management
76	Miscellaneous Repair Services	71	Arts, Entertainment, and Recreation
76	Miscellaneous Repair Services	81	Other Services (except Public Administration)
76	Miscellaneous Repair Services	335	Electrical Equipment, Appliance, and Component Manufacturing
76	Miscellaneous Repair Services	442	Furniture and Home Furnishings Stores
76	Miscellaneous Repair Services	443	Electronics and Appliance Stores
76	Miscellaneous Repair Services	451	Sporting Goods, Hobby, Book, and Music Stores
76	Miscellaneous Repair Services	488	Support Activities for Transportation
78	Motion Pictures	42	Wholesale Trade
78	Motion Pictures	51	Information
78	Motion Pictures	53	Real Estate and Rental and Leasing
78	Motion Pictures	54	Professional, Scientific, and Technical Services
78	Motion Pictures	56	Administrative and Support and Waste Management
78	Motion Pictures	71	Arts, Entertainment, and Recreation
78	Motion Pictures	334	Computer and Electronic Product Manufacturing
79	Amusement and Recreational Services	51	Information
79	Amusement and Recreational Services	53	Real Estate and Rental and Leasing
79	Amusement and Recreational Services	56	Administrative and Support and Waste Management
79	Amusement and Recreational Services	61	Educational Services
79	Amusement and Recreational Services	71	Arts, Entertainment, and Recreation
79	Amusement and Recreational Services	487	Scenic and Sightseeing Transportation
80	Health Services	54	Professional, Scientific, and Technical Services
80	Health Services	62	Health Care and Social Assistance
80	Health Services	339	Miscellaneous Manufacturing
81	Legal Services	54	Professional, Scientific, and Technical Services
82	Educational Services	51	Information
82	Educational Services	61	Educational Services
83	Social Services	62	Health Care and Social Assistance
83	Social Services	81	Other Services (except Public Administration)
83	Social Services	92	Public Administration
84	Museums, Art Galleries, Botanical and Zoological Gardens	71	Arts, Entertainment, and Recreation

Table A.1. (Continued).

SIC		NAICS	
Code	**Description**	**Code**	**Description**
86	Membership Organizations	56	Administrative and Support and Waste Management
86	Membership Organizations	81	Other Services (except Public Administration)
86	Membership Organizations	92	Public Administration
87	Engineering and Management Services	23	Construction
87	Engineering and Management Services	54	Professional, Scientific, and Technical Services
87	Engineering and Management Services	56	Administrative and Support and Waste Management
87	Engineering and Management Services	61	Educational Services
88	Private Households	81	Other Services (except Public Administration)
89	Miscellaneous Services	51	Information
89	Miscellaneous Services	54	Professional, Scientific, and Technical Services
89	Miscellaneous Services	71	Arts, Entertainment, and Recreation
91	Executive, Legislative, and General Government	92	Public Administration
92	Justice, Public Order, and Safety	92	Public Administration
93	Finance, Taxation, and Monetary Policy	92	Public Administration
94	Administration of Human Resources	92	Public Administration
95	Environmental Quality and Housing	92	Public Administration
96	Administration of Economic Programs	92	Public Administration
96	Administration of Economic Programs	488	Support Activities for Transportation
97	National Security and International Affairs	92	Public Administration

Table A.2. STCC2 to SCTG2 correspondence.

