Quick Response Freight Manual II

Publication No. FHWA-HOP-08-010 **September 2007**

U.S. Department of Transportation
Federal Highway Administration

<table>
<tr><td>1. Report No. FHWA-HOP-08-010
EDL No. 14396</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Quick Response Freight Manual II</td><td colspan="2">5. Report Date
September 2007</td></tr>
<tr><td colspan="2">6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s)
Daniel Beagan, Michael Fischer, Arun Kuppam</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address

Cambridge Systematics, Inc.
100 CambridgePark Drive
Cambridge, MA 02140</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
DTFH61-06-D-00004</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Department of Transportation
Federal Highway Administration
Office of Freight Management and Operations
1200 New Jersey Ave., SE
Washington, DC 20590</td><td colspan="2">13. Type of Report and Period Covered
Final Report
May 2006 – September 2007</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
FHWA COTR: Tianjia Tang, Office of Freight Management and Operations</td></tr>
<tr><td colspan="4">16. Abstract

This manual is an update to the Quick Response Freight Manual developed for FHWA in 1996. Like its predecessor, it is designed to provide background information on the freight transportation system and factors affecting freight demand to planners who may be relatively new to this area; to help planners locate available data and freight-related forecasts compiled by others, and to apply this information in developing forecasts for specific facilities; to provide simple techniques and transferable parameters that can be used to develop freight vehicle trip tables.</td></tr>
<tr><td>17. Key Words

freight, transportation, forecasting, modeling</td><td colspan="3">18. Distribution Statement

No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.</td></tr>
<tr><td>19. Security Classification
(of this report)

Unclassified</td><td>20. Security Classification
(of this page)

Unclassified</td><td>21. No of Pages

296</td><td>22. Price</td></tr>
</table>

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

Acknowledgments

We would like to thank Tianjia Tang, PE, the FHWA Project Manager, for his continued support and guidance during this project. We also would like to thank Erick Pihl, Lorrie Lau, Spencer Stevens, Sarah Sun, Bernadette Dupont, and Sarah Sun of FHWA, as well as Richard Nordahl, California Department of Transportation; Ted Dahlberg, Delaware Valley Regional Planning Commission; Vidya Mysore, Florida Department of Transportation; Lynn Soporowski, Kentucky Transportation Cabinet; Steve Slavick and Andy Mohr, Pennsylvania Department of Transportation; and Caroline Marshall, Atlanta Regional Commission for their comments, suggestions, and guidance during this project.

This report is based on work supported by the Federal Highway Administration under contract number DTFH61-06-D-00004. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the Federal Highway Administration.

Notice

Quality Assurance Statement

Table of Contents

PART A

PART B

Table of Contents
(continued)

Table of Contents
(continued)

Table of Contents
(continued)

Table of Contents
(continued)

Table of Contents
(continued)

PART D

Table of Contents
(continued)

List of Tables

List of Tables
(continued)

List of Figures

1.0 Introduction

The Federal law governing planning for transportation planning (23 USC 133 and 23 USC 134) as well as for transit planning (49 USC 5303 and 49 USC 5304) requires that states and metropolitan planning organizations (MPOs) consider freight in their long-range plans, transportation improvement programs, and annual work elements. There are, however, some issues that must be addressed before the states, MPOs, and other planning agencies can be effective in freight planning:

- Most of these agencies have more experience considering the movement of passengers rather than the movement of freight;
- Current and historical data on freight, especially truck movements, are extremely limited; and
- Most of the models in the literature are highly complex, and require data that are not generally available to planning agencies.

1.1 Objectives of the Quick Response Freight Manual

The objectives of this Manual are as follows:

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

The Manual addresses freight issues at different levels of analysis. On the more detailed site planning level, the methods include predicting the number and temporal distribution of truck trips to and from specific locations and identifying the routes used. On a more aggregate level such as corridor, metropolitan area, or regional level, the Manual helps develop forecasts of trips generated by various traffic analysis zones and distribute these trips to the transportation network.

The analytical methods contained in the Manual place special emphasis on the inclusion of transferable parameters that can be used as default values for model inputs when data specific to the state or metropolitan area are not available. In developing these methods, the circumstances giving rise to those parameters, such as geographic location or the industrial function, will be considered.

This Manual also identifies alternative analytical methodologies and data collection techniques in order to improve the accuracy of the freight analysis and planning processes.

1.2 Definition of Freight Transportation

If passenger transportation can be broadly defined as the movement of people, then freight can be broadly defined as the movement of goods from one place to another. However, freight as it is used in many economic analyses, including this Manual, define freight more specifically as the movement of goods from a place of production to a place of consumption in support of manufacturing processes. The surveys using this definition of freight specifically exclude goods moving to service establishments, construction, most retail industries, farms, fisheries, foreign establishments, and most government-owned establishments. On a geographic level, this definition of freight transportation is of most use when considering the movement of goods between metropolitan areas. Transportation planners are not only concerned with the shipment of these goods, but also need to consider the movement of goods within metropolitan areas. This may include the delivery of goods to the excluded industries as well as the movement of goods that are ancillary to the main purpose of the trip, such as service, utility, and construction trucks that carry goods to support their activities. For that reason, this Manual discusses methods that consider all movements of goods, whether over long distances or local deliveries, part of manufacture or trade, or are merely incidental to other activities.

1.3 Organization of the Manual

The Manual is organized in four parts with each divided into sections. Each section is independent of the others, and the user may read the section or sections that best serves his or her interests. The following describes the components of this Manual:

Part A consist of those sections that provide an **Introduction** to the material. It consists of this section, and:

- **Section 2.0: Freight and Commercial Vehicles Demand: Controlling Factors –** This section describes how an understanding of the controlling factors for freight can help identify issues to be addressed in forecasting. The factors to be discussed include:

  1. *Why* freight moves – The Economic/Industrial/Commodity factors that give rise to the demand for freight;
  2. *Who* moves freight – The Logistic factors that determine the spatial relationships, shipment sizes and frequencies that determine between shipper and receivers, the size and frequency, and other factors governing shipments;
  3. *What* moves freight – The Modal factors that determine the costs and service levels covered by the modes that carry freight: truck, rail, water, and air;[1]
  4. *Where* freight moves – The Vehicles/Volumes factors that are concerned with the movement of freight inside vehicles on the various modal network; and
  5. *How* freight moves – Public Policy that sets the rules and regulations under which freight must operate.

Part B consists of those sections that cover the **Methods** of freight forecasting – from simple factoring methods; to methods that incorporate freight forecasting in traditional transportation modeling in urban, state, and site settings; to commodity flow methods that utilize multimodal freight demand to forecast freight demand:

- **Section 3.0: Simple Growth Factor Methods –** This section describes how growth factor methods can be used for forecasting freight demand using historic trends, using regressions based on single and multiple independent variables, and using growth factors as applied to tables of freight flows.

- **Section 4.0: Incorporating Freight into "Four-Step" Travel Forecasting –** This section addresses how the traditional "four-step" transportation forecasting process (Trip Generation; Trip Distribution; Mode Split/Conversion to Vehicle Flows; and Network Assignment) is used to forecast goods movement in the traditional urban transportation planning models, in state transportation planning models, and in site planning. The methods discussed in this section consider the different definitions of freight transportation discussed in Section 1.2. The methods used in urban and site planning generally consider all trucks as freight trucks, while the state models use the commodity definition of freight.

---

[1] Large flows of freight are also carried by pipelines. Pipelines are not addressed in this Manual because the commodities carried, generally petroleum and other liquid products, are specialized and unique to pipelines, data on the distribution network and flows is not readily available, and the flow of goods by pipeline rarely is addressed by the transportation audience for whom this Manual is intended.

- **Section 5.0: Commodity Modeling –** This section discusses how acquiring a table of goods movement, defined by commodity can be used in freight forecasting. The issues covered include how to obtain a table of commodity flows, the geographic issues of the tables, and issues with disaggregating or factoring the flows.

- **Section 6.0: Hybrid Approaches –** This section discusses, in particular for urban truck forecasting models, how the different methods discussed for trucks in urban areas in Section 4.0 can be combined with multimodal commodity methods appropriate for state modeling as discussed in Section 5.0 or the commodity flow methods of Section 5.0 to forecast flows with at least one external trip end. This discussion will include the issues associated with logistic nodes (e.g., terminals) where external flows are distributed to internal zones.

- **Section 7.0: Economic Models –** This section discusses how freight forecasting can be included within more comprehensive economic/land use/ecological models such as Puget Sound Regional Integrated Simulation Model (PRISM), UrbanSim, etc.

- **Section 8.0: Model Validation –** This section discusses the special considerations in validating freight models, especially those with borrowed parameters. Consideration is given for how to calibrate freight models and forecasts (how well models correspond to existing conditions); and how to validate freight models (how well models correspond to expected changes). Consideration is given to the sources of validation and calibration data for freight forecasting. This section discusses the steps of freight models where changes can be made to improve calibration/validation.

Part C consists of those sections that discuss the various **Data Sources** that are available to support freight forecasting:

- **Section 9.0: Existing Data –** This section discusses the availability of data, the content of that data, and the advantages and disadvantages of using existing freight data. Particular attention will be given to how this data fulfills the needs identified in Part B to support the methods of forecasting. The data discussed includes: Commodity O-D tables, including the Freight Analysis Framework, (versions 1 and 2), the Commodity Flow Survey (CFS), and TRANSEARCH; vehicle data such as the Vehicle Inventory Usage Survey (VIUS) and weigh-in-motion (WIM) data; modal usage data such as the railroad Carload Waybill Sample, or the marine Waterborne Commerce; Employment/ Industry data such as County Business Patterns; and network performance data such as Intelligent Transportation Systems' Traffic Monitoring System, Automatic Traffic recorder data, and vehicle classifications counts.

- **Section 10.0: Data Collection –** This section discusses why existing data may be insufficient and why new data may be required to support methods in Part B. Topics discussed include data collection issues such as sample sizes, and implementation issues for various types of supporting data collection: various types of new collection methods such as new vehicle counts; establishment surveys, diaries, intercept surveys, etc.; and methods to collect information about freight infrastructure such as field inspections of freight facilities, line-haul, and terminals.

Part D consists of sections that deal with **Practical Applications** of freight forecasting**:**

- **Section 11.0: Application Issues –** This section discusses the reasons why freight forecasts are needed, the development of alternatives to be tested, and their attributes and how these forecasts will be used in the transportation planning process. The use of freight forecasts in the transportation planning process will include not only the preparation of plans, programs, and projects but also how these forecasts can be used in support of management systems. Among the other application issues discussed are the availability of base data and forecast variables and the private versus public concerns for freight.

- **Section 12.0: Case Studies –** This section covers how methodological and data issues were addressed in actual case studies, organized by the scope of the geographic area addressed in the case study: state and multistate, both large and small urban areas; and individual sites such as ports, airports, industrial parks, and intermodal railroad terminals.

- **Section 13.0: Intermodal Considerations, Including Drayage –** This section discusses issues that are unique to the transportation of freight in the connections with nonhighway modes. Issues that must be considered in intermodal/drayage considerations include linked and unlinked freight flows in data and forecasting; container and bulk/trainload modal exchanges; and special considerations for truck-rail, truck-air, and truck-water issues. Additional issues covered in freight forecasting include time lags between modal exchanges; special equipment needs in intermodal and drayage handling; the logistics and operation of intermodal facilities; and the geographic markets for drayage services.

Finally, the Manual contains additional material in **Appendices A** and **B:**

- **Appendix A – Glossary** defines some of the most common terms used in freight planning and analysis. Appendix A includes an Acronym List.

- **Appendix B – Classification Schemes** provides in tabular format some of the more common classification schemes used in freight, including commodity classification schemes, industry classification schemes, and vehicle/truck classifications schemes. Also included in the appendix are crosswalk tables between different classification schemes covering the same topic, e.g., different commodity classification schemes.

2.0 Freight Demand – Controlling Factors

This section of the QRFM update provides a detailed discussion on the controlling factors that impact freight demand analysis and forecasting. These factors can be broadly grouped into the following categories:

- Economic Structure;
- Industry Supply Chains and Logistics;
- Freight Infrastructure/Modes;
- Freight Traffic Flows; and
- Organization and Public Policy.

An understanding of how the above factors impact freight demand is critical to performing an accurate freight demand analysis in a region and developing reliable freight forecasts for planning purposes.

2.1 Economic Structure

Freight demand has a direct correlation with the type and amount of economic activity in a region. The amount of goods production and consumption in an area and the relationship between producers, consumers, and intermediate suppliers impact the magnitude and spatial distribution of freight flows. The dependence of freight demand on economic structure can be better understood by considering the following components of the economy, and analyzing their specific impacts on freight flows:

- Types of Industries;
- Personal Consumption; and
- Trade.

2.1.1 Types of Industries

Freight demand is a direct function of the types of industries in a region. The types of industries in an economy can be broadly classified into goods-related and service industries, each having unique impacts on freight flows. Goods production industries, for example, vary in the types and quantities of goods produced and consumed, as well as the types of transportation services used to meet the demand for production inputs and supply of outputs. Warehousing and distribution activities, big-box retail, hospitals, and other institutions also are major drivers of freight demand, especially in and around metropolitan areas. Transportation services in a region provide the supply to meet freight transportation demand, thus impacting the characteristics of modal freight flows such as the types of equipment, time-of-day activity, etc. Trucking flows generated by service industries in urban areas may account for a significant share of total trucking activity, and need to be considered in urban freight (truck) models in order to accurately predict total trucking demand on the highway network. Service-related trucking also is unique in terms of the types of equipment and time-of-day activity, which are important variables to consider in analyzing trucking activity in a region.

2.1.2 Personal Consumption

Personal consumption is another important component of an economy that has a major impact on freight demand. Personal consumption is driven by economic growth, and generates demands from households for goods and services. This demand translates to increased retail activity, which is a major generator of local truck trips, especially in urban areas. Freight flows associated with retail activities also have unique trip distribution and trip chaining patterns, which are important parameters for consideration in developing urban freight models. Personal consumption is a key data element in economic input-output models, which provide the total household consumption of goods and services. This information can be used to analyze total freight demand associated with personal consumption activity.

2.1.3 Trade

Trade activity is a critical component of the economic structure of a region and can be divided into three broad categories – international, domestic, and local. Each of these trade categories have distinct freight demand characteristics in terms of the origin-destination (O-D) patterns of shipments, commodities handled, modes used, types of facilities used, length of haul, size of shipments, and time dependencies. For example, local trade in a metropolitan area is dominated by the trucking mode and has different facility usage compared to international shipments, which have significant intermodal rail activity and logistics operations with unique facility usage (for example, container freight stations).

2.2 Industry Supply Chains and Logistics

Following are some important elements of industry supply chains and logistics that have a major impact on freight demand and are critical considerations in developing freight forecasts:

- Spatial Distribution Networks;
- Interactions between Logistics Players; and
- Supply Chain/Logistics Trends.

2.2.1 Spatial Distribution Networks

Industry supply chains are characterized by spatial relationships, which dictate the spatial distribution of commodity flows. For example, the spatial organization of distribution networks of a retailer influences the O-D patterns of freight flows moving through seaports as part of an international supply chain. These distribution patterns are typically influenced by market areas (for example, locations of distribution facilities close to customer markets). In terms of their importance in freight demand analysis and forecasting, these critical aspects of the supply chain directly impact the development of commodity flow databases, freight trip generation, and distribution models as well as freight traffic assignment.

2.2.2 Interactions between Logistics Players

Freight industry logistics decisions are typically shared by a host of players, which include producer/receiver logistics managers, third-party logistics managers, and integrated carriers. The interactions between these logistics players impact freight demand characteristics in terms of the choice of modes, the size of shipments, the ports of call, the time of day, frequency of shipments, etc., which are critical elements to be considered in the modeling of freight transportation demand.

2.2.3 Supply Chain/Logistics Trends

Due to the dynamic nature of the freight logistics system, trends in industry supply chains need to be considered, especially in freight forecasting. For example, increasing trend towards just-in-time (JIT) logistics is having an impact on the modes used, and size and frequency of shipments. Other important supply chain trends include shipper-carrier alliances impacting mode choice, and increased outsourcing activity impacting freight and intermodal traffic through seaports. Also, historic trends in transportation productivity, and the tradeoff between transportation and inventory are leading to increased transportation service demand relative to industry output.

■ 2.3 Freight Infrastructure/Modes

Each of the modes that carry freight provide different types of service, which in turn is the controlling factor of which modes will be chosen to carry freight. Among the important issues to be considered are:

- **Characteristics of Demand –** The origins and destinations served the shipment length, etc.;
- **Characteristics of the Supply –** The capacity, frequency, cost, special handling abilities, etc.; and
- **Characteristics of the Shipments –** Size of shipments, pick-up and delivery times, special handling characteristics, shipment value, etc.

These factors are discussed in more detail for the Trucking, Rail, Marine, and Air Cargo modes.

2.3.1 Trucking

Operational characteristics of the trucking industry pertaining to market area, type of carrier, and type of service impact various elements of trucking freight demand. When analyzing freight demand by market area, it is important to note that trucking dominates the short-haul freight market due to its flexibility and cost characteristics relative to other modes. For this reason, many urban freight models are typically "truck" models and do not involve a mode share component.

Trucking operations can be categorized into for-hire truckload, Less Than Truckload (LTL), and private, based on the type of carrier. Each of these carrier operations are associated with distinct freight demand characteristics pertaining to the market areas, commodities handled, size of shipments, trip chaining characteristics, time-of-day traffic distributions, and freight facilities used.

Trucks not only haul commodities, but also are used for "service trucking." Urban models that include freight, local goods movement, and service vehicles are often referred to as "commercial vehicle" models. Urban areas, in particular, have significant service trucking activity wherein service trucks can account for a notable share of the total truck traffic on key locations. This has significant implications in the development of commodity-based urban truck models, which need to account for service-related truck traffic in order to accurately predict total truck traffic in the region. Distinguishing service trucks from freight trucks in empirical data can be difficult, and it entails the need for more rigorous data collection through surveys to determine the share of service versus cargo trucking on specific highway facilities.

Trucking involves a wide array of equipment, from small delivery vans and pick-up trucks to 18-wheelers. The type of truck used can vary based on the type of operation (service or cargo trucking), and for cargo trucking, on the type of commodity hauled. For example, while tractor-trailers are most commonly used for carrying long-haul freight, they also can perform local pick-up and delivery of goods. This has implications in the development of commodity-based truck models, in terms of the use of accurate payload factors to convert commodity tonnages to equivalent truck trips. Truck equipment-type information also is important in the application of freight models for congestion, air quality, safety, and pavement impact analyses.

The highway infrastructure can be categorized into a shared-use or a truck-only facility based on the truck usage of the system relative to other vehicles. In a shared-use facility, trucks share the same network as autos and buses, which entails the need for the integration of passenger and truck models to predict the total traffic demand on the network. The type of infrastructure also plays a critical role in the analysis of key characteristics of freight flows on the network pertaining to travel times/speeds, reliability, safety, congestion, and related economic impacts.

2.3.2 Rail

Railroads are classified into Class I, II, and III, based on their operating revenue characteristics. This classification also is important in the analysis of rail freight demand, as each railroad class has distinct rail freight demand characteristics pertaining to the types of commodities handled (for example, increasing share of Class I railroad market being domestic and international intermodal cargo), O-D patterns and length of haul, and size of shipments.

Two main categories of railroad service – carload and intermodal – are the most important determinants of rail freight demand. Each of these categories is associated with different commodities, service characteristics, logistics, equipment, etc. Also, the rate of growth in rail freight demand for carload and intermodal freight have been different, with intermodal rail demand rising at an astonishing rate compared to carload. Due to these reasons, rail carload and intermodal services need to be analyzed separately, particularly in generating rail freight forecasts. Additionally for operational reasons, railroads may offer carload service for a single commodity, such as coal or grain, called unit trains.

Unlike highway infrastructure, railroads own their own networks, generally control operations and maintenance (O&M), and make investment decisions on the networks, mainly for capacity enhancements. Because of the private ownership of railroad networks, analysis of the factors affecting railroad routing decisions, as well as accurate determination of link-level rail traffic flows on the network, is nearly impossible due to the proprietary nature of the railroad data.

In addition to trackage (mainline, spurs, and sidings), railroad terminals, intermodal lifts, and classification yards are important railroad system elements. Consequently, forecasting freight movements through these railroad facilities is critical in the overall rail system planning process in order to avoid congestion and bottlenecks in the rail freight transportation network.

2.3.3 Marine

The two main operational types of marine freight transportation include inland and ocean shipping. These two operations not only involve different infrastructure (ocean versus inland waterway ports/terminals), and types of equipment (vessels, barges, terminal equipment, etc.), but also are unique in the types of commodities carried, shipment sizes, freight logistics/supply chains, and trading partners involved. Recent trends towards short-sea shipping services for domestic transportation between coastal cities on the west and east coasts of the United States indicate the importance of this form of ocean transportation in meeting growing freight demand.

The main types of marine transportation services include bulk, break-bulk, container, and roll-on/roll-off, depending on the type of commodity carried. Each of these services is considered separately in freight demand analysis due to the need for distinct representation of commodity flows (tonnages, TEUs,[1] number of trucks, etc.), as well as in the analysis of land side impacts of marine freight flows (for example, land side traffic impacts of bulk transport will be different compared to containerized transport because of differences in mode choices, as well as the size of shipments). Segregations based on the type of service also are pertinent for marine freight forecasting, since each service market is expected to have different growth trends in the future (for example, containerized cargo has been the fastest growing group in marine transport).