STCC Code	STCC Description	SCTG Code	SCTG Description
01	Farm Products	01	Live Animals and Live Fish
09	Fresh Fish or other Marine Products	01	Live Animals and Live Fish
01	Farm Products	02	Cereal Grains
01	Farm Products	03	Other Agricultural Products
08	Forestry Products	03	Other Agricultural Products
20	Food or Kindred Products	03	Other Agricultural Products
20	Food or Kindred Products	04	Animal Feed and Products of Animal Origin, Not elsewhere classified
09	Fresh Fish or other Marine Products	05	Meat, Fish, Seafood, and their Preparations
20	Food or Kindred Products	05	Meat, Fish, Seafood, and their Preparations
20	Food or Kindred Products	06	Milled Grain Products and Preparations, and Bakery Products
20	Food or Kindred Products	07	Other Prepared Foodstuffs and Fats and Oils
20	Food or Kindred Products	08	Alcoholic Beverages
21	Tobacco Products	09	Tobacco Products
14	Nonmetallic Minerals, except Fuels	10	Monumental or Building Stone
14	Nonmetallic Minerals, except Fuels	11	Natural Sands
14	Nonmetallic Minerals, except Fuels	12	Gravel and Crushed Stone
14	Nonmetallic Minerals, except Fuels	13	Nonmetallic Minerals, Not elsewhere classified
10	Metallic Ores	14	Metallic Ores and Concentrates
11	Coal	15	Coal
13	Crude Petroleum, Natural Gas, or Gasoline	16	Crude Petroleum
29	Petroleum or Coal Products	17	Gasoline and Aviation Turbine Fuel
29	Petroleum or Coal Products	18	Fuel Oils
13	Crude Petroleum, Natural Gas, or Gasoline	19	Coal and Petroleum Products, Not elsewhere classified
29	Petroleum or Coal Products	19	Coal and Petroleum Products, Not elsewhere classified
28	Chemicals	20	Basic Chemicals
28	Chemicals	21	Pharmaceutical Products
28	Chemicals	22	Fertilizers
28	Chemicals	23	Chemical Products and Preparations, Not elsewhere classified
30	Rubber or Miscellaneous Plastics Products	24	Plastics and Rubber
24	Lumber or Wood Products	25	Logs and other Wood in the Rough
24	lumber or Wood Products	26	Wood Products
26	Pulp, Paper or Allied Products	27	Pulp, Newsprint, Paper, and Paperboard
26	Pulp, Paper or Allied Products	28	Paper or Paperboard Articles
27	Printed Matter	29	Printed Products
22	Textile Mill Products	30	Textiles, Leather, and Articles of Textiles or Leather
23	Apparel	30	Textiles, Leather, and Articles of Textiles or Leather
31	Leather or Leather Products	30	Textiles, Leather, and Articles of Textiles or Leather
32	Clay, Concrete, Glass or Stone Products	31	Nonmetallic Mineral Products
33	Primary Metal Products	32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes
34	Fabricated Metal Products	32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes

Table A.2. (Continued).

STCC Code	STCC Description	SCTG Code	SCTG Description
34	Fabricated Metal Products	33	Articles of Base Metal
35	Machinery – other than Electrical	34	Machinery
36	Electrical Machinery, Equipment or Supplies	35	Electronic and other Electrical Equipment and Components, and Office Equipment
37	Transportation Equipment	36	Motorized and other Vehicles (including Parts)
37	Transportation Equipment	37	Transportation Equipment, Not elsewhere classified
38	Instruments – Photographic or Optical Goods	38	Precision Instruments and Apparatus
25	Furniture or Fixtures	39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs
36	Electrical Machinery, Equipment or Supplies	39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs
19	Ordnance or Accessories	40	Miscellaneous Manufactured Products
24	Lumber or Wood Products	40	Miscellaneous Manufactured Products
34	Fabricated Metal Products	40	Miscellaneous Manufactured Products
38	Instruments – Photographic or Optical Goods	40	Miscellaneous Manufactured Products
39	Miscellaneous Manufacturing Products	40	Miscellaneous Manufactured Products
40	Waste or Scrap Materials	41	Waste and Scrap
42	Shipping Devices Returned Empty	42	Miscellaneous Transported Products
43	Mail and Express Traffic	42	Miscellaneous Transported Products
44	Freight Forwarder Traffic	42	Miscellaneous Transported Products
45	Shipper Association or Similar Traffic	42	Miscellaneous Transported Products
47	Small Packaged Freight Shipments	42	Miscellaneous Transported Products
41	Miscellaneous Freight Shipments	43	Mixed Freight
46	Miscellaneous Mixed Shipments	43	Mixed Freight
48	Hazardous Waste	–	N/A
49	Hazardous Materials	–	N/A

APPENDIX B

Tool Components and Forecastable Performance Measures

Table B.1. Tool components required for developing measures of performance.