Vessel size is another important consideration in the analysis of marine freight demand. Vessel sizes have an impact on the port of call as well as land side traffic flows, and also are key inputs for the analysis of environmental impacts (such as emissions) associated with marine transportation. Other marine transportation system elements, including terminals, container yards, wharves, gates, and land side access routes, play a critical role in the marine freight transportation system and are useful elements to be considered in the freight modeling and forecasting process.

2.3.4 Air Cargo

The air freight system is typically characterized by low weight, small volume, high-value cargo. Consequently, air cargo constitutes a small fraction of total freight tonnage but a higher fraction of total value of freight in domestic and international trade. Air cargo, due to its high value, also has high travel-time sensitivities, implying that slight changes in transit times can have significant cost impacts for air cargo shippers.

Operationally, air freight transportation tends to concentrate in larger metro area hubs. However, it also involves freight moving through some regional freight-only airports. The analysis of hub activity in air freight transportation is important for the development

[1] TEU – Twenty-Foot Equivalent Unit, a standard measure of container volume. See Section 2.4.

of air cargo forecasts in metro areas. Hub activity also is an important consideration in land side traffic impact modeling, since it generates significant truck trips in metro areas.

Air cargo operations can be divided into air cargo freighters, integrated carriers (for example, FedEx), and cargo shipments in the belly of scheduled commercial carriers on passenger routes. These operations have distinct routing characteristics and time-of-day patterns, and also may be different in their underlying logistics frameworks.

Other aviation system elements useful for the analysis of air cargo flows include air-cargo terminals and sort facilities. Sort facilities may be located at off-airport sites, which generate truck trips, and also impact truck traffic distributions. Forecasting truck moves to and from these facilities is thus an important component of local freight planning.

2.4 Freight Traffic Flows

Freight traffic can be represented in many different ways, depending on the mode, type of vehicle/equipment, and commodity. A common representation is in terms of the number of vehicles (for example, number of trucks and carloads, for trucking and rail carload, respectively). Intermodal freight traffic is typically measured in terms of 20-foot equivalent units (TEU), where one TEU represents a standard 20-foot container, while commodity-based representation of freight traffic involves measuring the total weight (tonnage) or value (dollars) of shipments for each commodity group.

Measures of freight traffic flows are important in freight demand analysis for a host of applications such as congestion and safety impact analyses. For example, information on the number of trucks on the network is essential for integrating truck flows with autos on shared-use networks, to understand congestion impacts. Freight traffic flows also are key inputs for safety impact analyses, which are critical in the overall freight planning process for highway and rail modes. In the case of highways, the number of trucks on the network and their fractions relative to total traffic are important parameters to understand interactions between truck and auto traffic, and how they impact safety. Forecasting safety implications associated with rail traffic is particularly difficult, because of the absence of integrated network models, as well as limitations in the capability of government agencies to estimate accurate rail forecasts on private rail networks. Typical approach involves developing general rail traffic growth rates or relying on specific flow data from railroads to analyze rail/passenger conflicts.

Specific applications of freight traffic flow information in freight forecasting include trend analyses and trip generation estimation. Historic measures of freight traffic flows are often used for estimating growth rates based on a trend analysis approach to freight forecasting. Truck trips also are used for facility-level freight forecasting by developing trip generation rates for truck trips as a function of facility characteristics such as employment and land area.

2.5 Organization and Public Policy

There are many key private sector decision-makers within the freight logistics and industry supply chain framework. Shippers, consignees, carriers, and other logistics service providers play a critical role in contributing to decisions about what, how, when, and where transportation services are used to move goods across the supply chain. These organizational frameworks and their underlying decision-making processes are useful to understand in order to accurately model and forecast freight flows in a region.

Regulations have a significant impact on freight flows in a region. For example, safety regulations such as route restrictions, truck size, and weight limitations influence routing patterns of truck movements, types of equipment used, and shipment sizes. Environmental regulations pertaining to emissions will impact equipment types, while hours of service regulations impact time-of-day characteristics.

Land use regulations may have the most significant impact on freight demand due to the inherent interrelationship between land use and transportation. For example, land use regulation on the development of warehousing facilities in a region impacts truck traffic patterns and trip length distributions.

Increased surveillance and inspection practices for freight shipments to meet security rules and regulations can potentially find applications in modeling freight demand. For example, border and gateway simulation tools are being developed that can provide key inputs to freight models (such as for model calibration or validation). Security inspections and technology also may create new sources of data that can be used to understand freight flow characteristics and model freight demand.

3.0 Simple Growth Factor Methods

3.1 Introduction

Perhaps the simplest and most direct method to forecast future freight demand is to factor existing freight demand. This section provides simple methods that can be used to forecast the changes in freight demand due to changes in the level of economic activity or other related factors. The procedure involves applying growth factors to baseline freight traffic data or economic variables in order to project the future freight travel demands. The growth factor approach is classified into two types – the more commonly used method of forecasting future activity *based on historical traffic trends*, and the less commonly used method *based on forecasts of economic activity*. The first approach involves the direct application of a growth factor, calculated based upon historical traffic information, to the baseline traffic data. The second approach recognizes that demand for freight transportation is derived from underlying economic activities (e.g., employment, population, income, etc.). In this approach, forecasts of changes in economic variables are used to estimate the corresponding changes in freight traffic. A simple example is provided at the end of the section to illustrate and differentiate the two approaches.

Growth factors are commonly used by state DOTs, MPOs, and other planning agencies to establish rough estimates of statewide or regional growth for a variety of types of demand and are certainly applicable to establishing the freight traffic for the freight component of a transportation plan, program, or project design. At the local level, these methods might be used to project growth in freight traffic in a given corridor or the level of activity at an intermodal facility or port. This section also briefly describes a more elaborate alternative approach for freight transportation demand forecasting using simple statistical techniques.

The use of growth factors is a simple, inexpensive way to forecast freight, whether based on historical trends or based on historical relationships to economic data, but this method assumes that all of the relationships that are part of that history will continue during the forecast period. It is not well suited for situations that involve dramatic new changes in activity, such as the introduction of a new freight facility offering freight or new developments in shipping or receiving freight. It is most suitable for analyzing incremental changes in freight activity.

3.2 Growth Factors Based on Historical Freight Trends

Fitting historical data to a curve that can be used in forecasting is a topic that mathematicians would call linear or nonlinear regression, depending on the type of curve that is desired. This section presents simple procedures for using historical data for projecting future freight demand. The technique first describes a simple method using only two observations at different points in time, and then describes a method where the data available will be for many time periods. A regression of the line or curve can be found using statistical calculators, spreadsheet functions or, if available, statistical software packages.

3.2.1 Linear Growth

When assuming that freight flow grows in a linear fashion, also sometimes called proportional growth, the annual growth factor (AGF) rate will be the difference between the flow in the first observation and the flow in the second observation divided by the number of years between those observations:

$$AGF = (F_2-F_1)/(Y_2-Y_1)$$

where F_1 is freight flow in year Y_1 and F_2 is freight demand in year Y_2.

The linear annual growth factor can then be applied to predict future demand (F_3) for some future year (Y_3) as follows:

$$F_3 = F_2+AGF*(Y_3-Y_2)$$

For example, assume that the number of truck trips at a given location on an average weekday was 8,000 in 2000 and 10,000 in 2005. Using this simple procedure, the forecast number of truck trips for the year 2010 is 12,000; i.e.,

$$AGF = (10{,}000-8{,}000)/(2005-2000) = 400$$

$$12{,}000 = (10{,}000)+(400)*(2010-2005)$$

If more than two years of historical data are available for the variable to be forecast, this data can be used to solve a linear regression according to the formula:

$$F(n) = Constant+AGF*(n)$$

where n is the number of years from the first observation and Constant and AGF are found from the linear regression. Table 3.1 shows an example using a the regression package in Excel (first turning on the Tools/Add-ins/Analysis Tool Pak, and then selecting the Tools/DataAnalysis/Regression) and the data organized in a column, where the x-variable (independent variable) is the Years from 1993 and the y-variable (dependent variable) is the Tons. In this application, the linear regression solutions of both the intercept and the x-variable$_1$ coefficients can be taken to be the Constant and the AGF, respectively.

In this case, with an R-Square[1] of 0.812, the forecasting formula is:

$$F(n) = 104{,}739+1{,}357*(n)$$

and the results are shown in the last column of Table 3.1.

Table 3.1 Linear Growth Regression

Year	Tons	Years from 1993	Linear Regression
1993	104,432	0	104,739
1994	111,955	1	106,096
1995	101,807	2	107,453
1997	109,659	4	110,168
2003	117,896	10	118,311
2004	120,266	11	119,668
2005	121,445	12	121,025
2010	–	17	127,811
2015	–	22	134,597
2020	–	27	141,382

3.2.2 Compound Growth

By assuming that freight flow grows in a compound fashion, such as a manner similar to compound financial growth, the annual growth factor will be the ratio of the flow in the second and first raised to a power which is the inverse of the number of years between the first and second observations:

$$AGF = (F_2/F_1)^{(1/(Y_2-Y_1)}$$

where F_1 is freight flow in year Y_1 and F_2 is freight demand in year Y_2. This also can be expressed as a compound annual growth rate by subtracting 100 percent from the AGF.

[1] R2 is a statistic that provides information about the goodness of fit of a model.

The compound growth factor can then be applied to predict future demand (F_3) for some future year (Y_3) as follows:

$$F_3 = F_2 * AGF^{(Y_3 - Y_2)}$$

For example, assume that the number of truck trips at a given location on an average weekday was 8,000 in 2000 and 10,000 in 2005. Using this simple procedure, the forecast number of truck trips for the year 2015 is 15,625; i.e.,

$$AGF = (10{,}000/8{,}000)^{1/5} = 1.04564$$

$$15{,}625 = (10{,}000)\ (1.04564)^{10}$$

and the compound annual growth rate can be interpreted as 4.6 percent (104.564 percent minus 100 percent).

If more than two years of historical data are available for the variable to be forecast, this data can be used to solve a power regression according to the formula:

$$F(n) = Constant * AGF^{(n)}$$

where n is the number of years from the first observation and Constant and AGF are found from the linear regression. Table 3.2 shows an example using a the regression package in Excel (first turning on the Tools/Add-ins/Analysis Tool Pak and then selecting the Tools/DataAnalysis/Regression). The data are organized in a column, where the x-variable (independent variable) is the Years from 1993 and the y-variable (dependent variable) is the Tons expressed as a natural logarithm, Ln(tons). In this application, the linear regression solutions of the both the intercept and the $x\text{-variable}_1$ coefficients have to be converted from natural logs to whole numbers by taking the exponential of those terms, e.g., Constant = Exp (intercept) and AGF = EXP (x-variable coefficient).

In this case, with an R-Square of 0.798 the coefficients are:

$$F(Y) = 104{,}794 * (1.012)^{(n)}$$

and the results are shown in the last column of Table 3.2. This regression also can be interpreted as a compound growth rate of 1.2 percent (101.2 percent minus 100 percent) per year.

Table 3.2 Compound Growth Regression

Year	Tons	Ln(Tons)	Years from 1993	Compound Regression
1993	104,432	11.556	0	104,794
1994	111,955	11.626	1	106,064
1995	101,807	11.531	2	107,350
1997	109,659	11.605	4	109,970
2003	117,896	11.678	10	118,217
2004	120,266	11.697	11	119,650
2005	121,445	11.707	12	121,101
2010	–	–	17	128,623
2015	–	–	22	136,613
2020	–	–	27	145,099

3.2.3 Results

The historical regression can be done using either a linear growth or a nonlinear regression technique. The compound growth regression is only one of many nonlinear regressions can be done using any number of curve fitting techniques. Those interested in alternative techniques should pursue those elsewhere.

Linear growth will always be less than compound growth, as simple interest calculations in finance are always less than compound interest. The methods chosen should be consistent with the pattern of the observed data and for the intended purpose and should recognize the uncertainly of the forecast and the risk of the forecast being either too low or too high for the intended use. For example, a forecast of truck volumes to support pavement designs should be on the high side and compound growth may be preferred, while financial analysis such as tolling should be conservative on the low side and might be better suited for a linear regression.

The regressions can be successfully calculated even if observations are not available for all years, as shown above. Also, the regressions should only be used for a period consistent with the observations. By using these simple techniques to forecast growth for a period much longer than the observation, the assumption being made is that the underlying pattern will not change during the entire period, which may not be appropriate. In Tables 3.1 and 3.2, the forecast for 2020 is consistent with the period of observation but the forecast for 2025 is for a period longer than the observations and should be used with caution.

3.3 Growth Factors Based on Direct Economic Projections

This section presents a simple procedure for forecasting freight using projections of future demand or output for the goods being transported. It also describes various sources of economic forecasts that a freight analyst can use in applying this procedure as well as ways to improve its accuracy. A brief discussion of sensitivity analysis and alternative futures also is included.

3.3.1 Analysis Steps Explained

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

This procedure requires data or estimates of freight traffic by category/commodity type for a reasonably "normal" base year, as well as base 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. These forecasts may be of economic activity, for example Gross State Product (GSP), or of employment of the industry groups associated with each category/commodity.

2. Obtain or estimate the distribution of base year freight traffic by category/commodity and its associated industry group. This data might be available from an intercept survey of vehicles traveling on the facility for which forecast are being prepared. If actual data on the distribution are not available, state or national sources may be used to estimate this distribution. For example, the Census Bureau's VIUS[2] provides information on the distribution of truck VMT by commodity carried and industry group. Determine the annual growth factor (AGF) for each commodity or industry group as follows:

$$AGF = (I_2/I_1)^{1/(Y_2-Y_1)}$$

   where I_1 is the value of the economic indicator in year Y_1 and I_2 is the value of the economic indicator in year Y_2.

---

[2] The Vehicle Inventory and Use Survey (VIUS) is a periodic survey of private and commercial trucks registered (or licensed) in the United States. It is a sample survey taken every five years as part of the Economic Census. The funding for the 2007 VIUS has not been budgeted. The 2002 VIUS may be the last survey available.

3. Using the AGF and base year traffic, calculate forecast year traffic for each commodity or industry groups as follows:

$$T_f = T_b\ AGF^n$$

   where n is the number of years in the forecast period.

4. Aggregate the forecasts across commodity or industry groups to produce the forecast of total freight demand.

Alternatively, if the mix of traffic by industrial sector/commodity is not available and the national sources are not considered useful, the forecasts of employment may be converted to truck trips using available truck or vehicle trip rates for the economic indicator variable. In this case the method is 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. These forecasts may be of economic activity; for example, GSP, or of employment of the industry groups associated with each category/commodity.

2. Calculate the base year number of freight units, e.g., truck trips, for each sector based on the economic indicator variable and the freight units, e.g., truck trip rates for that sector. Calculate the forecast year number of truck for each sector based on the economic indicator variable and the truck trip rates for that sector.

3. Sum all of the truck trips for the base year and for the forecast year. Determine the total AGF as follows:

$$AGF = ((\Sigma I_2{*}FR)/(\Sigma I_1{*}FR))^{1/(Y_2-Y_1)}$$

   where $I_1{*}FR$ is the value of the economic indicator times the flow rate (e.g., truck trip rate) for that economic indicator in year Y_1 and $I_2{*}FR$ is the value of the economic indicator times the flow rate (e.g., truck trip rate) for that economic indicator in year Y_2.

4. Apply the total growth rate to the base freight flow to determine the future 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 indicator variables 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.

3.3.2 Sources of Economic Forecasts

The economic forecast should be applicable for the area being served by the freight facility. There are several sources which can be used by analysts at state DOTs, MPOs, and other planning agencies to obtain estimates of growth in economic activity (by geographic area and industry or commodity type). The availability of data specific to the geographic areas and industries being considered may, however, be limited and compromises may have to be made.

Many states fund research groups that monitor the state's economy and produce forecasts of changes in the economy. For example, the Center for the Continuing Study of the California Economy develops 10-year forecasts of the *value* of California products by the NAICS[3] code. Similarly, the Texas Comptroller of Public Accounts develops 10-year forecasts of *population* for 10 substate regions and 10-year forecasts of *output* and *employment* for 14 industries.

At 2.5-year intervals, the Bureau of Labor Statistics (BLS) publishes 10-year forecasts of *output* and *employment* for 242 sectors (generally corresponding to three- and four-digit NAICS industries).[4]

In addition to the state and Federal agencies, short- and long-term economic forecasts also are available from several private sources. The private firms use government and industry data to develop their own models and analyses. Among the best known private sources are Global Insight (formerly DRI-WEFA) and Woods and Poole.

Global Insight provides national, regional, state, Metropolitan Statistical Area (MSA), and county-level macroeconomic forecasts on a contract or subscription basis. Variables forecasts include gross domestic product, employment, imports, exports, and interest rates. Their United States county forecasts cover a 30-year period and contain annual data. They are available following completion of our long-term U.S. state and MSA forecasts on a semiannual basis with forecasts of more than 30 concepts, including: income and wages; employment for 11 major industry categories; population by age cohorts; households by age cohorts. The United States county forecasts are updated semiannually.

Woods and Poole provides more than 900 economic and demographic variables for every state, region, county, and metropolitan area in the United States for every year from 1970 to 2030. This comprehensive database is updated annually and includes detailed population data by age, sex, and race; employment and earnings by major industry; personal income by source of income; retail sales by kind of business; and data on the number of households, their size, and their income. All of these variables are projected for each year through 2030.

[3] NAICS – The North American Industrial Classification System, a hierarchical coding system for industries.

[4] The most recent BLS forecasts are contained in U.S. Department of Labor, Bureau of Labor Statistics, Employment and Output by Industry, 1994, 2004, and Projected 2014, http://www.bls.gov/emp/empinddetail.htm.

3.3.3 Improving the Demand Forecasts

The basic procedure presented above makes the simplifying assumption that, for any transport facility, the percentage change in demand for transport (i.e., freight traffic) of each commodity group will be identical to the percentage change in the corresponding indicator variable. However, for various reasons, the two percentage changes are likely to be somewhat different from each other. These reasons include changes over time in:

1. Real value of output per ton, adjusted for inflation;
2. Output per employee; also known as labor productivity;
3. Transportation requirements per ton; and
4. Competition from other facilities and modes.

To the extent that the likely effects of these changes are understood and can be estimated at reasonable cost, the basic procedure should be modified to reflect these effects. These effects are discussed below.

For most commodity groups, the relationship between value of output (measured in constant dollars) and volume shipped (measured in pounds, tons, cubic feet, etc.) may change over time. These changes may be due to a change in the mix of commodities being produced within a given commodity group (e.g., more aluminum and less steel) or a change in the average real value per ton of major products within the group. These changes may result in changing value per ton in either direction. For example, the shift to flat screen panel televisions from cathode ray tube televisions provides an important example of a product category. Computers, in which the value per ton, or per pound, has decreased appreciably. When transport demand is being forecast for several different commodity groups, adjustments for expected changes in value per ton for all commodity groups will be relatively expensive to make and may not have a very significant effect on the overall forecast of transport demand. However, when there are one or two commodity groups that are of particular interest, some consideration should be given, at least in an informal way, to determine how real value per ton for these groups has been changing and how it is likely to change over the forecast period.

Employment is related to transport demand less closely than is real output. Hence, employment is a less desirable indicator variable. However, because long-term forecasts of employment are more available than forecasts of output, employment forecasts must be used for some purposes. As a result of improvements in labor productivity, real dollar-valued output per employee increases over time, and physical output (in tons or cubic feet) tends to increase as well. Forecasts of the overall increase in real dollar-valued output per employee for goods-producing industries (agriculture, mining, construction, and manufacturing) can be obtained from the public and private sources listed above, but should consider the cyclical nature of commodity prices. In order to avoid a downward bias in the forecasts of transport demand, forecasts of percentage change in employment should be converted to forecasts of percentage change in (real dollar-valued) output by multiplying by estimated compound growth in labor productivity over the forecast period. Additionally, changes in production methods that result in a reduction in domestic employment, such as a shift to off-shore manufacturing, may change the origin and distribution and freight, but not the overall shipments.

Decreases in the real cost of transportation that have occurred over time have resulted in a general tendency for industry to increase its consumption of transport services in order to economize on other factors of production. This tendency has resulted in trends toward decreased shipment sizes and increases in both lengths of haul and standards of service, with the last effect resulting both in a demand for premium quality services (e.g., just-in-time delivery,) provided by traditional modes and in the diversion to more expensive modes that offer faster, more reliable service. In recent years, these decreases have been offset by increases in certain components of costs, particularly fuel costs. Recognizing that shippers will use transportation services that are the most cost-effective, any changes in transportation and inventory costs may result in changes in the distribution pattern or mode that is used by those shippers.

Finally, whenever relevant, forecasts of demand for a facility or mode should be adjusted to reflect expected changes in degree of competition from other facilities or modes. These changes may result from:

- Expected changes in relative costs;
- The elimination of base year supply constraints at the facility in question or at competing facilities;
- The development of future supply constraints at the facility in question or at competing facilities; or
- The development of new competing facilities.

The forecasting problems posed by base year supply constraints frequently can be avoided by choosing a base year when no significant supply constraints existed. When this is not practical, a combination of historic data and judgment may be used to adjust the estimates of base year facility usage to eliminate the effects of the supply constraints, thus producing estimates of base year demand in the absence of supply constraints; annual growth rates or growth factors can then be applied to these estimates of base year demand to produce the forecast demand.

3.3.4 Sensitivity Analysis

The growth factor methods presented above produce just a single forecast of freight demand. Planning decisions can then be made on the basis of this forecast. However, planners are cautioned that the forecast is likely not to be completely accurate either because some of the assumptions (e.g., those relating to economic growth) prove to be inaccurate, or because of deficiencies in the procedure itself. Because no forecast can be guaranteed to be perfectly accurate, effective planning requires that planning decisions be reasonably tolerant of inaccuracies in the forecast. The conventional approach to analyzing the effects of alternative futures is to subject a forecast to some form of sensitivity analysis.

The development of any forecast requires a number of assumptions to be made, either explicitly or implicitly. Some of the types of assumptions that may be incorporated into forecasts of demand for a transportation facility relate to:

- Economic growth – both nationally and locally;
- Growth in the economic sectors that generate significant volumes of freight handled by the facility;
- Transport requirements of these sectors (that may be affected by increased imports or exports or by changes in production processes);
- Modal choice (which may be affected by changing transport requirements or changing cost and service characteristics of competing modes);
- Facility usage per unit of freight volume (that may be affected by changes in shipment size or container size);
- The availability and competitiveness of alternative facilities;
- Value per ton of output; and
- Output per employee (if employment is used as an indicator variable).

Sensitivity analysis consists of varying one or more of these assumptions in order to produce alternative forecasts. The most common alternative assumptions to be considered are those related to economic growth; and, indeed, economic forecasters (including BLS) frequently provide high and low forecasts of growth in addition to a medium (or most likely) forecast. These alternative forecasts of economic growth can be used to generate alternative forecasts of transport demand, and additional alternative forecasts of exogenous variables (e.g., trade) can be used to produce an even larger set of forecasts of transport demand (e.g., high growth, high trade; high growth, low trade; etc.). However, simply varying these exogenous forecasts generally will not produce a set of transport-demand forecasts that represents the full range of demand that might exist in future years of interest. To produce a better understanding of the range of demand that might exist in the future, a more thorough sensitivity analysis should be conducted.

One approach to conducting a thorough sensitivity analysis consists of reviewing each of the assumptions explicit or implicit in the analysis and, for each assumption, generating a pair of reasonably likely alternative assumptions, one that would increase the forecast of demand and one that would decrease it. A high forecast of demand can then be generated by using all the alternative assumptions that would tend to increase the forecast (or at least all those that are logically compatible with each other); and a low forecast can be generated by using all the alternative assumptions that would tend to decrease the forecast. These high and low forecasts should provide planners with appropriate information about the range of transport demand that could exist in the future. Planning decisions can then be made that are designed to produce acceptable results for any changes in transport demand within the forecast range.

A somewhat more systematic type of sensitivity analysis consists of making small changes in the analytic assumption, one at a time, and determining the effect of each change on forecast demand. The results of this effort are a set of estimates of the sensitivity of the forecast to each of the assumptions. This type of sensitivity analysis can provide more insight into the relationships between the various analytic assumptions and the forecasts produced. However, this approach requires a greater expenditure of resources. Furthermore, the most important sensitivity results – high and low forecasts of demand – can be generated using either approach, though these forecasts will be affected by the alternative analytic assumptions used to generate them and the care with which the high and low forecasts are then generated.

3.3.5 Alternative Forecasting Methods

One alternative to the use of growth factor methods for forecasting freight travel demand is regression analysis. While the historical growth or time-series methods discussed in Section 3.2 also involve regression of observations against time periods, regression analysis as it is discussed here involves identifying one or more independent variables (the explanatory variables) which are believed to influence or determine the value of the dependent variable (the variable to be explained), and then calculating a set of parameters which characterize the relationship between the independent and dependent variables. For freight planning purposes, the dependent variable normally would be some measure of freight activity and the independent variables usually would include one or more measures of economic activity (e.g., employment, population, income). For forecasting purposes, forecasts must be available for all independent variables. These forecasts may be obtained from exogenous sources or from other regression equations (provided that the system of equations is not circular), or they may be developed by the forecaster using other appropriate techniques.

For forecasting purposes, regressions normally use historic time-series data (an alternative is cross-section data) obtained for both the dependent and independent variables over the course of several time periods (e.g., years). Regression techniques are applied to the historic data to estimate a relationship between the independent variables and the dependent variable. This relationship is applied to forecasts of the independent variables for one or more future time periods to produce forecasts of the dependent variable for the corresponding time periods.

It should be recognized that the economic forecast described above, to some extent, has been developed by regression and calibration to observed data. The use of regression of observed freight flows to economic data should be used with caution as an alternative to the economic forecast described above which also may consider many factors that cannot be considered in a simple regression.

3.3.6 Illustrative Example

The State of Minnesota used an economic factoring method to forecast truck flows on its Truck Highway (TH) system. For the TH 10 segment through Sherburne, Anoka, and Ramsey counties,[5] the State followed the following steps:

- Determined the base year truck volumes on individual sections of the corridor between major intersections interchanges from historical traffic counts;
- Obtained existing industrial employment by sector by county from the Minnesota Department of Employment Security (DEED);
- Obtained regional industrial employment projections for central Minnesota and the Twin Cities metro areas from the Minnesota Department of Employment Security, now the Minnesota Department of Employment and Economic Development (DEED);
- Developed county employment by industry for the base and forecast year by assuming that county employment is proportional to regional employment by sector;
- Converted the county employment forecast to truck trips based on rates shown in Table 3.3;
- Calculated the growth in trucks trips between the base year of 1999 and 2020 for each county by applying these rates to the existing and forecast county employment; and
- Applied those growth rates to the base year truck volumes on TH 10 depending on the county in which it is located.

The results of these calculations are shown in Table 3.4. The employment forecast was converted to trucks trips by industrial sector prior to calculating growth factors, in lieu of calculating VMT by commodity. The assumption was made that the growth in truck traffic for the segment of TH 10 in each county could be forecast completely by the growth in employment in that county, converted to truck trips. No consideration was given to trucks that might only be passing through these counties.

---

[5] *IRC TH 10 Corridor Management Plan: TH 24 in Clear Lake to I-35W*, prepared by Howard R. Green Company for the Minnesota Department of Transportation – Metro Division and Minnesota Department of Transportation – District 3, May 2002.

Table 3.3 Daily Truck-Trip Rates Used in Factoring Truck Trips

SIC	Description	Trips/Employee
1-9	Agriculture, Forestry, and Fishing	0.500
10-14	Mining	0.500
15-19	Construction	0.500
20-39	Manufacturing, Total	0.322
40-49	Transportation, Communication, and Public Utilities	0.322
42	Trucking and Warehousing	0.700
50-51	Wholesale Trade	0.170
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)	0.030
N/A	Government	0.027

Source: Minnesota DOT.

Table 3.4 Results of TH 10 Forecast Daily Trucks

Location			Growth 2000-2020 Total		2020 Projections Based On	
From	To	County	Employment	Internal Truck	1999	1995[a]
MN 25	MN 24 (Becker)	Sherburne	39%	30%	866	1,165
MN 25 (Becker)	MN 25 (Big Lake)	Sherburne	39%	30%	862	1,350
MN 25 (Big Lake)	CR 14/15	Sherburne	39%	30%	902	1,462
CR 14/15	TH 169	Sherburne	39%	30%	1,022	1,940
TH 169	MN 47	Sherburne/ Anoka	39%, 18%	30%, 8%	1,560	1,726
MN 47	TH 610	Anoka	18%	8%	3,019	2,763
TH 610	MN 65	Anoka	18%	8%	–	2,409
MN 65	I-35	Ramsey	8%	8%	–	1,979
I-35	I-694	Ramsey	8%	8%	–	1,610

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

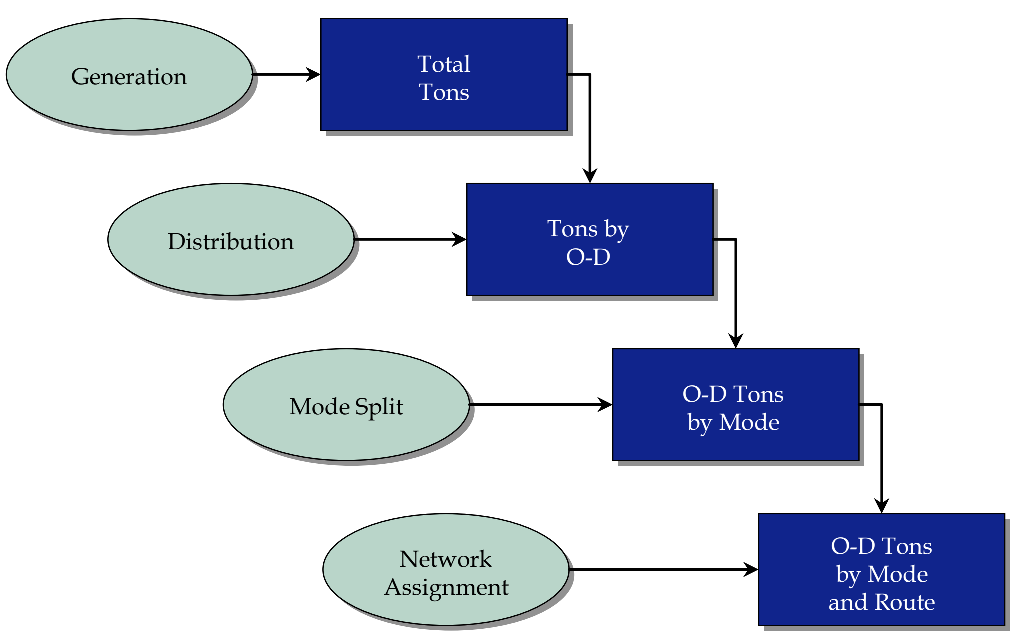
4.0 Incorporating Freight into "Four-Step" Travel Forecasting

This section explains the various methods of incorporating freight into the traditional "four-step" travel forecasting process. The four steps include trip generation, trip distribution, mode choice, and trip assignment. These are explained in more detail in the ensuing sections. The focus will be at three levels of geography – urban, statewide, and site specific.

■ 4.1 Introduction

The flow of freight can be measured in two forms – commodity and trucks. The following figure depicts the four steps to forecasting freight at any geographic level. As indicated in the initial steps, trip generation and distribution can either be in the form of commodities or trucks. The basic difference between commodity- and truck-based models is the form of the input data. However, for trip assignment purposes all forms of freight are converted to vehicles to be assigned onto a roadway network.

Figure 4.1 "Four-Step" Process of Freight Forecasting



The following subsections discuss the general issues of incorporating freight into tradition four-step transportation models, a topic that is discussed in detail in later sections as it applies to urban and state models.

4.1.1 Trip Generation

Trip generation uses economic variables to forecast freight flows/vehicle flows to and from a geographic area using equations. The trip generation equations are either borrowed from other sources or developed locally by using an existing commodity flow table or by estimating from vehicle surveys. The outcome of trip generation is the amount of a commodity and/or the number of vehicles that comes into or goes from a particular geographic unit in a specified unit of time.

Trip generation models used in freight forecasting include a set of annual or daily trip generation rates or equations by commodity. These rates or equations are used to determine the annual or daily commodity flows originating or terminating in geographic zones as a function of zonal or county population and/or industry sector employment data. In other words, employment and/or population data are the essential input data required for computing freight trip generation.

The independent variables, such as employment and population, usually dictate the level of detail the freight flows can be generated using a trip generation model. This may be a county or a traffic analysis zone (TAZ). The travel demand models usually use TAZ data, and so a freight forecasting model can be developed at a TAZ level as long as the base and forecast year data at the required level of industry detail is available at that geographic unit.

Before trip generation models are estimated, trucks are first classified by type of truck and/or trip purpose/sector. The various types of classification of trucks include the FHWA classification system, gross vehicle weight (GVW) ratings, type of goods carried, number of tires/axles, and body type.

Normally, one set of regression equations for the productions and one set of regression equations for consumption are estimated. These regression equations are either developed for each commodity group or truck type. A commodity group is analogous to a "trip purpose" in passenger modeling. The intercept is almost always forced to zero, because there should be no freight in or out of a zone with no related economic activity. The observations used to estimate the regression model would be the inbound tons of the commodity or number of trucks and the independent variables are usually employment, industry type, population, etc. for each geographic area.

Truck trip generation rates can be developed from trip diary surveys using regression equations by regressing the number of commercial vehicles on the number of employees in various industries and household population. Trip rates also can be estimated for each individual land-use type based on the ratio between the truck trips coming into and going out of the land area and the employment associated with that land use. The 1996 *Quick Response Freight Manual* (QRFM) was developed by the FHWA and it provides default values that can be used in models. The QRFM rates were developed using regression models developed from a trip diary in Phoenix. The NCHRP Truck Trip Generation Synthesis (298) is another source for a complete reference list of potential trip rates.

The various steps required to determine trip rates are:

1. Trip rates need to be estimated or identified (either through local surveys or using national default data);

2. Socioeconomic data (employment by industry and households/population) by TAZ is applied to the rates to get generation by TAZ;

3. The QRFM method assumes that productions equal attractions, but local data can be used to estimate separate production and attraction rates; and

4. If there are freight centers (ports, intermodal terminals), they should be treated as special generators and have their own trip rates determined from surveys since employment rates would not apply.

Table 4.1 is borrowed from the Phoenix Metropolitan Urban Truck Model.[1] There are far more four-tire truck trips per unit of activity than combination and large-truck trips, which is pretty typical in an urban area. It should be noted that households also do generate a lot of truck trips.

Table 4.1 Truck Trips Rates

Generation Variable (Employment or Households)	Four-Tire Trucks	Single Unit Trucks (6+ Tires)	Combination Trucks
Agriculture, Mining, and Construction	1.110	0.289	0.174
Manufacturing, Transportation/ Communications/Utilities, and Wholesale	0.938	0.242	0.104
Retail Trade	0.888	0.253	0.065
Office and Services	0.437	0.068	0.009
Households	0.251	0.099	0.038

[1] Earl Ruiter; Cambridge Systematics, Inc.; *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area;* February 1992; Report Number FHWA-AZ92-314; prepared for Arizona Department of Transportation and the Federal Highway Administration.

4.1.2 Trip Distribution

In trip distribution, one determines the flow linkages between origin and destination for those commodity tons/truck trips that were developed in trip generation. Trip distribution uses those flows/trips to and from and independent variables on the transportation system to forecast the flows/trip interchanges between geography areas.

The trip distribution equations can be borrowed from other sources or developed locally by using an existing commodity flow table or local vehicle surveys. A gravity model can be constructed and calibrated at a prespecified geographic detail. The gravity model is a statistical process that has been found useful to explain the relationship between transportation zones. The considerations are the total trips that begin in the first zone, the number ending in the second zone, and the impedance or difficulty to travel (such as cost or time) between them.

The average trip lengths needed to obtain trip-length frequency distributions and friction factors are normally obtained from surveys. The degree of difficulty of travel, usually a function of some impedance variable used in the distribution model needs to match the survey data (free flow time, congested travel time) and there must be a source of the impedance variable. The calculation of the degree of difficulty is often called a friction factor. With limited survey data, the model is typically calibrated at the district level, and the friction factors developed are assumed to apply at smaller units of geography. However, it is sometimes difficult to get survey data for trip distribution, and friction factors are often borrowed from other sources.

The friction-factors are usually calculated as a negative exponential function of the average trip time from origin TAZ to destination TAZ. The parameters in the exponential function are calculated from the trip length frequency distribution, which describes the shape of the curve that is summarized by the average trip length.

The friction factor curves for the PSRC truck model[2] were derived originally from the 1996 edition of the QRFM[3] and adjusted to provide the best fit with the average trip lengths from the origin-destination survey of trucks. The light, medium, and heavy trucks are distributed from origins to destinations using this gravity model technique with different parameters. These friction factors were developed using impedance functions that also varied by trip distances, that is different parameters were used for short and long distances, as shown below:

- Light impedance function:
  - exp (3.75 – 0.08 * light truck generalized cost skim) for less than 26 miles
  - exp (2.1 – 0.005 * light truck generalized cost skim) for greater than or equal to 26 miles

[2] Cambridge Systematics, *PSRC Model Improvements,* 2002.

[3] Cambridge Systematics, *Quick Response Freight Manual,* Federal Highway Administration, 1996.

- Medium impedance function:
  - exp (4.75 – 0.05 * medium truck generalized cost skim) for less than 27 miles
  - exp (4.2 – 0.003 * medium truck generalized cost skim) for greater than or equal to 27 miles
- Heavy impedance function:
  - 1.0 for less than 7.5 miles
  - exp (5.0 – 0.009 * heavy truck generalized cost skim) for greater than or equal to 7.5 miles

The below table shows the average trip lengths from the PSRC truck model compared against the observed trip lengths.

Table 4.2 Average Truck Trip Lengths

	Light Truck	Medium Truck	Heavy Truck
Observed Trip Length (Miles)	No data	27.51	30.81
Modeled Trip Length (Miles)	22.34	27.53	28.29

Another method that is less popular is the growth factor approach for trip distribution, also known as the Fratar method. This usually requires an existing base year trip table of freight flows or trip interchanges. The Fratar method assumes that the change in the number of trips in an O-D pair is directly proportional to the change in the number of trips in the origin and destination. The method lacks system sensitivity to the change in network-level characteristics such as congestion. Also, these methods allow preservation of observations as much as is consistent with information available on growth rates. If part of the base year matrix is unobserved, then this error is carried over in the forecasts. These methods cannot be used to fill in unobserved cells of partially observed trip matrices. Hence, they are of limited use to test new policy options.

4.1.3 Mode Split/Conversion to Vehicle Flows

Mode choice modeling is used if multimodal trip tables need to be prepared. This step allows the forecastability of mode splits as they change over time. The four major categories in which various factors that affect mode choice decision-making process fall into are:

1. **Goods Characteristics –** These include physical characteristics of goods such as the type of commodity, the size of the shipments, and the value of the goods;

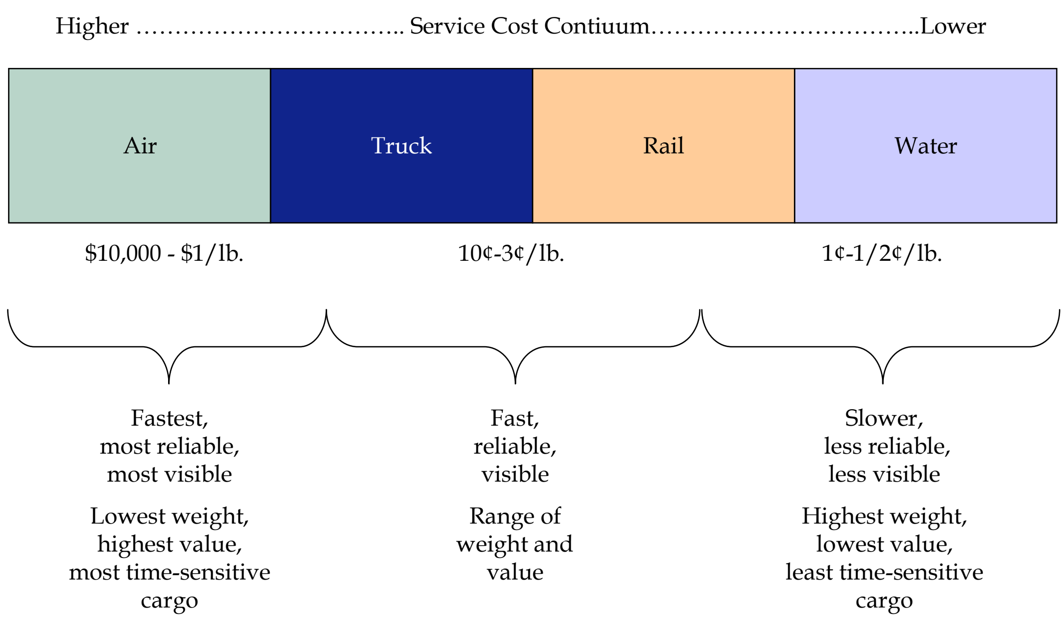
2. **Modal Characteristics –** Speed of the mode, mode reliability, and the capacity;

3. **Total Logistics Cost –** Inventory costs, loss and damage costs, and service reliability costs; and

4. **Overall Logistics Characteristics –** Length of haul and the shipment frequency.

Figure 4.2 shows the major characteristics of each of the freight modes in a continuum/ spectrum and shows how this relates to the types of goods that may be shipped by each mode. The rail and water modes have the highest capacity on this spectrum, while air and truck have the lowest capacity. The air and truck modes provide the highest level of service in terms of reliability and minimal loss and damage. So commodities that are needed for just-in-time production systems (like certain machinery parts) will need to use trucking and air. The mode associated with the highest cost is by air and, therefore, are only justified for high-value commodities such as electronics.

Figure 4.2 Goods and Modal Characteristics



The two common methods of computing mode splits market are the segmentation method and the choice method. The market segmentation method is described in detail under Section 4.17.

Choice Method

These methods are the most comprehensive as they examine the characteristics of each individual shipment and the available modes. The most common type of choice method is the discrete choice logit model. This formulation is very similar to the passenger mode choice modeling, but the variables and data sets used to estimate the parameters are very different. The logit discrete choice model shows the choices for individual shipments as a function of the utility that each mode provides to the shipper. Utility can be a function of any of the factors mentioned earlier in this section.

The logit model actually calculates the probability that each shipment will use a particular mode. Summing the probabilities across all of the shipments provides the overall mode share. Each modal alternative has a utility to the shipper that has a systematic component related to the factors we have described earlier and a random component that has to do with things like personal relationships. The coefficients in the utility function measure the relative importance of each factor in determining mode choice. The greater the utility that any alternative has, the higher the probability that this alternative will be selected.

Logit choice models are the most complete with respect to modeling all of the factors that affect mode choice. Thus, they can be applied to a wide range of policy and investment studies. However, they are complex to build and are very data intensive. Most of the data needed require the use of complex performance or simulation models. The truck surveys are helpful for estimating the choice parameters, but these surveys are expensive and time-consuming to conduct.