Performance Measure	Direct Factoring of Facility Flows	Direct Factoring of O-D Flows	Economic Modeling	Trip Generation	Trip Distribution	Mode Split	Traffic Assignment
Additional revenue earned by producers when shipping via rail.						X	
Administrative, engineering, and construction cost/ton-mile (owner cost).	X						X
Average circuity for truck trips of selected O-D pattern.							X
Average cost per trip.	X						X
Average crash cost per trip.	X						X
Average fuel consumption per trip for selected trips (or shipments).							X
Average shipment time, cost, variability in arrival time for freight shipments (local versus long distance, by commodity, by mode).							X
Average speed (passenger and commercial vehicles) on representative highway segments.							X
Average travel time from facility to destination (by mode).							X
Average travel time from facility to major highway, rail, or other network.							X
Business volume by commodity group.			X				
Cost per ton of freight shipped.						X	
Cost per ton-mile by mode.	X						X
Delay per ton-mile traveled (by mode).	X						X
Dollar losses due to freight delays.	X						X
Economic indicator for goods movement.			X				
Exposure (AADT and daily trains) factor for rail crossings.	X						X
Freight transport system supply (route miles, capacity miles, number of carriers, number of ports/terminals) per “demand unit” (dollar of manufacturing output, ton-mile of commodity movement, capita, employee, etc.).	X		X	X			X
Frequency of delays at intermodal facilities.	X						X

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Table B.1. (Continued).

Performance Measure	Direct Factoring of Facility Flows	Direct Factoring of O-D Flows	Economic Modeling	Trip Generation	Trip Distribution	Mode Split	Traffic Assignment
Fuel consumption per ton-mile traveled.	X						X
Interference of movement at grade crossings – delay time and speed.	X						X
Market share of international or regional trade by mode.						X	
Miles of freight routes with adequate capacity.	X						X
Mobility index (ton-miles of travel/vehicle-miles of travel times average speed).	X						X
Mode split (by ton-mile).	X					X	X
Number of shipping establishments per 1,000 businesses.			X				
Number of tons of freight moved by mode.						X	
Number of truck-days of highway closure on major freight routes.	X						X
Number of users of intermodal facilities.						fcm	
Origin-destination travel times (by mode).							X
Percent change in truck traffic at border crossings.	X						X
Percent increase in intermodal facilities use.						fcm	
Percent of freight traffic at facility on portion of network.	X						X
Percent of goods moved with option of more than one modal choice.		X			X		
Percent of major commodities moved by more than one mode.		X				X	
Percent of manufacturing industries within X miles of interstate or four-lane highway.			X				
Percent of person/freight trips occurring within peak periods.		X			X		

fcm = Four-Step Commodity Modeling tools only.

Table B.1. (Continued).

Performance Measure	Direct Factoring of Facility Flows	Direct Factoring of O-D Flows	Economic Modeling	Trip Generation	Trip Distribution	Mode Split	Traffic Assignment
Percent of the cost of goods and services attributable to transportation.							X
Percent of traffic on regional highway that is heavy truck.	X						X
Percent of truck VMT or tonnage affected by weight restrictions (or clearance) on bridges.							X
Regional truck VMT per unit of regional economic activity/output.							X
Revenue per ton-mile by mode.	X						X
Ton-miles of primary commodity by distance.	X						X
Ton-miles of primary commodity by mode.	X						X
Ton-miles of rail freight into/through metropolitan areas.	X						X
Ton-miles per gallon of fuel.	X						X
Ton-miles traveled by congestion level.	X						X
Tonnage moved on various transportation components (by mode).	X					X	X
Tonnage originating and terminating.				X			
Tons of commodity undergoing intermodal transfer.						X	
Tons transferred per hour.						fcm	
Transportation costs associated with each major commodity.							X
Truck VMT by light duty, heavy duty, and through trips.	X						X
Volume of traffic at border crossings.	X						X
V/C ratio on facility access roads and at border crossings.	X						X

fcm = Four-Step Commodity Modeling tools only.

Table B.2. Forecastable performance measures for states' primary freight policy and analytical needs.