Truck Conversion

The freight trip tables after the mode split step are multimodal commodity flow tables in annual tons. That is, after allocating the tables among the modes, the flow units will still be in annual tons. The flow unit in almost all highway travel demand models is daily or peak-period vehicles. Therefore, to consider the interaction of freight trucks on the highway with all automobiles and all other vehicles, the time period must be made consistent and the annual truck tables in tons must be converted from annual tons to daily trucks. Payload factors (average weight of cargo carried) are used to convert tons to trucks. The annual trips are then converted to daily trips by assuming an average number of operating days per year. But most travel demand models use average weekday travel. Various data sources can be used to estimate fraction of truck tonnage on weekdays and then divide this tonnage by number of weekdays per year. This process is discussed in more detail in Section 4.3.8.

Payloads or truck loads are limited by weight and volume considerations. The commodities carried by trucks have different densities and, therefore, different payloads for the same volume. Because of handling and packaging needs, payloads also may differ by commodity. For example, large size trucks carry heavier loads even for the same commodity. If payloads are calculated for different truck classes, the commodity tonnage needs to be allocated to the different truck classes. Smaller trucks tend to be used more in shorter-haul service. To the extent that length of haul and truck size are correlated, length of haul (directly available from commodity flow data) can be used in calculating payload factors. Payload factors can be calculated for loaded trucks only (estimated truck volumes must then be adjusted to account for percent of empties) or they can average empty and loaded weights.

The various sources of payload factors are 1) shipper or carrier surveys that provide information about the tonnage and commodity being carried; 2) weigh stations that typically have weight information by truck type, but not by commodity; and 3) the VIUS[4] is a part of the Economic Census and is collected every five years.

4.1.4 Network Assignment

The process of allocating truck trip tables or freight-related vehicular flows to a predefined roadway network is known as the traffic assignment or network assignment. There are many types of assignments that are dependent on a number of factors such as level of geography, number of modes of travel, type of study and planning application, data limitations, and computational power such as software. The various types of assignments and their applications are explained in detail under Section 4.18.

In developing a truck trip assignment methodology, some of the key issues and model components that need to be addressed and evaluated are as follows:

- **Time-of-Day Factors –** These distribution factors by truck type separate truck trips that are in motion during each of the four modeling time periods; these factors need to be examined through recent data.
- **Roadway Capacity and Congested Speeds –** A single truck will absorb relatively more of the available capacity of a roadway than an automobile, and a given volume of trucks will often result in a much greater impact on congested speeds than a similar volume of automobiles. So passenger car equivalent (PCE) factors are required to convert the truck flows to PCEs before the assignment process.
- **Volume-Delay Functions –** These functions are used to estimate average speeds as a function of volume and capacity may be different for trucks than for automobiles.
- **Truck Prohibitions –** Some freeways and major principal arterials in the region have prohibitions for certain classes of trucks, and this needs to be addressed before the assignment. A truck network also may be built based on the local knowledge of truck prohibitions and truck routes.

[4] Vehicle Inventory and Use Survey, U. S. Census Bureau, 2002. The survey was first conducted in 1963, under the name of Truck Inventory and Usage Survey (TIUS). It was renamed as VIUS in 1997. The survey was discontinued after the 2002 survey year was processed. It had been conducted for years ending in "2" and "7."

■ 4.2 Urban Freight and Commercial Trucks

4.2.1 Definition of Trucks

In order to capture trucks accurately in a truck-travel model system, the mode "truck" needs to be defined first. This can be accomplished by examining the different types of trucks and identifying the different types of truck classification variables in the region. This essentially involves the way a truck is defined by its physical characteristics. This section describes the various classification variables that have been widely used by various agencies.

Number of Axles

The total number of axles on the trucks are normally categorized into four axle categories – two axles with four tires, two axles with six tires, three axles, and four or more axles. This information on vehicles can be obtained by visual identification or manual counts, or the use of axle sensor-based counters that are often used to collect accurate truck counts. The number and spacing of axles is used to classify trucks into FHWA's 13-category classification scheme. Most of the vehicle classification count studies across the country classify trucks into these 13 categories, as listed below:

- **Class 1: Motorcycles (Optional) –** All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the state.

- **Class 2: Passenger Cars –** All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

- **Class 3: Other Two-Axle, Four-Tire Single Unit Vehicles –** All two-axle, four-tire vehicles, excluding passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carry-alls, and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification. Because automatic vehicle classifiers have difficulty distinguishing Class 3 from Class 2, these two classes may be combined into Class 2.

- **Class 4: Buses –** All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.

- **Class 5: Two-Axle, Six-Tire, Single-Unit Trucks –** All vehicles on a single frame, including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.

- **Class 6: Three-Axle Single-Unit Trucks –** All vehicles on a single frame, including trucks, camping and recreational vehicles, motor homes, etc., with three axles.

- **Class 7: Four-or-More-Axle Single-Unit Trucks –** All trucks on a single frame with four or more axles.

- **Class 8: Four-or-Fewer-Axle Single-Trailer Trucks –** All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.

- **Class 9: Five-Axle Single-Trailer Trucks –** All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

- **Class 10: Six-or-More-Axle Single-Trailer Trucks –** All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

- **Class 11: Five-or-Fewer-Axle Multitrailer Trucks –** All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.

- **Class 12: Six-Axle Multitrailer Trucks –** All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

- **Class 13: Seven-or-More-Axle Multitrailer Trucks –** All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Gross Vehicle Weight (GVW)

GVW is a unique characteristic of a vehicle that is the sum of the empty vehicle weight and its payload. GVW classification ratings are primarily used for air quality modeling purposes. GVW ratings of vehicles cannot be observed or measured but can only be determined while administering intercept surveys. Hence, it is hard to associate a vehicle of certain GVW to a particular FHWA vehicle configuration as it only gives an indication about probable body type or even vehicle configuration. EPA provides guidance on the mapping of FHWA vehicle classes to MOBILE 6 vehicle classes for air quality modeling.[5] The VIUS database also provides a correlation between number of axles and GVW, and the GVW classes included in VIUS are: less than 6,000 pounds; 6,001 to 10,000 pounds; 10,001 to 14,000 pounds; 14,001 to 33,000 pounds; and greater than 33,001 pounds.

---

[5] http://www.epa.gov/ttn/chief/eiip/techreport/volume04/ (see PDF of Chapter 2).

- **Vehicle Configuration –** This is primarily based on the physical appearance of a vehicle. The classification scheme adopted by FHWA separates vehicles into 13 categories depending on whether the vehicle carries passengers or commodities. Nonpassenger vehicles are further subdivided by number of axles and number of units both power and trailer units. The VIUS database also has information on vehicle configuration but it classifies vehicles into four more general categories than the FHWA 13 vehicle classes. It also provides information on the axle arrangement, i.e., truck type and number of axles on a particular truck and/or combination. This variable in VIUS has more detail to the tune of 72 vehicle classes. So the correlation between FHWA and VIUS classifications is not very strong in terms of a perfect match.

- **Length of Vehicle –** The length of a vehicle also is an important variable of interest if it can be measured accurately. The counters recommended by the traffic monitoring guide use two inductance loops to estimate length of vehicles crossing the loops. These dual loop sensors are generally capable only to classify vehicles into fewer categories than the FHWA 13 vehicle classes. The VIUS database reports the overall length of the vehicle or vehicle and trailer as it was most often operated.

- **Body Type –** This type of classification is based on the appearance of the body of the vehicle and the type of commodity it carries most often. The Department of Motor Vehicles (DMV) data classifies vehicles based on body type. The California DMV data from the California Energy Commission that was used for the Southern California Council of Governments (SCAG) Heavy Duty Truck (HDT) Model Update classifies vehicles into about 55 categories and has a correlation with the GVW ratings. The VIUS adopts a different body type classification (32 classes) that is quite different from the DMV database. This type of information can be gathered only by visual or manual observations. Also, the plethora of body types makes it hard to correlate it to any other classification system.

The definition and classification of trucks into appropriate categories are very important so that accurate and reliable data is modeled to produce good forecasts. Hence, a proper classification system that is consistent across all the data sources should be developed. It is not just enough if a proper classification system is identified when developing a truck model, but also should ensure that observed data within the same classification system can be collected to validate the truck model against.

The SCAG HDT model represents heavy-duty trucks only, that is, trucks that are over 8,500 pounds. The primary use of this model is for air quality purposes and so it uses the weight-based classification system. These are:

- Light-heavy (8,500 to 14,000 pounds);
- Medium-heavy (14,000 to 33,000 pounds); and
- Heavy-heavy (greater than 33,000 pounds).

The PSRC truck model also classifies trucks based on weight but these categories also are loosely correlated to other defining characteristics of trucks for other purposes. These are:

- **Light Trucks –** Four or more tires, two axles, and less than 16,000 pounds (this also includes nonpersonal use of cars and vans);

- **Medium Trucks –** Single unit, six or more tires, two to four axles and 16,000 to 52,000 pounds; and

- **Heavy Trucks –** Double or triple unit, combinations, five or more axles, and greater than 52,000 pounds.

The San Joaquin Valley truck model in central California is designed to generate truck volumes based on truck classes that the California Air Resources Board defines as medium-heavy and heavy-heavy duty for regulatory purposes (more than 14,000 pounds gross vehicle weight rating). These are:

- **Medium-Heavy Duty Trucks –** GVW rating between 14,001 and 33,000 pounds; and
- **Heavy-Heavy Duty Trucks –** GVW rating of 33,001 pounds and more.

The current Maricopa Association of Governments (MAG) truck model is based on GVW as well that includes three classes – light (less than 8,000 pounds), medium (8,000 to 28,000 pounds), and heavy (greater than 28,000 pounds). As the vehicle classification counts are based on FHWA classes, and due to the difficulty in correlating the GVW classes to FHWA classes, the new MAG truck model will include three groups of trucks. These are based on the FHWA classification system, as shown below:

- Class 3 – 2-axle, 4-tire commercial vehicles ("Light");
- Classes 5-7 – 3+ axle, 6+ tire, single unit commercial vehicles ("Medium"); and
- Classes 8-13 – 3+ axle, 6+ tire, combination unit commercial vehicles ("Heavy").

4.2.2 Trucks that Do Not Carry Freight

There is a unique segment of truck population that does not carry freight, which also is known as the service sector. This includes trucks that are used in the utility sector and other services related to commercial and residential land uses (i.e., business and personal services). Data on this type of trucking activity is difficult to collect through conventional survey methods because of overlapping nature of these types of truck trips with other industry types. As part of the FHWA commercial vehicle study, a method was developed based on various data sources that are commonly available to an agency. This methodology is provided in this section.

Model Methodology

If a separate model is to be created for trucks that do not carry freight, then it may be necessary to conduct a survey of the activity of these types of trucks. Without such a survey, it may be extremely difficult to update or calibrate this part of the truck model. There was data collected as part of the FHWA research on accounting for commercial vehicles in urban transportation models[6] that identified the magnitude and distribution of service vehicles in four categories: safety, utility, public service, and business and personal service vehicles. Data from the California DMV was used to identify fleet sizes for these vehicles. Average daily trip lengths were identified for these vehicles from the 2002 VIUS, which was summarized for metropolitan areas. VIUS also can be summarized by state or metropolitan areas within a state, but this may be too small a sample size. A similar approach currently is being proposed in the Phoenix MPO, the MAG, truck study where the size and weight of the vehicles in this category will be determined from the MAG region DMV registration data. In the event of lack of DMV data, truck population data by FHWA classes will be derived from the most recent county-by-county estimates of trucks from MAG's Air Quality Planning department.

The four types of service vehicles in an urban metropolitan area are:

1. Safety vehicles;

2. Utility vehicles;

3. Public service vehicles; and

4. Business and personal service vehicles.

Public service vehicles are publicly owned. Business and personal service vehicles are privately owned. Safety and utility vehicles may be either publicly or privately owned.

About 5.9 percent of the total vehicle miles traveled in the urban areas in the United States each year is attributable to vehicles in these four categories. Business and personal-service vehicles alone contribute 3.6 percent of the total VMT in urban areas across the nation, while public-service vehicles contribute 1.6 percent of the total VMT and safety and utility vehicles contribute 0.4 percent each.

Many older urban transportation models currently do not include specifically include commercial service vehicles, although some models have identified a commercial vehicle trip purpose that is based on a fixed factor of personal nonhome-based travel. Some truck models also include delivery and service vehicles that are four-tire commercial vehicles, based on the inclusion of these vehicles in the 1996 edition of the *Quick Response Freight Manual*.

[6] Cambridge Systematics, Inc., *Accounting for Commercial Vehicles in Urban Transportation Models*, prepared for Federal Highway Administration, February 2004.

Data Sources

One of the key sources of information essential for estimating a model for this sector is the truck populations for the four categories of service vehicles. DMV registration data and commercial vehicle surveys have been used to estimate truck populations for this sector. These are described below.

Cambridge Systematics, Inc. (CS) created a dataset combining data on safety, utility, public service, and business and personal service vehicles.

- Safety vehicles were derived from two sources: 1) California DMV data on police, fire and rescue vehicles, and tow trucks for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) the Detroit commercial vehicle survey, which includes snow plows and tow trucks.

- Utility vehicles were derived from two sources: 1) California DMV data on utility cars and trucks, water and irrigation trucks, and garbage trucks for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) three commercial vehicle surveys that included utility and maintenance vehicles for the Detroit, Atlanta, and the Triad cities regions.

- Public service vehicles were derived from a single source: California DMV data on city, county, state, Federal, other, and school and college cars for Los Angeles, San Francisco, San Diego, and Sacramento.

- Business and personal service vehicles were derived from two sources: 1) California DMV data on "other commercial cars," armored, panel and pickup trucks, vans and step vans for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) three commercial vehicle surveys that included vehicles used for office, professional, or personal services in the Detroit, Atlanta, and Denver areas.

Data for four cities – Los Angeles, San Francisco, San Diego, and Sacramento – were compiled and analyzed because these were the only four cities with a comprehensive assessment of all commercial service vehicles. Demographic data for each city, including total population and employment by type (government, utility, business and personal services, and total), were derived from the 2000 Census.

For the new MAG truck model update, a new approach on deriving this data is being proposed due to the lack of DMV data. The truck population data and the VMT distributions at the county level is being prepared before estimating parameters for this sector. CS obtained the truck population data at the county level for all the counties in the State of Arizona. These data are at the 13 FHWA classes and will be disaggregated to the 28 MOBILE6 vehicle categories to get a better sense of the body type of trucks. This disaggregation process will be based on the VMT mix data for the 28 vehicle classes that already are derived for air quality modeling purposes at MAG. For the FHWA research project, CS developed a method that correlates body type of trucks to the use of the truck or industry sector. This method will be used here to identify those vehicle classes out of the 28 that fall under the service industry sector.

Aggregate Demand Method

The Aggregate Demand Method estimates service vehicle fleet size based on two demographic factors: total employment (possibly stratified by type) and population. A summary of the travel behavior characteristics is provided in Table 4.3. This summary includes estimates of fleet size, number of trips, and VMT calculated from a statistical analysis of the available data combined with demographic data. The only comprehensive data source (including both public and private sector data) is the motor vehicle registration data, so only these data are used in estimating rates of travel by commercial service vehicles. The data shown in Table 4.3 do not show trips per vehicle, so the commercial vehicle surveys from other cities are used to provide data on this variable for private sector vehicles only. The percent of vehicle miles traveled will be derived from MAG's air quality modeling work.

Table 4.3 Travel Behavior Characteristics for All Commercial Service Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population, based on data from truck populations.	0.05 per population (data from four cities).
Trip/Tour Length	Average mileages are consistent across different cities and categories, ranging from 29 to 49 miles per day. National average miles traveled will be derived from VIUS data. Average mileage will be derived from other commercial vehicle surveys.	41 average miles traveled per day, average trip length is 14 miles (data from eight cities).
Trips	Trips per vehicle can be derived from a commercial vehicle and government vehicle survey.	Three daily trips per vehicle (data from four cities).
Vehicle Miles Traveled	Service vehicles typically range from 5 percent to 13 percent of total VMT (based on estimates from other cities derived from DMV and VIUS data).	5.9 percent of total VMT (data from four cities).

Network-Based Quick Response Method

Data on public and private service vehicles were available for only four cities: Los Angeles, San Francisco, San Diego, and Sacramento. No data was available for the number of vehicle trips or mileages for these four cities because the DMV data for those cities contains only fleet size. Data on vehicle trips and mileages are available from commercial vehicle surveys for private sector service vehicles for the cities of Atlanta, Denver, Detroit, and the Triad cities. Additional data are necessary to more accurately evaluate travel behavior for all service vehicles. Table 4.4 presents a summary of the travel behavior characteristics for the Network-Based Quick Response Method.

Table 4.4 Travel Behavior Characteristics for All Commercial Service Vehicles Using the Network-Based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with employment variables. Government, utilities, and business and personal services employment are the most likely variables. Trip rates will be based on the truck population data and the Bureau of the Census. Typically, there are 0.1 per total employment or 0.05 per population.
Distribution	All service vehicles are distributed widely throughout the region and could be distributed with a gravity model. National average miles traveled will be derived from VIUS data. Average trip lengths will derived from other commercial vehicle surveys.
Vehicle Type	Service vehicles are primarily light-duty vehicles, dominated by public service, business, and personal service types (all light-duty vehicles). Some safety and utility vehicles are medium- and heavy-duty trucks (fire trucks, ambulances, utility trucks, etc.). Of all the commercial service vehicles, 91 percent are light-duty vehicles and 9 percent are medium-/heavy-duty trucks (based on data from other cities).
Time of Day	The majority of private service vehicles operate between 9:00 a.m. and 3:00 p.m., based on private service vehicles from the commercial vehicle surveys. The majority of public service vehicles also operate in this period. Of all total trips, 11 percent occur in the a.m. peak, 23 percent in the p.m. peak, 53 percent in midday, and 14 percent at night (data from other cities).
Trip Assignment	Service vehicles operate on all facilities.

4.2.3 Integration of Trucks in Four-Step Passenger Models

The truck-trip generation process in a four-step travel model system is independent of the passenger modeling components. The socioeconomic and demographic (SED) data is often shared between these two models that serve as the basic input providing a host of independent variables to compute productions and attractions. After the truck Ps and As are computed, they are fed into the truck distribution process which requires skim data that may include either travel time or distance. These skim data are derived from the assignment process which is a common modeling component for the truck model as well as the passenger model. This is the first point of integration between the truck model and the four-step passenger model. More details about this process are described in the trip distribution section of this section.

After the trip distribution models, truck trip tables are produced that are ready to be assigned to the highway network along with other modes considered in the passenger model. Trucks are much larger in size than the passenger cars and the presence of these large and low-performance vehicles in the traffic assignment process results in a reduction of the roadway capacity. The *Highway Capacity Manual* (HCM) cites that the reduction in roadway capacity is due to the fact that heavy vehicles such as trucks take up more space and have lower performance, especially on grades and during congestion. So the traffic volumes containing a mix of vehicle types of different sizes must be converted into an equivalent flow of passenger cars often referred to as the passenger car equivalents (PCE).

Different models use different PCE factors for trucks that are appropriate to the local region. It also depends on the different sizes and speeds of trucks in the model; the ideal way to calculate PCE factors is by collecting observed data. This can be done by gathering information on the vehicular composition at certain key segments of a region's highway corridors that also includes speeds, travel times, grade, and congestion. As the data required for such an elaborate method is often scarce, most urban models assume these factors and calibrate them during the assignment process.

The PSRC truck model that includes three classes of trucks assumed light trucks to be equivalent to 1.5 passenger cars, medium trucks at 2.0, and heavy trucks at 2.5. After several rounds of calibration with more recent data, the PCE factors were updated and are now 1.0 for light, 1.5 for medium, and 2.0 for heavy trucks. Similarly, in the San Joaquin Valley truck model, there were no observed data available to support the development of PCE factors specific to the San Joaquin region. Therefore, the PCE factors used in the model based on guidelines provided by the Institute of Traffic Engineers were 2.0 for medium-heavy and 2.5 for heavy-heavy trucks.

The current SCAG HDT model includes a state-of-the-art PCE factor methodology that accounted for roadway grade, congestion levels, and percentage trucks in the traffic stream. The variable PCE factors have proven to be complex in their implementation and do not always represent the assignment process accurately. In the ongoing SCAG HDT model update, the variable PCE factor approach is being evaluated based on recent data to determine if it results in more accurate assignments. One area where the variable PCE factor does appear to provide improved assignments is the adjustment related to roadway grade. In the SCAG HDT model update, the locations where grade have been incorporated in the network are being reviewed for accuracy and additional locations with significant grade are being identified and incorporated in the highway network.

4.2.4 Data Requirement for Truck Models

In order to determine the data required to build a truck travel model, the first step is to assess the various truck parameters that need to be estimated. In statistical terms, these also are referred to as the dependent variables that depend on a host of explanatory or independent variables that often serve as the inputs to an urban truck model. The truck parameters of primary interest, but not limited to, are:

- Truck productions and attractions by land use or sector or trip purpose;
- Truck trips per day by truck type (GVW, FHWA class, etc.);
- Truck trip lengths by truck type;

- Truck trip time-of-day distributions; and
- Truck volumes.

The aforementioned parameters are dependent on various inputs or independent variables that include, but not limited to:

- **SED Data or Employment Data –** These data are essential to estimate truck production and attraction trip rates which are a function of observed truck trips coming into and going out of various land use types for which the SED or employment data are known beforehand. The observed truck trips are determined based on truck travel surveys. Different models use different types of employment data depending on the availability for the base and forecast years. Most of the current urban truck models use the two-digit SIC system of employment data. The level of aggregation or disaggregation of these into a finite number of categories depends on the variance of truck travel patterns associated with different land use types. The variance largely depends on the region's economic activity that includes production and consumption of commercial goods. More recently, the NAICS system of employment data is being developed to better correlate and associate various employment categories to different types of businesses prevalent in an urban area.