Performance Measure	Policy Needs	Analytical Needs
Additional revenue earned by producers when shipping via rail.	Rail Planning; Modal Diversion	
Administrative, engineering and construction cost/ton-mile (owner cost).	Policy and Economic; Project Prioritization	Pavement and Safety; Needs Analysis
Average circuity for truck trips of selected O-D pattern.		Truck Flows; Project Development
Average cost per trip.	Modal Diversion	Commodity Flow
Average crash cost per trip.		Pavement and Safety; Needs Analysis
Average fuel consumption per trip for selected trips (or shipments).	Modal Diversion	Performance Measurement
Average shipment time, cost, variability in arrival time for freight shipments (local versus long distance, by commodity, by mode).	Modal Diversion	Commodity Flow
Average speed (passenger and commercial vehicles) on representative highway segments.		Truck Flows
Average travel time from facility to destination (by mode).	Modal Diversion	Terminal Access
Average travel time from facility to major highway, rail, or other network.		Terminal Access
Business volume by commodity group.		Commodity Flow
Cost per ton of freight shipped.		Modal Diversion
Cost per ton-mile by mode.		Modal Diversion
Delay per ton-mile traveled (by mode).	Rail Planning	Modal Diversion
Dollar losses due to freight delays.	Policy and Economic	Project Prioritization; Needs Analysis
Economic indicator for goods movement.	Policy and Economic	Needs Analysis
Exposure (annual average daily traffic and daily trains) factor for rail crossings.	Rail Planning	Pavement and Safety
Freight transport system supply (route miles, capacity miles, number of carriers, number of ports/terminals) per "demand unit" (dollar of manufacturing output, ton-mile of commodity movement, capita, employee, etc.).	Policy and Economic	Needs Analysis
Frequency of delays at intermodal facilities.		Project Development; Bottlenecks
Fuel consumption per ton-mile traveled.	Modal Diversion	Needs Analysis
Interference of movement at grade crossings– delay time and speed.		Operational Needs; Truck Flows
Market share of international or regional trade by mode.	Modal Diversion; Trade and Border	
Miles of freight routes with adequate capacity.	Policy and Economic	
Mobility index (ton-miles of travel/vehicle-miles of travel times average speed).	Policy and Economic	Performance Measurement

Table B.2. (Continued).

Performance Measure	Policy Needs	Analytical Needs
Mode split (by ton-mile).	Modal Diversion	
Number of shipping establishments per 1,000 businesses.	Policy and Economic	Performance Measurement
Number of tons of freight moved by mode.		Commodity Flow
Number of truck-days of highway closure on major freight routes.	Modal Diversion	Performance Measurement
Number of users of intermodal facilities.		Project Development
Origin-destination travel times (by mode).	Modal Diversion	Truck Flows
Percent change in truck traffic at border crossings.	Trade and Border	
Percent increase in intermodal facilities use.		Project Development; Needs Analysis
Percent of freight traffic at facility on portion of network.		Project Development; Bottlenecks; Operational Needs
Percent of goods moved with option of more than one modal choice.	Modal Diversion	Performance Measurement
Percent of major commodities moved by more than one mode.	Modal Diversion	Performance Measurement
Percent of manufacturing industries within X miles of interstate or four-lane highway.		Performance Measurement; Truck Flows
Percent of person/freight trips occurring within peak periods.		Truck Flows; Operational Needs
Percent of the cost of goods and services attributable to transportation.		Commodity Flow; Performance Measurement
Percent of traffic on regional highway that is heavy truck.		Pavement and Safety; Operational Needs
Percent of truck vehicle-miles traveled (VMT) or tonnage affected by weight restrictions (or clearance) on bridges.		Needs Analysis; Operational Needs
Regional truck VMT per unit of regional economic activity/output.	Policy and Economic	Needs Analysis
Revenue per ton-mile by mode.	Policy and Economic	Needs Analysis
Ton-miles of primary commodity by distance.		Commodity Flow
Ton-miles of primary commodity by mode.		Commodity Flow
Ton-miles of rail freight into/through metropolitan areas.		Needs Analysis; Commodity Flow
Ton-miles per gallon of fuel.	Modal Diversion	
Ton-miles traveled by congestion level.	Project Prioritization	Project Development
Tonnage moved on various transportation components (by mode)	Modal Diversion	
Tonnage originating and terminating.		Commodity Flow
Tons of commodity undergoing intermodal transfer.		Commodity Flow
Tons transferred per hour.		Operational Needs
Transportation costs associated with each major commodity.		Commodity Flow
Truck VMT by light duty, heavy duty, and through trips.	State Planning; Project Prioritization	
Volume of traffic at border crossings.	Trade and Border	
Volume-to-capacity (V/C) ratio on facility access roads and at border crossings.	Trade and Border	Terminal Access; Bottlenecks

APPENDIX C

References with Mode Components

This appendix includes references that were reviewed during the development of this Toolkit. These references may be useful to practitioners undertaking freight forecasting. The references are annotated by the model component(s) to which it applies. The model components are those described in Section 4.0 of the Toolkit.

Table C.1. References.

Reference	Model Component					
	Direct Factoring	Trip Generation	Trip Distribution	Mode Choice	Assignment	Economic and Land Use Modeling
Abrahamsson, T., *Estimation of Origin-Destination Matrices Using Traffic Counts – A Literature Survey*, IR-98-0212, International Institute for Applied Systems Analysis, May 1998.	●					
Aerde, M., Rakha, H. and Paramahamsan, H., *Estimation of O-D Matrices: The Relationship between Practical and Theoretical Considerations*, Transportation Research Board CD-ROM, 2003.	●					
Ashtakala, B. and Murthy, A.S.N., *Optimized Gravity Models for Commodity Transportation*, Journal of Transportation Engineering, Vol. 114, No. 4, 1988, pp. 393-409.			●			
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Black, W.R., *The Utility of the Gravity Model and Estimates of Its Parameters in Commodity Flow Studies,* Proceedings of the Association of American Geographers, Volume 3, 1971, pp. 28-32.			●			
Black, W.R., *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment*, Phase 2, Transportation Research Center, Indiana University, Bloomington, July 15, 1997.		●	●		●	
Branyan, C.O. and Mickle, G.D., *Projecting Commodity Movements for Inland Waterways Port Development,* Transportation Research Record #669, 1978, pp. 5-7.	●					
C. Apffel, J. Jayawardana, et al., *Freight Components in Louisiana's Statewide Intermodal Transportation Plan*, Transportation Research Record 1552, 32-41, 1996.	●			●	●	
Cambridge Systematics, et al., *Quick Response Freight Manual, Federal Highway Administration, Travel Model Improvement Program*, Report DOT-T-97-10, September 1996.		●	●		●	

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Table C.1. (Continued).

Reference	Model Component					
	Direct Factoring	Trip Generation	Trip Distribution	Mode Choice	Assignment	Economic and Land Use Modeling
Cambridge Systematics, Inc., *Alternative Planning Approaches: Structural and Direct, Statewide Freight Demand Forecasting*, National Cooperative Highway Research Program (NCHRP) Project 20-17, May 1980.	●	●	●	●	●	
Cambridge Systematics, Inc., *Characteristics and Changes in Freight Transportation Demand*, National Cooperative Highway Research Program (NCHRP) Report 388, 1993.	●	●	●	●	●	●
Cambridge Systematics, Inc.; *Vermont Statewide Freight Study*; Final Report, prepared for the Vermont Department of Transportation; March 2001.		●	●	●	●	
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Chang, T. et al., *Routing Hazardous Materials With Stochastic, Dynamic Link Attributes: A Case Study,* Transportation Research Board 2002 CD-ROM.					●	
Chin, S. et al., *Estimating State-Level Truck Activities in America*, Journal of Transportation and Statistics, January 1998, pp. 63-74.	●					
Coutinho-Rodrigues, et al., *Interactive Spacial Decision-Support Systems for Multiobjective Hazardous materials Location-Routing Problems,* Transportation Research Record, No. #1602, 1997, pp. 101-109.					●	
De la Barra, T., *Integrated Land Use and Transport Modeling: Decision Chains and Hierarchies.*, Cambridge University Press, 1989.						●
E. Jones, A. Sharma, *Development of Statewide Freight Forecasting Model for Nebraska*, Transportation Research Board, 2003.		●	●	●	●	
Hewitt, et al., *Infrastructure and Economic Impacts of Changes in Truck Weight Regulations in Montana*, Transportation Research Record, No. #1653, 1999, pp. 42-51.	●					●

Table C.1. (Continued).