- **Level of Service Data –** These data include travel times and/or travel distances of vehicles in an urban area. This data is produced within a model system and is often known as the skim data. The skim data is an essential input to the gravity-based trip distribution models that estimates truck trip interchanges. The skim data is used as an independent variable to compute the travel impedances, which is then used to allocate the truck productions and attractions from the trip generation model to the appropriate origins and destinations in a region. This results in a truck trip table matrix, which is used in combination with truck travel distances to calculate the average truck trip lengths and frequency distributions.

- **Time-of-Day Factors –** The truck travel surveys or classification counts are normally used to determine the time-of-day factors, which are proportions of truck trips occurring during a finite set of time periods. These time periods are decided beforehand depending on the level of detail necessary for an agency's transportation planning purposes. The proportions or factors are applied to the daily trip tables coming out of the trip distribution model to produce trip tables by time period. These time period specific truck trip tables are then assigned to the traffic network along with the corresponding time period specific passenger trip tables.

- **Truck Classification Counts –** The most important data that cannot be transferred or borrowed are the classification counts. Every model update includes the collection of these data. These are used to calibrate and validate the traffic assignment process that includes both passenger cars and trucks. Some agencies have a continuous traffic count program on key facilities such as freeways and expressways that are used in regular time intervals to update regional travel models. The level of detail of truck counts by various truck types or classes largely depends upon the truck model structure. Most count programs collect axle-based truck classification counts as these are easily captured by manual and machine counters. Agencies that use truck models based on GVW ratings convert the axle-based truck counts to appropriate GVW classes based on internally developed algorithms. The count locations also are important in the validation process of a truck model. These are usually collected on all the major facilities such freeways, expressways, and arterials. These also are collected at various points on a screenline and many screenlines are defined upfront of the count program. In addition to counts, other observed data that is necessary are truck speeds or travel times on key routes.

- **Level of Geography –** Truck models are usually developed at the same level of geography as the passenger travel models. Almost all of the known urban area models use the TAZ-level geography. The primary reason for this being that all of the input data to a truck model is being developed at the TAZ level. There also are some aggregate levels of geography such as districts, super-districts, and counties that are often used to summarize truck model outputs during validation processes.

- **Roadway Networks –** This forms the backbone of any model development effort that represents any region's transportation infrastructure system. Truck models often use the highway networks that are developed for the passenger travel models and appropriate modifications are made based on the truck travel characteristics. These include coding truck only lanes, truck prohibition lanes, and/or truck priority lanes. The "truck" mode of travel, even though it is a vehicle class not a passenger mode, also is coded as a separate mode to distinguish from other passenger travel modes and to determine truck travel volumes.

4.2.5 Special Generators at Intermodal Terminals

An intermodal terminal can be defined as a location for the transfer of freight from one transport mode to another such as between water and road (ports), road and rail (rail yards), or air and road (airports). The coordination of resources to achieve intermodal efficiency is a challenging task that involves government, the private sector, and various interest groups.[7] Intermodal terminals, which include seaports, airports, and rail terminals, serve as principal interchange points for both international and domestic freight movements.

The data collection efforts at intermodal terminals are always a challenge owing to the enormous time and costs associated. In addition, these data are specific to each type of intermodal terminal and cannot be transferred or borrowed. Specific models also are built based on the capacity and volume of traffic being handled at these facilities. The Southern California Association of Governments (SCAG) HDT model and Los Angeles Metropolitan Transportation Authority (LAMTA) CubeCargo model are perhaps the only two models

[7] http://www.doi.vic.gov.au/DOI/Internet/Freight.nsf/AllDocs/.

that capture the truck traffic coming out of and going into each of these three intermodal facilities in the region at the TAZ level.

Port Model

The port model for the SCAG HDT model included trip generation and distribution components. The port trip generation model was developed based on a detailed port area zone system and specialized trip generation rates for automobiles and trucks by type (Bobtail, Chassis, and Containers). The model generates three outputs – container terminal truck trips, container terminal automobile trips, and noncontainer truck trips. These three types of trips are usually the same across every seaport in the country. The Port of Long Beach (POLB) has a custom-built spreadsheet tool called the QuickTrip model that includes detailed input variables such as mode split (rail versus truck moves), time-of-day factoring, weekend moves, empty return factors, and other characteristics that affect the numbers of trucks through the gates. These factors vary by terminal at the ports, so a separate QuickTrip model is used for each terminal.

For trip distribution of port trips, a detailed and comprehensive truck-driver survey was undertaken at port marine container terminals. The surveys were used to develop detailed origin/destination "trip tables" for use in the port area travel demand model. The stated trip origin and destination from every valid survey was correlated with the travel demand model traffic analysis zone (TAZ) system. The survey results were then used to develop port truck origin/destination matrices by truck type for use in the model. The port trip matrices included a unique trip interchange percentage between every port marine container terminal and each of the model's TAZs. This includes not only trips from marine terminals to land uses outside the ports, but also "interterminal" trips from one marine terminal to another marine terminal.

Rail Intermodal Facility

For LA MTA's CubeCargo model, an innovative approach was used that yielded reliable information on the six rail facilities at a fraction of the investment in time and cost. The approach for the rail intermodal facilities began with contacts with the rail companies (BNSF and UP) regarding the six facilities. These contacts served a couple of purposes, namely, identifying the largest customers for each facility, and obtaining lift, gate, and train data. Additional data also was gathered that included lifts by day, split out by containers (international and domestic) versus trailers, and gate transactions by day by type (inbound, outbound, loaded, empty, bobtail). These data yielded the flow through the facilities without becoming entangled in short-term changes to train schedules and other operating adjustments. The train schedules themselves were available on-line and were supplemented with railroad records of actual arrivals and departures since some trains are run as extra or second sections.

By contacting the six facilities, relevant facility data were obtained that included a few relevant features of the rail facilities such as total acres, number of parking spaces, number of gates, number of employees/contractors, etc. The major customer contacts yielded the location and nature of their facilities, the location of their major markets or customer concentrations, and their pattern of truck trips between their facilities/markets and the six rail intermodal terminals in both directions, including empties and trips to obtain empties for loading. This information was then used to characterize and construct trip matrices for the nonport portions of truck traffic to and from the six rail intermodal facilities.

Air Cargo Trips

In the SCAG HDT model, air-cargo truck trips come from the agency's Regional Airport Demand Allocation Model (RADAM) that was developed as a separate two-step process – airport trip generation and distribution. Three types of airport truck trips were accounted in this process. Heavy-duty trucks associated with airport operations such as maintenance, supplies, deliveries, and retail facility support comprised one category. Traffic between the five airports or with destination points outside of the airport area formed another element, while internal trips made by trucks within the airports formed the third component. The process of air-cargo trip generation involved the conversion of air cargo tonnage to truck trips, using the factors and relationships developed as part RADAM. The distribution was developed based on approximations of air cargo trip interchanges between airports and RADAM TAZs.

4.2.6 Constraints to Trip Generation

The general notion of building a trip table involves assuming that productions equal attractions. Depending on the availability of truck travel survey data, trip rates for a given sector or land use are either considered the same for production and attraction or they are estimated separately at each trip end. If the trip rates are assumed to be the same at both ends, then typically these are land use-based trip rates.

If data permits estimating two different rates for production and attraction, then these may be either employment- or land use-based trip rates. That is, the employment at that particular land use will drive the productions and/or attractions for any given sector. For example, "retail employment" in a TAZ can produce and attract trips that belong to the "mail/parcel" sector, if the supported by the data. If there are 200 "mail/parcel" expanded trips that are produced from a "retail" store, and if there are 300 "mail/parcel" expanded trips that are attracted to a "retail" store, then the production rate will be (200 trips/retail employee) and the attraction rate will be (300 trips/retail employee). These rates also can be estimated based on regression techniques where the dependent variables if the number of truck trips for a given sector and the independent variables are different types of employment. The coefficients associated with each employment variable are the trip rates. In other words, every sector (or trip purpose) will have a production rate and attraction rate for every type of land use (or employment) where trucks in that sector make stops at.

In the event of different productions and attractions, these will need to be balanced during trip distribution, so that the total number of trips originating from a given TAZ equal the number of trips destined to that particular TAZ.

4.2.7 Borrowed versus Survey-Based Truck Models

The borrowing of truck trip rates is a very common practice due to the lack of good survey data. This should, however, be done with caution. Almost one-half the urban truck models across the nation are based on the 1992 Phoenix metropolitan area truck model. The current QRFM recommends using the trip rates and gravity models from this model as a starting point, and then calibrating the parameters until they validate well with observed local count data. There are some limitations to this approach that needs to be understood well before borrowing truck parameters from other area models. The observed count data will serve well to validate the truck trip assignments but there will be no data for calibrating and validating trip generation and distribution models. That is, the precise estimates of total number of truck trips within each trip purpose or sector cannot be collected through a vehicle classification count program. Trip rates can be adjusted only after looking at the assignment results. Also, the average trip lengths and trip length frequency distributions can be calibrated only to approximate values and distributions borrowed from other area models.

The best way to estimate truck-model parameters is by collecting data through truck travel surveys. Different types of surveys such as trip dairy approach, establishment surveys, shipper/receiver surveys, and intercept surveys, provide different aspects of truck travel characteristics depending upon the type of business sector or trip purpose of trucks. The many benefits of using survey data are that:

- Truck trip rates by sector or trip purpose can be estimated precisely as it will be calibrated and representative of the local truck travel behavior;
- Observed data on average trip lengths and trip length frequency distributions can be used to calibrate/validate the trip distribution model;
- Precise time-of-day factors can be derived from the observed survey data; and
- Information on local issues also can be gathered from truck operators and drivers that could include commodity carried, qualitative data on what shippers and truckers see as their most difficult infrastructure problems (i.e., difficult intersections, bottlenecks, bridges, turning radii, road conditions, etc.), what most impacts their operation, etc.

The major limitation of truck travel surveys is the cost associated to conduct them especially since the response rates are well known to be very low. A considerable amount of resources and expertise is required to administer and conduct a successful truck travel survey.

4.2.8 Market Segmentation-Based Mode Split

The market segmentation-based method uses information from commodity flow data and base year mode split to forecast future mode split. It assumes that commodity and length of haul are good predictors of mode choice. The market segmentation method looks at the base year mode split by commodity and origin-destination pair and assumes that this reflects the relative service characteristics of available modes in these traffic lanes.

The basic assumption in this approach is that mode share for each commodity/O-D pair remains fixed in the future. But in the real world, the changes in the mix of commodities traded and the trading partners do affect overall mode share. So while using this approach, forecasters can do "what-if" scenarios by focusing on those markets (commodity/ O-D) where modes actually compete to see if changes in modal characteristics could actually have a significant change on an overall mode share. The main data component here is the commodity flow data. When used for modal diversion analysis, the focus is primarily on intermodal cargoes and this can be determined from commodity flow data.

The following is presented as an example that explains the market-segmentation method when applied to modal diversion analysis for a state or a group of states. Using GIS tools or a routing network, the first step might be to determine a 500-mile radius from the centroid of each zone within the study area, where a zone might be defined as a county. O-Ds farther than 500 miles from a zone usually represent O-D pairs where rail could compete with trucking. Now, using CFS or other national sources, those commodities need to be identified for lengths of haul greater than 500 miles where rail captures a known share of the market (e.g., 20 to 70 percent). The next step is to identify commodity/O-D pairs (at least one trip end in the study area) where rail is competitive but rail share is less than 50 percent. This will help in conducting what-if scenarios to see what impact would be if rail share could grow to 50 percent or 70 percent in all of the competitive markets. The changes or results of this modal diversion analysis can be seen in the total tonnage splits. It is always better to use national data to identify commodities for which truck and rail compete than to use study area commodity flow data. This is due to the fact that the lack of rail services may be limiting local markets and that is what requires change.

Pros

The advantages of the market-segmentation method are that:

- It is simplistic in approach and in application;
- The data is usually available for such an approach and is easy to process; and
- It is reliable enough for modal networks and characteristics that do not change over time.

Cons

The limitations of this approach include:

- Insensitiveness to policy impacts on mode choice;
- Insensitiveness to implications of network investment strategies on mode choice; and
- Assumption that modal characteristics remain constant over time when in reality there is a lot of variation.

4.2.9 Assignment Models

Traffic assignment is the last step in a travel-model system and there are a couple of broad ways to assign trucks to a roadway network. Truck assignments on highways could be either fixed or dynamic path assignment. In a fixed assignment, trucks are assigned to already existent fixed paths, whereas in a dynamic assignment, a computer program builds paths for the trucks. The key factors that go into the building of these paths, fixed or dynamic, are:

- Infrastructure limitations (low bridges, bridge weight limits, speed limits, etc.) affect route choice.
- Specific routings are usually selected as a function of cost, average travel time, the reliability of that travel time, and the general quality of service for the operators (safety, amenities, etc.). This happens after taking into account the limitations among available route choices.
- The route may need to use specialized equipment or facilities, such as refrigerated terminal, or the cargo may be restricted from certain routes, like hazardous material/cargo prohibitions in tunnels.
- The route may take competition among truck carriers or between modes into account (ship to certain intermediate destinations, less than truckload handling).
- The operational characteristics of the network may be important, such as special truck routes, climbing lanes, or truck exclusions. The conditions probably vary by time of day in urban areas, which may affect the routing.
- Highway routings or traffic assignment may be affected by all of the aforementioned factors, but only a few of them may be considered by the fixed path or dynamic models.

Fixed-Path Assignment

Fixed paths are provided by others, that is, paths already built are used. It may sometimes represent current routings of traffic or results of another dynamic assignment (e.g., ORNL routes for CFS flows). In fixed paths, if the network attributes change, either because of new facilities or congestion, there is no easy way to vary the paths. Also, the business decisions of carriers (which railroads work together) that are not easily modeled can be defined in these fixed paths.

The basic procedure in any assignment is to translate trip-table flows into link flows on a network and to use those link flows to determine system performance. The intermediate step used to make this translation is the information about the path or sequence of network facilities (links) used to travel from an origin to a destination. The basic feature of these paths in this assignment method is that they are fixed and would not vary, depending on network condition, congestion, new facilities, etc. These fixed paths can come from a variety of sources (TRANSEARCH, MapQuest, etc.). Invariably, these paths were created by the dynamic assignment methods that are described in the following section, but they have been saved by others as fixed paths for use in these assignments.

Once the paths are identified, it may be desirable to find the network flows a) for only selected origins or destinations (selected zone assignment); b) for only selected commodities (selected purpose assignment); or c) for only those flows that use certain facilities (selected link assignment).

For fixed-path assignment, the network needed does not have to be as rigorous as those used in sophisticated models, although for data management purposes alone, it is highly advisable. The paths are a file of the sequence of links used between each origin-destination pair. In order to produce system performance, the performance attributes for each link are required. These include information about the network and information about particular links in terms of travel times, costs, and distances among other parameters.

Fixed-path assignment methods are typically used to analyze long-haul traffic patterns at state or multistate level. Since the trips are over very long distances, the routing decisions are less responsive to local changes in network conditions and may remain fixed over long periods of time. These methods often develop deficiencies as traffic grows over time. However, they cannot be used to examine alternatives as the assignments are not responsive to network changes. Since routing models for nonhighway modes are generally proprietary or carrier-specific (and routing choices are more limited than for trucking), fixed path assignments can be very well used in these applications.

Dynamic Path Assignment

In dynamic assignment, paths are calculated by a computer program and may be used and discarded without the planner ever seeing them. Since the dynamic paths are computed as they are used, it is possible for the assignment to account for changes in the network. Dynamic assignment is the most commonly used process in urban automobile and transit passenger modeling. The outcomes from a dynamic assignment are similar to those of the fixed path assignment, such as link flow and network performance; however, dynamic path assignment can take congestion into consideration.

These paths also are a file of the sequence of links used between each origin-destination pair, but these files are temporary and created by the computer program. In order to calculate system performance, the impedance attributes are used to calculate the performance of each link. These include information about the network and information about particular links in terms of travel times, costs, and distances among other parameters.

Dynamic assignments can be used for any level of geography for which flows and networks are available and is the approach often used for modeling truck traffic at the metropolitan level. It is a more accurate way to estimate the impact of congestion on freight system performance, as the model can calculate new routes as congestion increases. It also is the best approach for alternatives analysis because the network can be modified to reflect alternative investment projects.

As explained for fixed-path assignments, the basic procedure in any assignment is to translate trip table flows into link flows on a network and to use those link flows to determine system performance. The intermediate step used to make this translation is the information about the path or sequence of network facilities (links) used to travel from an origin to a destination. In a dynamic path assignment, this path file is temporarily created within the assignment program. Just like in a fixed path assignment, the paths calculated in a dynamic process can be applied to perform selected zone assignment, selected purpose assignment, or selected link assignment.

For dynamic-path assignment, the network needs to follow the rules of the assignment program. In order to produce system performance, the performance attributes for each link are required and coded on to the highway network. These include information about the network and information about particular links in terms of travel times, costs, and distances among other parameters.

It is possible to calculate a wide variety of performance measures for dynamic-path assignments. It also is possible to do assignments for selected groups of commodities or other parameters analogous to trip purposes in passenger travel demand models. It is relatively complex to implement since special networks and software are required. Since it is so complex, the results of changes to the network may be counterintuitive or at least not obvious beforehand. However, it is very easy to modify the paths to account for new facilities or network conditions.

Type of Dynamic Assignments

There are a variety of methods to dynamically calculate paths which are described below.

- **All-or-Nothing or Preload Assignment –** In the All-or-Nothing procedure, also referred to as preload, freight traffic is assigned to network without recalculating times or costs taking capacity constraints into consideration. It is appropriate for long-distance traffic flows where there may only be one desirable path anyway. Since a straight All-or-Nothing assignment typically loads too many trips onto the major facilities, a procedure to adjust the impedances for nonmajor segments is often applied.

- **Multiclass or Simultaneous Assignment –** Truck trips are usually assigned together with the passenger vehicle model, because congestion has a significant impact on travel times experienced by trucks. If either nonfreight trucks or other vehicle trip tables are not available for congestion calculations, then they are preloaded onto the network using an All-or-Nothing procedure. Some agencies believe that trucks should be preloaded in all cases, because they do not believe that trucks, particularly larger less maneuverable trucks that may be operated by drivers not familiar with alternative routes, are as likely as automobiles to change their paths in response to congestion. Truck volumes are converted to Passenger Car Equivalents (PCE) to account for the fact that larger trucks take up more capacity and congestion for assignment of both trucks and passenger cars. This is explained in detail under Section 4.1.3.

- **Stochastic Assignment –** In a stochastic or random assignment, all reasonable paths are used and are typically used in urban areas. It takes multiple paths in a network into consideration, and the user has control over how big a difference from the shortest path is reasonable. In any event, equal time/cost paths between the same O-D pair will receive an equal share of the O-D flows.

- **User-Equilibrium Assignment –** In equilibrium assignments, the travel times are recalculated based on delays associated with a loading and paths are recomputed and combined, such that all used paths have same travel time. This method is generally used in urban areas where there is a lot of congestion, and it takes network's current capacity into consideration. Under equilibrium conditions, traffic arranges itself on congested networks in such a way that no individual trip maker can reduce his cost by switching routes. The equilibrium method attempts to find a solution where all used paths have the same travel time by iterating between All-or-Nothing traffic loadings and recalculating link impedances, such as travel time, based on the link volumes and capacity after each iteration. In fact, equilibrium is capacity restrained, since link times are recalculated based on capacity after each iteration. Capacity restrained assignment typically refers to those assignments where the user, not the computer, chooses how to proportion the flows from each iteration. For example, under equilibrium assignment, the computer calculates and may decide that equal times are achieved if 33 percent of the first assignment flows and 67 percent of the second assignment are used. Under capacity restrained assignment, the user may decide beforehand that 50 percent of each assignment is to be used.

■ 4.3 State Freight Forecasting

4.3.1 Type of Model, Zone Structure, and Networks

Freight models in states that are geographically small and densely populated with adjoining urban areas, such as Connecticut and New Jersey, tend to take the form of urban truck models discussed in Section 4.1 above and will not be discussed further here. Freight models in larger states, particularly those with larger rural areas and/or large percentages of pass-through traffic, such as Indiana, Florida, and Wisconsin, forecast freight in "four-step" commodity models, are a principal focus of this section. Still other states, such as Virginia, Tennessee, and Georgia, follow the general form of commodity model, but use acquired commodity freight tables in lieu of forecasting those tables in the trip generation and trip distribution, and will be discussed in Section 5.0.

State "four-step" commodity models are truly multimodal. The modes considered in these models typically include truck, rail, water, and air, even though the assignment step may only address trucks, and sometimes rail. As multimodal commodity models, the flow unit is common to all modes, and is typically tons. These models tend to be calibrated from annual commodity flow tables and the forecasts in the first forecasting steps will be annual tons.

Freight forecasting models, as all models, should have boundaries such that they internalize most of the trips that will be subject to forecasting. In the case of passenger modeling, these boundaries can be set at the jurisdictional boundaries of the state. Internal freight traffic within a state is typically no more than 25 percent of the flow total and the flow to, from, and through the state due to national traffic comprise the majority of the freight flows. In order to properly forecast this traffic, the geographical area covered by state freight models typically is most of the continental United States, if not all of North America. The inclusion of modes that primarily travel distances of over 500 miles, such as rail, water, and air also suggests that the freight modal boundary should be much greater than just the state boundary. States that have developed "four-step" commodity freight models typically already have developed detailed travel-demand model zones and networks within the state boundary. These models and zone systems have been extended by inclusion of national highway and rail networks.

4.3.2 Integration with Four-Step Passenger Models

There is value in being able to forecast freight flows, even when those forecasts are not integrated with passenger forecasting models. However, those states that have developed "four-step" commodity freight forecasting models have almost always had an existing passenger model. That passenger model has a zone structure and at least a highway network that can be used in developing commodity freight models. There is an additional reason for integrating freight and passenger model. At least for certain modes, always for trucks and passenger automobiles, and less often for freight and passenger rail, the modal networks are shared by passenger and freight vehicles and theses vehicles will interact in causing and being impacted congestion. There are several issues that must be addressed in integrating the passenger and freight models. The time period for passenger models is typically daily, while the time period for state freight models is typically annual. Before combining the forecasts, the freight flows are typically converted to daily flow units. The passenger and freight models can be kept separate through the trip generation, trip distribution, and mode split steps. However, the socioeconomic and transportation data used by these respective models should be the same. The tables of travel times covering the same areas should be the same for both models. The employment for the freight model may include more detailed industrial classifications, but the employment data and forecasts should be consistent with the employment and zone totals that are used in the passenger model. The freight and passenger models need to be combined in the modal-assignment step and that is when the vehicles will be combined. Therefore, the issues that will be discussed in later sections include converting the commodity freight flow units to vehicles and, for highway assignments, dealing with the issues of combining trucks and automobiles through the use of PCEs, and in what order the trucks and automobiles should be assigned and interact.

4.3.3 Data Requirement for State Freight Models

For statewide freight models, data are needed to develop and specify the equation used in the various steps, and forecast adapt is needed in the same format to create freight flow forecasts. In a passenger forecast, the equations and relationships are developed from a household survey of travelers. In freight models, a commodity flow survey, typically either the publicly available Census Bureau's CFS or the private commercially available TRANSEARCH data available from Global Insight. These tables tend to have limitations that must be overcome in using them to survey as freight surveys for model development. The CFS is publicly available only for 114 zones nationally, while TRANSEARCH is available for county zones, but the number of zones increases the purchase price. The challenge in the use of both models, either through additional processing of the CFS, or eventually through the FAF2 database derived in part from the CFS or through purchase of TRANSEARCH, is to develop zone structures that are detailed within the model study area, the state, and increasing less detailed at distances from the state model area. The state counties in TRANSEARCH led their zone structure to be used at the aggregate level to develop district relationships between freight flow and an economic variable, usually employment, which can then be applied to smaller units of geography. The commodity table typically has what is referred to as two-digit level of detail. Employment data are needed at an industry detail matching this freight commodity structure. Even the 40-50 commodities available provide data management and computational challenges and commodities carried forward are typically those that are the largest and most important to the study area. The associated employment must be available for those important commodities but may be aggregated to less detail matching the aggregated commodities. For example, printing may be included with all nondurable manufactured goods while food products would be retained as a separate category.

These commodity-flow surveys also provide information needed to calibrate the trip distribution and mode split steps. Commodity flows will typically need to be converted into units of daily vehicles because this more easily integrates with passenger forecasts and other transportation design and operations tasks are typically based on daily flows. Data are needed to develop factors that can be used to convert from annual tons to daily trucks. The model needs to be validated to observed counts. This validation data, on highways, is observational, such as truck classification counts and typically will have no information on the commodities being carried. Since observational counts also include no information on truck purpose, those counts probably include trucks carrying local delivery of local freight or trucks used in construction, service, and utility trucks, none of which are included in the freight commodity model. Conversion from annual flows to daily modal vehicle flows is needed only for those modes that will be used in assignment.

In addition to calibration data, there is a need for forecast variables. The creation of a model that forecasts freight flows based on detailed industry employment for the zones in the model provides no value unless the detailed employment forecast can be obtained or created for the same industry and geographic detail in that same detail on coverage similar to zone structure.

4.3.4 Trip Generation

Trip-generation equations allow the development of forecasts for the flow of freight entering or leaving a zone based on economic conditions in that zone, most often employment. Since the amount of freight consumed or produced by employees will be different commodities and both in the amounts and the types of industries involved, these state models develop different equations for different commodities. The number and types of commodities to be included depends largely on the computational resources available and the economy of the state. These equations are developed through regression of the observed commodity survey data to employment by industry. Examples are provided in this section for the trip-generation equations developed for the Indiana, Florida, and Wisconsin "four-step" commodity freight models. Indiana developed trip generation equations using the 1997 CFS as the sample survey and employment by NAICS industry as the independent variable in the regression as shown in Table 4.5. Indiana developed equations for each of the two-digit Standard Classification of Transported Goods (SCTG) commodity categories used in the CFS. The production equations are shown in Table 4.6. In almost all instances in these equations, the employment variable in the production equation is related to the related industry producing the commodity. The equations produce annual thousands of tons of freight shipment by all modes. For example, according to the regression developed from the Indiana CFS data as shown in Table 4.6, each employee in the Chemical Industry (NAICS 324) produces 3,151 tons of Chemicals (SCTG 20) for shipment each year, with a "goodness of fit" (R-squared) of 78.2 percent.

The attraction equations are related to the industries that consume commodities. Although it is possible to test all possible employment by industry to determine the statistically most significant industries, that effort may be considerable. To assist in the development of these equations, candidate industries, as well as population for consumer goods that will be tested in the regression, are identified by examining national input-output models. Indiana developed equations for each of the SCTG two-digit commodity categories. The attraction equations are shown in Table 4.7. For example, according to the regression developed from the Indiana CFS data shown in Table 4.7, each employee in the Food Manufacturing Industry (NAICS 311) consumes 315 tons of Base Metal (SCTG 32) for shipment each year and each employee in the Transportation Equipment Industry (NAICS 336) consumes 79 tons, with a "goodness of fit" (R-squared) of 91.1 percent. It must be noted that it is not the point of this manual to justify these equations or relationships, nor to suggest that they are transferable to other regions, only to suggest that these are the findings for this freight model. It may be that these relationships indicate commodities being consumed that are locally prominent but not obvious unless more detailed information on commodity shipments, (i.e., shipment information for more digits in the hierarchical commodity classification system) is available. It also may be that the correlation is merely a spurious statistical aberration or a correlation with another more meaningful variable. Those developing the models should be aware of these concerns before choosing the variables to be used.

Table 4.5 Indiana Freight Model Variables Used in Trip Generation

NAICS Employment	Description
212	Minerals and Ores
311	Food Manufacturing
312	Beverages and Tobacco
313	Textiles and Fabrics
314	Textile Mill Products
315	Apparel and Accessories
321	Wood Products
322	Paper
324	Printing
325	Chemicals
326	Plastics and Rubber Products
327	Nonmetallic Mineral Products
331	Primary Metal Products
332	Fabricated Metal Products
333	Machinery, Except Electrical
334	Computer and Electronic Parts
335	Electrical Equipment
336	Transportation Equipment
337	Furniture and Fixtures
421	Wholesale Trade, Durable Goods
422	Wholesale Trade, Nondurable Goods
POP	Population

Table 4.6 Indiana Freight Model Production Equations
Thousands of Annual Tons

SCTG	Name	Coefficient Times (NAICS3 Employment)[a]	Degrees of Freedom	R-Squared
1	Live Animals and Fish	0.003*(331)+.007*(337)	22	0.498
2	Cereal Grains	0.256*(311)	36	0.337
3	Other Agricultural Products	0.135*(311)	34	0.647
4	Animal Feed	0.149*(311)	41	0.772
5	Meat, Fish, Seafood	0.054*(311)	42	0.880
6	Milled Grain Products	0.045*(311)+0.027*(333)	43	0.853
7	Fats and Oils	0.000748*(Pop)+0.141*(335)+0-083*(311)	46	0.964
8	Alcoholic Beverages	0.0002188*(Pop)+0.013*(334)	46	0.882
9	Tobacco Products	0.009*(313)+0.005*(337)	19	0.690
10	Building Stone	0.016*(422)+0.0001118*(Pop)+0.005*(331)	22	0.919
11	Natural Sands	0.087*(421)	28	0.839
12	Gravel and Crushed Stone	0.835*(326)+1.145*(314)+0.443*(311)	40	0.940
13	Nonmetallic Minerals	0.226*(325)	29	0.507
14	Metallic Ores	N/A		
15	Coal	7.34*(212)	30	0.604
17	Gasoline and Fuel	7.812*(324)	44	0.873
18	Fuel Oils	4.017*(324)	45	0.939
19	Products of Petroleum	3.388*(324)+0.142*(325)	41	0.918
20	Basic Chemicals	3.151*(324)	43	0.782
21	Pharmaceutical Products	0.011*(337)+0.007*(313)	35	0.793
22	Fertilizers	0.00081*(Pop)	35	0.304
23	Chemical Products	0.025*(332)+0.017*(325)	44	0.790
24	Plastics and Rubber	0.912*(324)	46	0.709
25	Logs and Rough Wood	0.667*(321)	21	0.518
26	Wood Products	0.544*(321)	44	0.826
27	Pulp Paper	0.225*(322)+0.058*(324)	44	0.810
28	Paper Products	0.029*(311)+0.015*(334)+0.053*(314)	45	0.931
29	Printed Products	0.024*(422)+0.040*(322)	43	0.946
30	Textiles and Leather	0.101*(314)+0.051*(313)+0.058*(324)	44	0.970
31	Nonmetallic Minerals	0.002*(Pop)+0.248*(311)	45	0.909
32	Base Metal	0.356*(331)+0.080*(336)	45	0.911
33	Fabricated Base Metal	0.030*(332)+0.266*(324)+0.033*(327)	45	0.949
34	Machinery	0.019*(333)+0.026*(326)	47	0.897
35	Electrical Equipment	0.017*(332)+0.074*(324)	46	0.913
36	Vehicles	0.061*(336)	44	0.798
37	Transportation Equipment	0.008*(331)	33	0.620
38	Precision Instruments	0.001*(421)	39	0.826
39	Furniture	0.020*(337)+0.004*(336)	45	0.918
40	Miscellaneous Manufacture	0.000183*(Pop)+0.066*(314)+0.022*(311)	39	0.946
41	Waste and Scrap	0.099*(332)	37	0.931
43	Mixed Freight	0.0004*(Pop)	38	0.905

[a] See Table 4.2.

Table 4.7 Indiana Freight Model Attraction Equations
Thousands of Annual Tons

SCTG	Name	Coefficient Times (NAICS3 Employment)[a]	Degrees of Freedom	R-Squared
1	Live Animals and Fish	0.004*(311)	18	0.488
2	Cereal Grains	2.724 *(324)	37	0.399
3	Other Agricultural Products	1.196*(324)	45	0.504
4	Animal Feed	0.148*(311)	45	0.839
5	Meat, Fish, Seafood	0.030 *(311)+0.00015 *(Pop)+0.0004 *(336)	48	0.971
6	Milled Grain Products	0.00018 *(Pop)+0.025 *(311)+0.022 *(325)	47	0.980
7	Fats and Oils	0.000903 *(Pop)+0.068 *(311)+0.104 *(322)	48	0.986
8	Alcoholic Beverages	0.000250*(Pop)+0.008*(334)+0.023*(315)+0.078*(312)	47	0.984
9	Tobacco Products	0.008*(313)+0.004*(337)	44	0.732
10	Building Stone	0.015*(325)	22	0.688
11	Natural Sands	0.00121*(Pop)	30	0.899
12	Gravel and Crushed Stone	0.395*(311)+1.237*(314)+0.903*(331)+2.003*(312)	41	0.966
13	Nonmetallic Minerals	0.338*(322)	37	0.628
14	Metallic Ores	0.172*(331)	29	0.651
15	Coal	3.472*(212)+0.727*(311)	42	0.847
17	Gasoline and Fuel	4.60*(3,241+0.00169*(Pop)	44	0.912
18	Fuel Oils	3.237*(324)+0.110*(325)	47	0.943
19	Products of Petroleum	2.936*(324)+0.199*(325)	44	0.899
20	Basic Chemicals	3.218*(324)+0.050*(334)	46	0.865
21	Pharmaceutical Products	0.006*(325)+0.002*(422)	48	0.866
22	Fertilizers	0.000653*(Pop)	40	0.372
23	Chemical Products	0.000104*(Pop)+0.208*(324)+0.061*(314)+0.026*(326)	47	0.965
24	Plastics and Rubber	0.041*(325)+0.295*(324)+0.027*(333)+0.062*(314)	45	0.931
25	Logs and Rough Wood	0.683*(321)	33	0.555
26	Wood Products	0.494*(321)+0.391*(324)	47	0.908
27	Pulp Paper	0.043*(311)+0.123*(322)+0.122*(324)	47	0.970
28	Paper Products	.00007030*(Pop)+0.017*(334)+0.021*(311)	48	0.951
29	Printed Products	0.000295*(Pop)	45	0.964
30	Textiles and Leather	0.000041*(Pop)+0.079*(314)+0.032*(313)+0.058*(324)	47	0.983
31	Nonmetallic Minerals	0.00177*(Pop)+0.227*(311)	47	0.918
32	Base Metal	0.315*(311)+0.079*(336)	47	0.911
33	Fabricated Base Metal	0.428*(324)+0.035*(333)	46	0.927
34	Machinery	0.015*(333)+0.009*(336)+0.013*(325)	47	0.939
35	Electrical Equipment	0.000076*(Pop)+0.076*(324)+0.011*(326)	48	0.957
36	Vehicles	0.053*(336)	48	0.860
37	Transportation Equipment	0.035*(324)	39	0.723
38	Precision Instruments	0.000415*(421)+0.001848*(314)+0.000442*(422)	48	0.959
39	Furniture	0.000068*(Pop)	48	0.899
40	Miscellaneous Manufacture	0.000235*(Pop)+0.031*(321)+0.014*(313)	44	0.946
41	Waste and Scrap	0.051*(332)+0.066*(331)+0.037*(311)	40	0.941
43	Mixed Freight	0.000356*(Pop)+0.036*(314)	46	0.924

[a] See Table 4.2.

Florida developed trip-generation equations using the 1998 TRANSEARCH data for Florida as the sample survey and employment by SIC industry for counties as the independent variable in the regression. Florida developed equations not for all commodities in the TRANSEARCH database, but only for those commodities it determined to be the most important commodities in Florida as shown in Table 4.8. The production equations are shown in Table 4.9. In almost all instances, the employment variable in the production equation is related to the industry producing the commodity. The equations produce annual tons of freight flows, by all modes. For example, according to the regression developed on the Florida TRANSEARCH data shown in Table 4.9, each employee in the Chemical Industry (SIC 28) produces 678 tons of Chemicals (STCC 20) for shipment each year, with a "goodness of fit" (R-squared) of 60.9 percent.

The attraction equations are functions of the industries that consume commodities. Florida developed equations for each of the 14 commodity categories shown in Table 4.8, identifying candidate industries to be tested by examining an input-output model. The attraction equations are shown in Table 4.10. For example, according to the regression developed from the Florida TRANSEARCH data, each employee in the Nondurable Warehousing Industry (SIC 51) consumes (receives) 109 tons of Food Products (STCC 20) each year, with a "goodness of fit" (R-squared) of 89.1 percent. It must be noted that it is not the point of this manual to justify these equations or relationships, nor to suggest that they are transferable to other regions, only to suggest that these are the findings for this freight model.

Table 4.8 Florida Freight Model Commodity Groups

Commodity Group Code	Commodity Group Name	STCC Codes in Commodity Group	Actual Production Tonnage	Actual Attraction Tonnage
1	Agricultural Products	1, 7, 8, 9	5,502,692	3,368,257
2	Minerals	10, 13, 14, 19	50,450,949	49,485,912
3	Coal	11	3,113,832	26,316,127
4	Food	20	21,528,927	23,389,919
5	Nondurable Manufacturing	21, 22, 23, 25, 27	3,778,169	4,456,032
6	Lumber	24	9,906,141	13,916,051
7	Chemicals	28	5,482,657	5,090,377
8	Paper	26	27,683,647	32,411,062
9	Petroleum Products	29	5,438,235	41,896,320
10	Other Durable Manufacturing	30, 31, 33-39	6,969,684	13,199,839
11	Clay, Concrete, Glass, and Stone	32	53,193,380	56,777,305
12	Waste	40	5,537,231	4,663,125
13	Miscellaneous Freight	41-47, 5,020, 5,030	3,462,632	5,991,052
14	Warehousing	5,010	69,759,287	70,051,969

Table 4.9 Florida Freight Model Production Equations

Commodity Groups				
Code	Name	Coefficient	Variable	R-Squared
1	Agricultural	45.957	SIC07	0.409
2	Nonmetallic Minerals	6,977.771	SUM(SIC10-14)	0.738
3	Coal	0.000	No Production in Florida	
4	Food	245.464	SIC20	0.743
5	Nondurable Manufacturing	18.024	SUM(SIC21, 22, 23, 25, 27)	0.963
6	Lumber	241.464	SIC24	0.535
7	Chemicals	678.583	SIC28	0.609
8	Paper	190.814	SIC26	0.643
9	Petroleum Products	795.117	SIC29	0.573
10	Other Durable Manufacturing	23.578	SUM(SIC30, 31, 33-39)	0.696
11	Clay, Concrete, Glass	1,498.501	SIC32	0.704
12	Waste	0.500	TOTEMP	0.393
13	Miscellaneous Freight	0.599	SUM(SIC42, 44, 45)	0.436
14	Warehousing	157.426	SUM(SIC50, 51)	0.766

Table 4.10 Attraction Equations

Commodity Groups						
Code	Name	Coefficient 1	Variable 1	Coefficient 2	Variable 2	R-Squared
1	Agricultural	23.537	SIC20			0.479
2	Nonmetallic Minerals	1,461.302	SIC28			0.556
3	Coal	178.639	SIC49			0.008
4	Food	109.51	SIC51			0.891
5	Nondurable Manufacturing	24.698	SIC51			0.873
6	Lumber	147.624	SIC25	0.448	Pop	0.877
7	Chemicals	83.247	SIC51			0.891
8	Paper	23.924	SIC51			0.852
9	Petroleum Products	0.228	Pop			0.864
10	Other Durable Manufacturing	46.762	SIC 50			0.837
11	Clay, Concrete, Glass	2.964	Pop			0.930
12	Waste	68.089	SIC33			0.263
13	Miscellaneous Freight	0.962	SUM(SIC42, 44, 45)			0.072
14	Warehousing	2.926	Pop			0.572

Wisconsin developed trip-generation equations using the 2001 TRANSEARCH data as the sample survey and county employment by SIC industry as the independent variable in the regression. Wisconsin developed equations for the commodities determined to be the most important for Wisconsin. The production equations are shown in Table 4.11. In almost all instances, the employment variable in the production equation is related to the same industry producing the commodity. The equations produce annual tons of freight flows by all modes. For example, according to the regression developed on the Wisconsin TRANSEARCH data, each employee in the Chemical Industry (SIC 28) produces 476 tons of Chemicals (STCC 20) for shipment each year, with a "goodness of fit" (R-squared) of 81 percent.

The attraction equations are related to the industries that consume commodities. The candidate industries tested in the regression were identified through examination of an input-output model. Indiana developed equations for each of the 24 commodity categories shown in Table 4.11. For example, according to the regression developed on the Wisconsin TRANSEARCH data, each person (Population) consumes two-tons of Food Products (STCC 20) shipments each year, with a "goodness of fit" (R-squared) of 71 percent. It must be noted that it is not the point of this manual to justify these equations or relationships, nor to suggest that they are transferable to other regions, only to suggest that these are the findings for this freight model.

Table 4.11 Wisconsin Freight Model Trip Production and Attraction Regression Models

	Trip Production			Trip Attraction		
Commodity	**Production Coefficient**	**Production Variables**	**R-Squared**	**Attraction Coefficient**	**Attraction Variables**	**R-Squared**
Farm and Fish	767.90	SIC01, SIC02, SIC07, SIC09	0.20	31.07	SIC20, SIC54	0.27
Forest Products	–	–	–	–	–	–
Metallic Ores	–	–	–	–	–	–
Coal	–	–	–	–	–	–
Nonmetallic Minerals, Except Fuels	701.05	SIC14, SIC15, SIC16, SIC17	0.63	898.32	SIC14, SIC15, SIC16, SIC17	0.95
Food or Kindred Products	325.17	SIC20	0.85	2.13	Population	0.71
Lumber or Wood Products	422.85	SIC24	0.49	168.54	SIC24, SIC25, SIC50	0.60
Pulp, Paper, or Allied Products	197.10	SIC26	0.91	97.42	SIC26, SIC27	0.79
Chemicals	476.18	SIC28	0.81	5.80	Total Employment	0.81
Petroleum or Coal Products	–	–	–	2.52	Population	0.87
Clay, Concrete, Glass, and Stone	2,023.11	SIC32	0.61	6.26	Population	0.84
Primary Metal Products	200.38	SIC33	0.85	36.73	SIC33, SIC34	0.23
Fabricated Metal Products	83.102	SIC34	0.88	0.55	Population	0.90
Transportation Equipment	63.29	SIC37	0.36	10.34	SIC42	0.42
Waste or Scrap Materials	0.46	Population	0.78	–	–	–

Table 4.11 Wisconsin Freight Model Trip Production and Attraction Regression Models (continued)

Commodity	Trip Production: Production Coefficient	Trip Production: Production Variables	Trip Production: R-Squared	Trip Attraction: Attraction Coefficient	Trip Attraction: Attraction Variables	Trip Attraction: R-Squared
Secondary Warehousing	447.00	SIC42	0.69	6.83	Population	0.85
Rail Drayage	–	–	–	–	–	–
Other Minerals	–	–	–	–	–	–
Furniture or Fixtures	13.17	SIC25	0.47	0.05	Population	0.72
Printed Matter	75.01	SIC27	0.66	0.46	Total Employment	0.92
Other Nondurable Manufacturing Goods	9.49	SIC21, SIC22, SIC23	0.33	0.11	Population	0.38
Other Durable Manufacturing Goods	21.87	SIC30, SIC31, SIC35, SIC36, SIC38, SIC39	0.95	40.93	SIC50	0.59
Miscellaneous Freight	–	–	–	–	–	–
Hazardous Materials	–	–	–	–	–	–
Air Drayage	–	–	–	–	–	–

In comparing the production equation for the same commodity, Chemicals, in Indiana, Florida, and Wisconsin, the coefficients are different, reflecting the unique composition of industries in each state. This suggests further that it is more appropriate to transfer the methods, not the rates, to other states. The same is true for the attraction equations. In comparing the attraction equations for Florida and Wisconsin, which use the same commodity and industry classifications, the independent variable in Florida was chosen to be Warehousing Employment, while in Wisconsin it was chosen to be Population. Both findings may be appropriate and reflect local business patterns, further reinforcing that it is the method not the coefficients that would be transferable.

However, the trip-generation equations for the three states shown do indicate that it is possible to develop meaningful equations of commodity flow based on employment, as shown by the high R-squared values. The types and ranges of the coefficient can guide developers of other models.

In order to use these models as forecasting tools, it is necessary to have a forecast of zonal employment for these same industries. This information may not be directly available but may be estimated through application of current shares and local knowledge of planned industry growth to less detailed industry forecasts. Also, the coefficients in these equations are based on current labor productivity (the amount of goods produced or consumed by an employee). As industrial processes change, labor becomes more productive and those productivity increases may be known for individual industries. The relative growth in productivity between the base and forecast years should be applied to the coefficients in these equations when developing forecasts.

4.3.5 Special Generators at Intermodal Terminals

The development of trip-generation equations from employment is based on the assumption that freight shipments to and from a zone are related to the industrial activity associated with a commodity. It is possible to have freight activity in a zone when there is little or no activity in related industries. These zones by commodity will be easily identifiable as outlier data points in the development of the trip generation regressions. The fact that these zones are outliers does not mean that the data are incorrect. It may indicate that the commodity productions or attractions in that zone may need to be treated as a special generator.

The need for special generators also will depend on whether the commodity flow survey being used as the sample survey is a database of unlinked commodity trips (e.g., TRANSEARCH) or linked trips (e.g., CFS). When the database is unlinked, records will begin or end not only at the ultimate producing and consuming zones, but also at intermodal transfer points, such as intermodal rail yards, ports, or airports. Since there will likely be no industrial employment associated with these intermediate zones, they will need to be treated as special generators. When the database includes linked modal trips, for example for the "rail-truck" mode in the CFS, the freight flows begin or end in the ultimate producing and consuming zones, but there is no information on where the intermodal exchange is made. Even in these linked trip databases, international gateways, such as border crossings and ports, may still need to be treated as special generators.

The Florida and Wisconsin models were developed using the TRANSEARCH database as the sample survey. The magnitude of the special generator issue from each of these freight models is shown in Tables 4.12 through 4.14. For these zones, since the trip-generation equations could not be used, forecasts need to be obtained from local officials, such as facility operators in the case of terminal facilities. The productions and attractions for these special generators are added to the productions and attractions developed in the trip generation step. The special generators listed in Tables 4.12 through 4.14 are not meant to be transferable, only an indication of the method, scale, and type of commodities that might be encountered in developing state-freight models.

Table 4.12 Florida Freight Model Productions and Attractions for Ports and Terminals
(Annual, Thousands of Tons)

Commodity Code	Description	Productions	Attractions
01	Agricultural	463	478
02	Nonmetallic Minerals	8,813	8,814
03	Coal	9,300	9,300
04	Food	4,386	3,212
05	Nondurable Manufacturing	891	1,233
06	Lumber	204	285

Table 4.12 Florida Freight Model Productions and Attractions for Ports and Terminals (continued)

(Annual, Thousands of Tons)

Commodity Code	Description	Productions	Attractions
07	Chemicals	1,491	713
08	Paper	11,977	9,060
09	Petroleum Products	2,369	46,396
10	Other Durable Manufacturing	3,196	3,410
11	Clay, Concrete, and Glass	8,391	8,391
12	Waste	644	644
13	Miscellaneous Freight	2,083	2,084
14	Warehousing	18,391	22,608
Total		**72,600**	**116,628**

Table 4.13 Wisconsin Freight Model Freight Outbound Special Generators and Tonnages

Commodity	Special Production County Name	Tonnage	Comments (Possible Cause for Special Generation)
Farm and Fish	Lacrosse	2,173,173	Port, Reinhardt
	Portage	1,901,216	Potatoes, crops
Forest Products	Very low tonnage	Total Tonnage for WI = 18,332	Provide single growth factor for State of Wisconsin
Metallic Ores	Brown	2,371,126	Port of Green Bay
	Douglas	1,587,324	Port of Duluth Superior
	La Crosse	668,395	Port of LaCrosse
	Milwaukee	140,055	Port of Milwaukee
Coal	Douglas	12,444,327	Port of Duluth Superior
Nonmetallic Minerals	Milwaukee	21,792,428	Sand and gravel pits
Food or Kindred Products	No special generators	–	
Lumber or Wood Products	Douglas	1,627,383	Port of Duluth Superior
	Sheboygan	1,503,401	
Pulp, Paper, or Allied Products	No special generators	–	
Chemicals	No special generators	–	

Table 4.13 Wisconsin Freight Model Freight Outbound Special Generators and Tonnages (continued)

Commodity	Special Production County Name	Tonnage	Comments (Possible Cause for Special Generation)
Petroleum or Coal Products	Douglas	2,717,057	
	Waukesha	1,967,124	
	Milwaukee	960,732	
	Dane	833,881	
	Winnebago	729,764	
	Ashland	542,406	
	Portage	540,501	
	Brown	145,156	
	Outagamie	117,685	
Clay, Concrete, Glass, or Stone Products	Milwaukee	9,525,503	Port of Milwaukee
Primary Metal Products	Rock	1,040,050	Many manufacturers
Fabricated Metal Products	Milwaukee	1,372,127	Many manufacturers
Transportation Equipment	Rock	1,108,735	GM plant
Waste or Scrap Materials	Grant	2,600,812	Fly ash (power plants)
	Douglas	497,483	Scrap
	Brown	326,510	
Ware Housing Secondary	Outagamie	9,426,510	
Rail Drayage	Milwaukee	1,296,539	Chicago intermodal
	Winnebago	1,011,177	Chicago intermodal
	Brown	923,456	Chicago intermodal
	Trempealeau	228,971	Ashley intermodal
	Dane	184,334	Chicago intermodal
	Waukesha	164,566	Chicago intermodal
	La Crosse	111,985	Twin Cities and Chicago
	Rock	106,424	Chicago intermodal
Other Minerals	Very low tonnage	Total Tonnage = 53,629	
Furniture or Fixtures	Trempealeau	83,462	
Printed Matter	Milwaukee	378,646	
Other Nondurable Manufacturing Products	Milwaukee	34,248	
Other Durable Manufacturing Products	No special generators	–	
Miscellaneous Freight	Milwaukee	182,492	
	Brown	115,303	
	Trempealeau	111,000	
Air Drayage	Very low tonnage	Total Tonnage = 116,931	Provide single growth factor for State of Wisconsin
Hazardous Materials	Very low tonnage	Total Tonnage = 17	Provide single growth factor for State of Wisconsin

Table 4.14 Wisconsin Freight Model Freight Inbound Special Generators and Tonnages

Commodity	Special Attractor County Name	Tonnage	Comments (Possible Cause for Special Generation)
Farm and Fish	Douglas	5,560,394	Port of Duluth Superior
	Jefferson	1,435,994	Livestock
Forest Products	Very low tonnage	Total Tonnage = 18,332	Provide single growth factor for State of Wisconsin
Metallic Ores	Douglas	9,342,656	Port of Duluth Superior
Coal	Douglas	16,322,948	Port of Duluth Superior
	Kenosha	5,167,839	Pleasant Prairie
	Columbia	4,476,274	Columbia Plant
	Sheboygan	3,542,520	Edgewater Plant
	Milwaukee	3,512,500	Oak Creek Power Plant
	Marathon	2,354,536	Weston Power Plant
	Buffalo	1,809,495	Power Plant @ Alma
	Brown	1,641,810	Pulliam, De Pere
Nonmetallic Minerals	Outagamie	26,160,819	
	Winnebago	14,371,919	
Food or Kindred Products	Milwaukee	5,683,901	
Lumber or Wood Products	Milwaukee	5,740,909	
Pulp, Paper, or Allied Products	Milwaukee	3,965,026	Wholesale/retail/printing
Chemicals	Milwaukee	3,467,274	General manufacturing
Petroleum or Coal Products	No special generators	–	
Clay, Concrete, Glass, or Stone Products	No special generators	–	
Primary Metal Products	Milwaukee	2,966,812	Raw steel/iron
	Rock	806,748	
Fabricated Metal Products	Milwaukee	2,479,333	Processed metal products
	Rock	315,205	GM, Stoughton Trlr, others
Transportation Equipment	Milwaukee	881,894	Automobile dealerships
	Rock	795,415	GM – components
Waste or Scrap Materials	Grant	471,001	
	Douglas	454,251	
	Milwaukee	367,036	
	Brown	222,142	
	Buffalo	178,566	
	Waushara	165,471	
Warehousing Secondary	No special generators	-	
Rail Drayage	Milwaukee	1,173,005	
	Winnebago	947,578	
	Brown	786,440	
	Trempealeau	162,427	
	Dane	161,237	
	Waukesha	148,886	
Other Minerals	Very low tonnage	Total Tonnage = 53,993	
Furniture or Fixtures	Milwaukee	364,949	
Printed Matter	Milwaukee	837,500	Quad Graphics, Journal-Sentinel
Other Nondurable Manufacturing Products	Milwaukee	594,710	
Other Durable Manufacturing Products	Milwaukee	3,598,312	
Miscellaneous Freight	Trempealeau	234,632	
	Milwaukee	139,136	
	Brown, Wisconsin	90,240	
	Crawford	43,238	
	Grant	21,957	
	Winnebago	14,254	
Air Drayage	Very low tonnage	Total Tonnage = 146,793	
Hazardous Materials	Very low tonnage	Total Tonnage = 447	

4.3.6 Trip Distribution

The market for freight trips in commodity freight forecasting will be national, if not international, in scope. The trip distribution equation to be used will most often be a gravity model. Gravity model programs are included in virtually all of the major travel demand model software packages. The gravity model uses the zonal productions and attractions, which were calculated in the trip generation and special-generator steps, and the difficulty of travel or friction factor for the travel between the production and attraction zone:

$$T_{ij} = \frac{P_i A_j F_{ij}}{\sum_{j=1}^{n} A_j F_{ij}}$$

where:

- T_{ij} = trips (volume in tons) originating at analysis area i and destined to analysis area j;
- P_i = total trips produced/originating at i;
- A_j = total trips attracted destined at j;
- F_{ij} = friction factor for trip interchange ij;
- i = origin analysis area number, $i = 1, 2, 3... n$;
- j = destination analysis area number, $j = 1, 2, 3... n$; and
- n = number of analysis areas.

and further:

$$F_{ij} = e^{-(1/k)*t_{ij}}$$

where:

- k = average distance between all zones;
- t_{ij} = a measure of the travel impedance between i and j, expressed in miles or time; and
- e = the exponential natural constant.

In freight forecasting, each commodity will have a different average distance travel and hence a different coefficient for the trip distribution equation. This average distance can be easily calculated for each commodity from the database. What it also requires is a table of the travel impedance between the zones that is easily obtained from the transportation network. From these distances, it is easy to calculate the ton-miles (or ton-hours, if the impedance unit is travel time) for each zone, to sum these ton-miles for a commodity over all zones, and to then divide by the totals tons for all zones for that commodity. When the friction factor is an exponential distribution, the average distance can be used as the coefficient in that equation.

As can be seen in Tables 4.15 through 4.18, the average distances traveled by most commodities is measured in hundreds of miles. These average distances are beyond the scope of most existing state passenger model boundaries and explain why the scale of the geography for freight models must be national. The tables from the three models also indicate that the coefficients in trip distribution are not readily transferable. For Paper Products, the average distance traveled is 299 miles in Indiana (SCTG 27), 649 miles in Florida, and 922 miles in Wisconsin. These distances are appropriate for use in these models, but the differences show how the distribution patterns differ with the local economy. In the Florida freight model, impedance variables were tested for both time and distance. Only for those commodities that travel a short distance, such as Concrete and Warehousing, did time provide a better variable for impedance.

Table 4.15 Indiana Freight Model Trip Distribution Model Coefficients

SCTG	Commodity	Mean Distance	Modeled Coefficient
1	Live Animals and Fish	253	-0.0040
2	Cereal Grains	410	-0.0024
3	Other Agricultural Products	400	-0.0025
4	Animal Feed	213	-0.0047
5	Meat, Fish, Seafood	458	-0.0022
6	Milled Grain Products	472	-0.0021
7	Fats and Oils	313	-0.0032
8	Alcoholic Beverages	343	-0.0029
9	Tobacco Products	245	-0.0041
10	Building Stone	93	-0.0108
11	Natural Sands	58	-0.0172
12	Gravel and Crushed Stone	51	-0.0196
13	Nonmetallic Minerals	222	-0.0045
14	Metallic Ores	526	-0.0019
15	Coal	446	-0.0022
17	Gasoline and Fuel	106	-0.0094
18	Fuel Oils	172	-0.0058
19	Products of Petroleum	462	-0.0022
20	Basic Chemicals	564	-0.0018
21	Pharmaceutical Products	243	-0.0041
22	Fertilizers	489	-0.0020
23	Chemical Products	530	-0.0019
24	Plastics and Rubber	76	-0.0132
25	Logs and Rough Wood	294	-0.0034
26	Wood Products	549	-0.0018
27	Pulp Paper	299	-0.0033
28	Paper Products	292	-0.0034
29	Printed Products	538	-0.0019
30	Textiles and Leather	100	-0.0100
31	Nonmetallic Minerals	350	-0.0029
32	Base Metal	457	-0.0022
33	Fabricated Base Metal	542	-0.0018
34	Machinery	683	-0.0015
35	Electrical Equipment	464	-0.0022
36	Vehicles	686	-0.0015
37	Transportation Equipment	738	-0.0014
38	Precision Instruments	581	-0.0017
39	Furniture	354	-0.0028
40	Miscellaneous Manufacture	225	-0.0044

Table 4.16 Florida Freight Model Trip Distribution Results

Commodity Group	Average Impedance	Coincidence Ratio	Adjusted R-Squared
Agricultural	1,254 (miles)	0.752	0.775
Minerals	311 (miles)	0.503	0.396
Coal	818 (miles)	0.452	0.449
Food	659 (miles)	0.833	0.646
Nondurable Manufacturing	555 (miles)	0.870	0.959
Lumber	581 (miles)	0.820	0.645
Paper	649 (miles)	0.826	0.749
Chemicals	754 (miles)	0.741	0.743
Petroleum Products	1,078 (miles)	0.855	0.988
Durable Manufacturing	917 (miles)	0.813	0.713
Clay, Concrete, Glass	263 (free flow minutes)	0.790	0.832
Non-Municipal Waste	959 (miles)	0.546	0.661
Miscellaneous Freight	928 (miles)	0.625	0.743
Warehousing	411 (free flow minutes)	0.820	0.936

Table 4.17 Wisconsin Freight Model Average Trip Lengths by Commodity

Number	Commodity Group	Average Trip Length	Friction Factor between Zones i and j
1	Farm and Fish	731.96	exp(-distance i-j/731.96)
2	Forest Products	1,644.20	exp(-distance i-j/1,644.2)
3	Metallic Ores	586.82	exp(-distance i-j/586.82)
4	Coal	830.67	exp(-distance i-j/830.67)
5	Nonmetallic Minerals, Except Fuels	153.12	exp(-distance i-j/153.12)
6	Food or Kindred Products	784.93	exp(-distance i-j/784.93)
7	Lumber or Wood Products	780.78	exp(-distance i-j/780.78)
8	Pulp, Paper, or Allied Products	922.64	exp(-distance i-j/922.64)
9	Chemicals	956.15	exp(-distance i-j/956.15)
10	Petroleum or Coal Products	541.74	exp(-distance i-j/541.74)
11	Clay, Concrete, Glass, and Stone	451.74	exp(-distance i-j/451.74)
12	Primary Metal Products	694.71	exp(-distance i-j/694.71)
13	Fabricated Metal Products	816.90	exp(-distance i-j/816.9)
14	Transportation Equipment	1,070.93	exp(-distance i-j/1,070.93)
15	Waste or Scrap Materials	565.88	exp(-distance i-j/565.88)
16	Secondary Warehousing	320.37	exp(-distance i-j/320.37)
17	Rail Drayage	134.29	exp(-distance i-j/134.29)
18	Other Minerals	1,601.01	exp(-distance i-j/1,601.01)
19	Furniture or Fixtures	1,496.62	exp(-distance i-j/1,496.62)
20	Printed Matter	734.23	exp(-distance i-j/734.23)
21	Other Nondurable Manufacturing Goods	1,590.87	exp(-distance i-j/1,590.87)
22	Other Durable Manufacturing Goods	1,271.49	exp(-distance i-j/1,271.49)
23	Miscellaneous Freight	1,547.35	exp(-distance i-j/1,547.35)
24	Hazardous Materials	2,779.89	exp(-distance i-j/2,779.89)
25	Air Drayage	100.07	exp(-distance i-j/100.07)

4.3.7 Mode Split

Although the purpose of developing multimodal freight tables in the trip generation and trip distribution steps was to allow modes choice to be considered in the forecasting steps, in reality the ability to forecast mode choice is fairly limited. Information about the utility of each mode considered in the decision by shippers is limited. Information about the time, cost, and reliability for modes other than trucking is difficult to obtain, particularly since most state freight models still only include highway networks and do not include other modal networks that could be used to develop these characteristics. Finally, the modeling basis for most mode choice models, the logit choice equation, is based on the assumption that each shipping unit is a decision-maker. While the decision-maker for a person trip in a passenger model is an individual, the decision-maker for millions of tons of freight, the flow unit, may be a single individual and, therefore, the mathematical basis for the use of this equation may not be satisfied and the observed mode splits may reflect the business decisions of a few individuals. For all of these reasons, most state freight models assume that existing mode splits by commodity, modified qualitatively if at all, can be applied to forecast tables of multimodal freight flows.

The Indiana Freight Model developed a mode split step that was based solely on replicating the existing observed mode shares based on the distance between zones. However, since the distance between zones will not change, the mode choice step at this point defaults to applying an estimate of the observed mode shares by commodity to forecast freight bales.

The Florida Freight Model applies the existing mode share from air and water to forecast freight flows. It does attempt to estimate the mode split for truck and rail based on utilities for each mode estimated solely from the highway distances. Those estimated utilities are applied to a set of coefficients developed by applying the ALOGIT software to the TRANSEARCH database used as a revealed-preference survey.

The Wisconsin Freight Model makes no attempt to model changes in mode split. It applies the observations of mode split observed in the 2001 Wisconsin TRANSEARCH database to forecast of freight flows.

4.3.8 Conversion to Vehicles

The multimodal nature of state commodity models required that the units of freight flow be expressed in a term that was common to all modes. That unit in most models is annual flow in tons. Prior to assignment in modal networks, particularly when the freight flow will be combined with passenger flow, it is appropriate to convert the modal flow in tons to flow in vehicles. This is almost always done for the truck mode, it is done for the rail flow only if there is a rail network and railcar flow will be considered in that assignment.

The conversion of tons to vehicles is often referred to as payloads or density. It is typically based on observed loadings of freight by vehicle by commodity. This conversion can be considered analogous to the automobile occupancy factor used to convert person trips to automobiles. As expected the conversion factors differ by commodity, since each commodity will have different densities, shipment size, and handling characteristics, and may use different truck body types. The payload factors may be developed from national data such as the Census Bureau's VIUS, state records within VIUS, or from commercial vehicle surveys. The payload factors for Indiana are shown in Table 4.18 for both rail cars and trucks. These densities were modified from the Strategies Freight Transportation Analysis report for the State of Washington.

Table 4.18 Indiana Freight Model Commodity Density Values for Railcars and Trucks

SCTG	Commodity	Railcar Density Tons per Car	Motor Carrier Density Tons per Truck
1	Live Animals and Fish	9.77	3.9
2	Cereal Grains	96.63	30.1
3	Other Agricultural Products	86.79	22.3
4	Animal Feed	88.28	25.3
5	Meat, Fish, Seafood	74.41	18.6
6	Milled Grain Products	85.50	21.4
7	Fats and Oils	87.02	21.0
8	Alcoholic Beverages	87.31	21.0
9	Tobacco Products	45.75	18.3
10	Building Stone	100.00	25.4
11	Natural Sands	97.97	25.4
12	Gravel and Crushed Stone	97.97	24.1
13	Nonmetallic Minerals	100.44	23.4
14	Metallic Ores	95.91	21.4
15	Coal	109.36	22.0
17	Gasoline and Fuel	84.04	28.2
18	Fuel Oils	88.22	20.0
19	Products of Petroleum	73.66	23.5
20	Basic Chemicals	98.66	17.5
21	Pharmaceutical Products	N/A	13.2
22	Fertilizers	101.81	27.4
23	Chemical Products	93.96	20.1
24	Plastics and Rubber	94.30	13.3
25	Logs and Rough Wood	64.11	29.2
26	Wood Products	82.41	24.2
27	Pulp Paper	82.75	23.5
28	Paper Products	70.90	17.2
29	Printed Products	N/A	15.1
30	Textiles and Leather	14.17	13.3
31	Nonmetallic Minerals	98.64	21.2
32	Base Metal	91.47	18.4
33	Fabricated Base Metal	79.66	12.2
34	Machinery	49.77	13.8
35	Electrical Equipment	16.69	12.7
36	Vehicles	21.73	13.3
37	Transportation Equipment	41.36	12.1
38	Precision Instruments	N/A	9.0
39	Furniture	15.00	10.7
40	Miscellaneous Manufacture	65.22	14.0
41	Waste and Scrap	79.86	20.0
43	Mixed Freight	32.45	14.2

The Florida Freight Model developed payload factors for trucks from the Florida data records in VIUS, as shown in Table 4.19. The payloads are inferred by comparing the loaded and empty weight of the truck and the percentage of miles driven for each commodity is taken from the records. The data records also include the range of the trip in miles, which makes it possible to develop payload factors that vary by distance range. The VIUS data records include information on the percentage of miles driven empty. For the Florida Freight Model since empty truck trips are not being explicitly modeled, the payload factor was adjusted to include empty miles. This adjustment ensures that the number of truck trips, if not the direction, is reflected in the model.

Table 4.19 Florida Freight Model Tonnage to Truck Conversion Factors

	Average Payload in Pounds					
Commodity Group	**On Road Average**	**Less Than 50 Miles**	**50-100 Miles**	**100-200 Miles**	**200-500 Miles**	**500+ Miles**
Agricultural	16.36	9.20	18.14	21.95	19.48	17.79
Minerals	20.82	20.62	17.50	21.07	N/A	23.00
Food Products	18.23	8.64	18.60	22.29	21.10	21.23
Nondurable Manufacturing	8.68	3.58	5.05	18.10	6.22	14.79
Lumber	14.03	4.70	25.19	22.39	28.32	24.16
Paper	15.11	11.32	9.96	19.86	17.00	18.48
Chemicals	16.59	11.61	20.75	19.62	23.46	18.66
Petroleum Products	21.04	19.55	25.52	27.32	21.85	17.33
Durable Manufacturing	11.38	5.12	6.97	18.72	19.21	17.23
Concrete, Clay, Glass, Stone	18.47	15.82	20.31	19.97	22.71	22.40
Non-Municipal Waste	12.90	10.28	17.03	16.15	23.07	21.03
Miscellaneous Freight	12.44	6.90	7.21	20.89	19.29	18.43
Warehousing	9.07	9.02	6.53	23.91	3.34	11.56
Average	14.21	9.97	12.02	20.57	19.61	18.80

The Wisconsin Freight Model developed payload factors for trucks from the Wisconsin data records in VIUS, as shown in Table 4.20 in the same fashion as Florida.

Table 4.20 Wisconsin Freight Model Truck Payload Factors by Commodity and Distance Class

Commodity Group	Description	Truck Payload Factor (Tons per Truck) 0-50 Miles	50-100 Miles	100-200 Miles	200-500 Miles	500+ Miles
1	Farm and Fish	10.64	12.66	14.25	15.86	18.48
2	Forest Products	13.16	18.59	20.74	21.67	21.47
3	Metallic Ores	23.69	19.68	23.05	23.05	23.05
4	Coal	23.70	19.70	23.00	23.05	23.05
5	Nonmetallic Minerals, Except Fuels	23.69	19.68	23.05	23.05	23.05
6	Food or Kindred Products	8.43	11.38	15.11	17.28	21.70
7	Lumber or Wood Products	12.15	12.26	14.30	18.18	18.27
8	Pulp, Paper, or Allied Products	20.35	13.46	17.04	17.99	19.02
9	Chemicals	6.32	7.73	14.87	18.21	24.14
10	Petroleum or Coal Products	7.15	9.81	22.50	21.97	27.56
11	Clay, Concrete, Glass, and Stone	13.13	12.28	13.75	13.41	17.09
12	Primary Metal Products	7.14	12.71	11.81	21.43	20.04
13	Fabricated Metal Products	8.22	11.85	15.92	21.16	21.22
14	Transportation Equipment	6.81	8.90	9.31	17.15	19.90
15	Waste or Scrap Materials	10.21	11.58	14.44	17.83	19.98
16	Secondary Warehousing	10.21	11.58	14.44	17.83	19.98
17	Rail Drayage	10.21	11.58	14.44	17.83	19.98
18	Other Minerals	9.94	7.90	10.99	19.93	22.39
19	Furniture or Fixtures	2.20	5.63	10.76	17.41	15.06
20	Printed Matter	20.35	13.46	17.04	17.99	19.02
21	Other Nondurable Manufacturing Goods	4.53	5.12	15.40	20.15	20.53
22	Other Durable Manufacturing Goods	6.61	14.38	12.36	17.13	16.57
23	Miscellaneous Freight	10.21	11.58	14.44	17.83	19.98
24	Hazardous Materials	10.21	11.58	14.44	17.83	19.98
25	Air Drayage	10.21	11.58	14.44	17.83	19.98

For all freight models, in addition to the conversion from tons to trucks or other modal vehicles, there is typically a conversion from annual flows to average daily flows that can be compared to daily vehicle assignments or counts. Each of the models shown use the same value for each commodity, 306 average working days per year (representing 52 weeks of 6 working days less 6 major holidays), although other values may be considered, such as varying the assumptions of working days per week between 5 and 7 and the number of holidays from 0 to 12. Although none of the freight models shown in this section do so, it is possible to use different annual to daily factors for each commodity; however, doing so increases the computational and data management issues.

4.3.9 Assignment

After the modal vehicle trip tables are assigned, the modal freight vehicle trip table can be assigned to the modal networks. While modal tons tables are created for each of the three state freight models discussed in this section, each of these models only assign the freight trucks. In each state, the rail tables are preserved in the event that rail networks are constructed and used at some future date.

At the time this manual was prepared, the Indiana Freight Model had not yet been integrated into the Indiana Statewide Travel Demand Model (ISTDM), and assignment results were not available. The Florida Freight Model was assigned as part of an equilibrium mutliclass assignment with automobiles in the Florida Interstate Highway Model using congested times. No Passenger Car Equivalent was applied to trucks as part of the assignment. The results of the assignment are shown in Tables 4.21 and 4.22. As shown in these tables, the match between the modeled and the observed truck counts was quite good. The validation count locations were chosen as rural Interstates and other facilities where freight trucks were expected to represent most of all truck trips, excluding urban locations where other truck purposes that were not modeled would represent the majority of the observed trucks.

Table 4.21 Florida Freight Model State Line Volume/Count Ratio

Interstates Freeway	Model Volume	Observed Count	V/C
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 4.22 Florida Freight Model Major Statewide Screenline Volume/Count Ratio

Screenline	Model Volume	Observed Count	V/C
North Central Statewide	26,559	30,016	0.88
Southeast Statewide	24,724	24,696	1.00

In the Wisconsin Freight Model freight, truck flows include only a subset of all heavy trucks reported in Wisconsin DOTs traffic count program, which is the Traffic Analysis Forecasting Information System (TAFIS). On rural Interstate facilities, where freight trucks predominate, the difference between observed truck volumes and TRANSEARCH freight trucks will be minimal. On urban highways, where urban activity generates significant additional trucking activity, the differences will be greater. Generally, it was determined from other sources that freight truck traffic at the state level in Wisconsin represents 60 percent or more of all truck VMT.

As with any truck count data, the TAFIS database does not distinguish between commodity and non-commodity truck volumes. It is, therefore, difficult to compare the modeled freight truck volumes directly with the TAFIS average annual daily truck counts. However, since the TAFIS truck counts are classified based on axle categories, it is possible to compare the modeled commodity truck volumes with TAFIS three-axle or higher truck counts. Admittedly, this was an approximate way of checking the reasonableness of modeled truck volumes, but in consultation with Wisconsin DOT, this was determined to be the best validation procedure given the data limitations. The comparison between the observed trucks and the assigned freight trucks volumes from the freight model was adjusted to reflect observed TAFIS truck length adjustments by functional classification. As shown in Table 4.23, the match between the assigned and observed truck VMT on a systems level was considered acceptable.

Table 4.23 Wisconsin Freight Model HPMS versus Model Truck VMT by Functional Class

FHWA Functional Class	Functional Class Name	HPMS Total 3-Axle and Truck DVMT	HPMS Total ST 4-Axle and Truck DVMT	2000 Model Commodity Truck VMT	Truck Length Difference Factor	2000 Predicted Commodity Truck VMT After Length Adjustment	Percent of HPMS 3-Axle or Higher
Rural							
1	Interstate	3,528,471	3,387,684	2,761,871	82%	3,366,233	95%
2	Other Principal Arterials (PA)	2,426,032	2,090,873	2,347,979	95%	2,467,805	102%
Urban							
11	Interstate	1,369,176	1,223,630	1,690,912	139%	1,213,852	89%
12	Other Freeway/ Expressway	570,328	468,678	797,307	163%	488,147	86%
14	Other PA	1,034,015	703,218	521,625	94%	555,703	54%
1+11	Total Interstate	4,897,648	4,611,314	4,452,783	100%	4,580,086	94%
2+12+14	Total PA	4,030,375	3,262,769	3,666,911	98%	3,511,655	87%

■ 4.4 Site/Facility Planning

Site/facility planning is an essential component of a comprehensive freight planning process. A large fraction of freight traffic flows in a region move to and from freight facilities (manufacturing plants, warehouse/distribution centers, or intermodal transfer facilities). Consequently, development of a new facility or expansion of an existing facility can have a significant impact on the magnitude and spatial distribution of freight flows in a region.

Multimodal access route planning is one of the most important elements in a site/facility planning process. This involves predicting mode-specific freight traffic demand generated by the facility and using these predictions for planning the development of multimodal freight access routes to ensure efficient handling of demand by each access mode. Multimodal access routes provide the critical link between the facility and the larger transportation network, and consequently, any bottlenecks on access routes can have significant impacts on facility operations (for example, economic impacts associated with transportation delays).

The site/facility planning process can be subdivided into two broad steps that include freight modeling and the planning applications step. These steps are discussed in greater detail in the following sections, focusing specifically on planned sites/facilities. The planning approach for existing sites/facilities is relatively straightforward and involves collecting simple traffic counts and observing where and when these counts are taken, and using simple trend analysis or trip generation rates using existing counts to forecast freight flows on the network.

The freight modeling step in a site/facility planning process involves predicting freight flows generated by the facility on the surrounding transportation network. The steps involved in freight modeling include the following:

- Data collection;
- Network identification;
- Trip generation;
- Trip distribution; and
- Traffic assignment.

The forecasting steps are followed by a planning analysis where the performance of the freight system associated with these forecasts.

4.4.1 Data Collection

This is the first step in the freight modeling process, which involves gathering all the information pertaining to the planned facility that will potentially feed into the freight modeling framework. The types of data collected include, but are not limited to, the following:

- Type of facility (industrial, manufacturing, warehousing, retail, intermodal, etc.);
- Facility size (land area, floor area, number of employees, etc.);
- Types of commodities, products, and services produced and consumed;
- Expected shipment volumes (weight, volume, value, etc.);
- Frequency and schedules (timing) of shipping operations;
- Types of carriers and vehicles used for transportation;
- Location of markets for commodities/services produced and consumed (local, inter-city, out-of-state, and international); and
- Types and locations of intermediate facilities (warehouses, consolidation facilities, etc.) serving the planned facility.

Sources for obtaining data on the planned facility include the developer, designer, owner, contractor, or the municipal/city engineer's office responsible for approving plans and specifications, and issuing construction permits. Typically, basic information such as type of facility and facility size can be obtained from available documents, while more detailed data on commodities, market area, intermediate facilities, schedules, etc. may only be gathered through surveys of appropriate individuals (facility operators, carriers, shippers, and receivers).

4.4.2 Network Identification

Network identification is the second step in the freight modeling process, which involves identifying all the transportation facilities surrounding the site. These include roadways (freeways, arterials, collectors, and locals), rail network (mainline, spurs, etc.), waterway network, and transportation terminals (rail, intermodal, trucking, marine, and air cargo). A critical element in the network identification step is collecting data on physical and operating characteristics of the transportation network, including size, geometry, capacity, traffic volumes, speed limits, and any other network restrictions (for example, truck size and weight limits). Transportation network information is important in site/facility planning to analyze the choice of mode (based on relative level of service characteristics of available modes), as well as routing patterns of freight movements to and from the facility. Sources of transportation network information include state DOTs, MPOs, and traffic divisions of city or local governments.

4.4.3 Trip Generation

This step of the freight-modeling process estimates the average total freight trips (by mode) that would be generated by the planned facility for a specific time period (daily, annual, etc.). The total trips generated by the facility include both production (originating from the facility) and attraction (destined to the facility) trips.

The most common methods used for facility trip generation include trip generation rates, regression equations, and surveys. Using trip generation rates is the simplest approach for trip generation, in which estimates of number of trips per employee (or any other facility variable such as land area) are applied to the target facility to estimate the total trips generated. Trip generation rates also can vary based on truck types and the type of facility (land use). The trip generation rates used in this approach can be derived from previous surveys of freight flows associated with similar facilities or from standard sources providing average trip generation rates for facilities, based on facility and truck types.

The use of regression equations for trip generation offers the ability to predict the total trips generated as a function of more than one facility variable, which makes this approach potentially more robust and reliable compared to the use of trip generation rates. For example, a regression equation predicting total daily freight trips as a function of land use category, number of employees, and building/floor area. However, caution should be maintained when developing and using regression equations for trip generation, as equations with statistical inconsistencies (for example, using two facility variables in the regression equation that are correlated) will not result in reliable estimates.

Conducting surveys is the most time- and cost-intensive approach for trip generation, but it can provide the most accurate results, compared to trip generation rates and regression equations. This approach is useful in the case of special trip generators such as intermodal terminals, in which trip generation estimates are derived through direct contacts with a limited number of firms (facility operators and users – carriers, shippers, etc.). This approach is particularly effective if the planning agency has been building contacts with the freight community over a longer period of time.

A discussion on generating mode-specific trip generation estimates is presented below.

Highway

For trucking, the objective of the trip-generation step is to determine average daily truck activity (inbound and outbound) associated with the site/facility, by truck classification. The usual approach for developing these estimates is by conducting surveys of fleet managers of the planned site/facility.

Rail

The primary source for developing trip-generation estimates for rail is the Carload Waybill Sample. This data source provides extensive rail shipment data that can be accessed by state agencies from the Surface Transportation Board (STB). Some key rail shipment data available from the Carload Waybill Sample include origin and destination points, number of carloads, tonnage, participating railroads, and interchange locations.

Marine

Trip generation for marine freight flows typically are used for port facilities. Intermodal freight flows through ports are represented in terms of loading and unloading of TEUs, or 40-foot equivalent units (FEU). Key maritime data sources that could be used for trip generation include U.S. Waterborne General Exports and Outbound Intransit Shipments, and U.S. Waterborne General Imports and Inbound Intransit Shipments (providing shipment weight and value and percentage of containerized cargo by port), and Tonnage for Selected United States Ports (providing total, domestic, and international tonnage handled for selected ports). Available from the U.S. Army Corps of Engineers, these tonnage estimates also can be used to develop trip generation estimates for truck and rail modes generated by the port facility, after applying mode share ratios based on surveys of port facility operators.

Air

The Airport Activity Statistics of Certificated Route Air Carriers database is a primary data source for air traffic statistics, providing detailed data on freight express and mail traffic associated with each airport and individual airline. Trip generation estimates also can be derived through surveys of air cargo terminal operators. In cases where truck trip generation estimates for air cargo terminals cannot be derived from primary surveys (for example, due to higher costs) or through secondary data sources, default truck trip generation rates derived from a single study of truck trip rates for air cargo operations at the JFK International Airport can be used, which are presented in Table 4.24. However, these default estimates should be used with caution since they were developed from a survey of a single air cargo terminal operation.

Table 4.24 Truck Trip Generation Rates for Air Cargo Operations

Type of Firm	Number of Firms	Number of Workers per Firm	Truck/Van Trips per Day per Firm	Truck/Van Trips per Day per Employee
Courier	3	35	26	0.75
Forwarder	9	39	27	0.67
Broker	5	20	22	0.91
Trucking	1	20	25	0.50
Total/Average	**18**	**33**	**25**	**0.73**

Source: Characteristics of Urban Freight Systems, Table 5.7.

4.4.4 Trip Distribution

Depending on the characteristics of the facility, and the types of products/shipments involved, the freight trips generated by a facility may have origins and destinations at several different locations, with distributions ranging from short-distance local to long-haul interstate and international trips. The trip-distribution step in the freight modeling process determines these origin-destination distribution patterns of the freight trips generated by the facility.

There are three broad classes of origin-destination trip patterns that guide the trip distribution process, which include the following:

- **Long-Haul –** Trips with trip lengths of at least 250 miles to/from the facility.
- **Short-Haul –** Interstate or interregional trips moving within a 250-mile radius to/from the facility (for example, delivery movements from a wholesale distribution warehouse to retail establishments).
- **Local –** Short-distance local delivery trips. Examples of trips falling in this group include local distribution trips related to retail activity and intermodal drayage trips generated by rail or marine terminals.

Trip-distribution tables for a facility are typically developed by applications of standard gravity models, or by conducting surveys of facility operators or shippers/receivers. A key indicator that is critical to establishing the origin-destination patterns of freight trips generated by the facility is the economic input-output characteristics of the activities associated with the facility. An example of an economic indicator is the types and quantities of raw materials used by a manufacturing facility to produce final products, and in what quantities.

4.4.5 Traffic Assignment

This is the penultimate step in the facility freight-modeling process that involves "loading" the predicted freight trips, by origin-destination and mode, on the transportation network surrounding the facility. The modal transportation network used in this step may include roadways, rail network, waterways, and transportation terminals (nodes).

The criteria used in the traffic assignment process vary depending on the mode of transportation. For example, freight trips to/from the facility occurring by barge will typically have limited waterway routing options, usually just one, in which case, all the trips will be assigned to that route. On the other hand, truck O-D trips will typically have a number of routing options on the roadway network surrounding the facility, which are assigned using standard traffic assignment criteria, which include costs, travel times, traffic volumes, speed/weight/height limits, or other level of service measures.

In order to assess the impacts on traffic conditions and level of service (LOS) due to the planned facility, both passenger as well as freight trips associated with the facility need to be added to the transportation network. A similar approach is followed to estimate facility-related passenger trips, based on the knowledge of the approximate number of employees expected to work at the planned facility.

4.4.6 Planning Analyses

This is a step in site/facility planning wherein the results of the freight modeling step are used for conducting planning analyses pertaining to the facility. As discussed earlier, multimodal access route planning is the core component of a facility planning process. Based on the facility freight modeling results, the following types of analyses are typically conducted to support the facility planning process:

- Level of service (LOS); and
- Time of day.

Level of Service (LOS) Analysis

LOS analysis involves assessing the level of service of the transportation network surrounding the facility after accounting for the additional freight and passenger trips occurring due to the development of the planned facility. Important LOS characteristics analyzed include delay, congestion, physical deterioration, accidents, air quality, and noise. The inclusion of key safety and environmental impact parameters in the LOS analysis underscores the importance of incorporating safety and environmental impacts in the facility planning process, in addition to standard considerations pertaining to transportation system efficiency and reliability.

Time-of-Day Analysis

Time-of-day analysis is a critical component of the analyses conducted for planning freight facilities. This analysis typically feeds into the LOS analysis and involves assessing the performance of the transportation system at different times of the day. Analyzing time-of-day interactions between freight and passenger traffic, and how they impact LOS, is an important component of freight planning because of the variances in time-of-day distributions of freight and passenger trips. Time-of-day analysis also is important to assess environmental impacts at different times of the day (for example, noise during the nighttime period).

5.0 Commodity Models

5.1 Introduction

In Section 4.0, the methods to forecast freight demand that were discussed involve the creation of flows of freight between zones, trip tables, and using trip generation and distribution steps. For urban models, trip tables (generally just for trucks) are created by trip generation and distribution equations that are created from trip diaries or surveys of commercial vehicles or using the coefficients of others that have been developed from such surveys. Those statewide models that deal with commodity freight develop trip generation and distribution equations from surveys of commodity flows, such as the Commodity Flow Survey, the Freight Analysis Framework, or TRANSEARCH. Urban commercial vehicle surveys will always only be a statistical sample of all truck trips. However, even if commodity flow surveys are developed from statistical samples, they are generally expanded into complete flow tables, typically for an entire year. Since these commodity flow tables are themselves trip tables, if freight flow patterns are expected to be fairly stable, instead of using the commodity flows surveys as a means of developing trip generation and distribution equations, these commodity flow surveys themselves can be used as trip tables. This section discusses how commodity flow surveys can be used directly as trip tables in freight forecasting.

Although the organization of a commodity flow database might not look like a trip table to those who are familiar with travel demand models, its data fields easily can be reorganized into a trip table of freight flows. It contains as attributes origins and destinations, commodity type (purpose), and units of flow by mode. A sample frame of the TRANSEARCH database as used in the Tennessee Freight Model is shown in Figure 5.1, where the records are identified by the origin, the destination, and the commodity (purpose). The flow for each of these records by mode is specified in annual tons.

Figure 5.1 Tennessee Freight Model TRANSEARCH Database Sample Frame