	Model Component					
Reference	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Choice**	**Assignment**	**Economic and Land Use Modeling**
Holguin-Veras and Thorson, E., *Trip Length Distributions in Commodity-Based and Trip-Based Freight Demand Modeling Investigation of Relationships,* Transportation Research Record, No. – 1707, 2000, pp. 37-48.			●			
Horowitz, A.J., *Guidebook on Statewide Travel Forecasting*, Federal Highway Administration, FHWA-HEP-99-007, July 1999.	●	●	●	●	●	●
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J. Brogan, S. Brich, M. Demetsky, *Identification and Forecasting of Key Commodities for Virginia*, Transportation Research Record 1790, 73-79, 2002.	●			●	●	
Kim, H. et al., *Origin-Destination Matrices Estimated with a Genetic Algorithm from Link Traffic Counts,* Transportation Research Record, No. #1771, pp. 156-163, 2001.	●					
Lau, S., *Truck Travel Surveys: A Review of the Literature and State-of-the- Art, MTC, Oakland, CA,* January 1995, NCHRP Web Doc 3 Multimodal Transportation Planning Data: Final Report, 1997, http://books.nap.edu/books/nch003/html/166.html	●					
Lawrence, M.B. & Sharp, R.G., *Freight Transportation Productivity in the 1980s: A Retrospective*, Journal of the Transportation Research Forum, Vol. XXXII, No. 1, 158-171, 1991.		●		●		
Lee, H. and Viele, K, *Loglinear Models and Goodness-of-Fit Statistics for Train Waybill Data*, Journal of Transportation and Statistics, Vol. 4, No. 1, 2001, http://www.bts.gov/publications/jts/v4n1/paper5/lee.html.	●					
Linsenmeyer, D., *Effect of Unit-Train Grain Shipments on Rural Nebraska Roads*, Transportation Research Record, No. #875, 1982, pp. 60-64.				●		
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Table C.1. (Continued).

	Model Component					
Reference	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Choice**	**Assignment**	**Economic and Land Use Modeling**
McCrary, J. and Harrison, R., *North American free Trade Agreement Trucks on U.S. Highway Corridors*, Transportation Research Record, No. #1653, 1999, pp. 79-85.	●					
Mendoza et al., *Multiproduct Network Analysis of Freight Land Transport Between Mexico and the United States*, Transportation Research Record, No. #1653, 1999, pp. 69-78.					●	
Metaxatos, P., *Accuracy of Origin-Destination Highway Freight Weight and Value Flows*, Transportation Research Board 2003 CD-ROM.	●		●			
Middleton et al., *Trip Generation for Special-Use Truck Traffic*, Transportation Research Record, No. – 1090, 1986, pp. 8-13.		●				
Morlok, E. and Riddle, S., *Estimating the Capacity of Freight Transportation Systems*, Transportation Research Record, No. #1653, 1999, pp. 1-8.				●	●	
Morlok, E.K. et al., *A Sequential Shipper-Carrier Network Model for Predicting Freight Flows*, Transportation Science, Vol. 20, No. 2, May 1986, pp. 80-91.		●	●	●	●	
Morlok, E.K., and Warner, J.A., *Approximation Equations for Costs of Rail, Trailer-on-Flatcar, and Truck Intercity Freight Systems*, Transportation Research Record. No. – 637, 1997, pp. 71-77.				●		
Morton, A.L., *A Statistical Sketch of Intercity Freight Demand*, Highway Research Record 296, 47-65, 1969.	●			●		
Murthy, A.S.N. and Ashtakala, B., *Modal Split Analysis Using Logit Models*, Journal of Transportation Engineering, Vol. 113, No. 5, 1987, pp. 502-519.				●		
National Cooperative Highway Research Program (NCHRP) Synthesis 298, *Truck Trip Generation Data*, Transportation Research Board, 2001.		●				
URS Greiner Woodward Clyde, "Statewide Model Truck Trip Table Update Project," prepared for the New Jersey Department of Transportation, January 1999.		●	●		●	

Table C.1. (Continued).

	Model Component					
Reference	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Choice**	**Assignment**	**Economic and Land Use Modeling**
Ohio Department of Transportation, *Interim Model on Freight Impacts on Ohio's Roads*, (to be fully functional on 2005).	●			●	●	
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Rios, A. et al., *The Value of Different Categories of Information in Estimating Freight Origin-Destination Tables,* presented at the 81st Annual Meeting of the Transportation Research Board (CD-ROM), January 2002.	●					
Russel, E. et al., *Monitoring Travel Patterns of Heavy Trucks – Summary Report*, Unpublished, Prepared for the Kansas Department of Transportation, K-Trans Study No. 92-3, 1997.	●				●	
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(continued on next page)

Table C.1. (Continued).

	Model Component					
Reference	**Direct Factoring**	**Trip Generation**	**Trip Distribution**	**Mode Choice**	**Assignment**	**Economic and Land Use Modeling**
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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation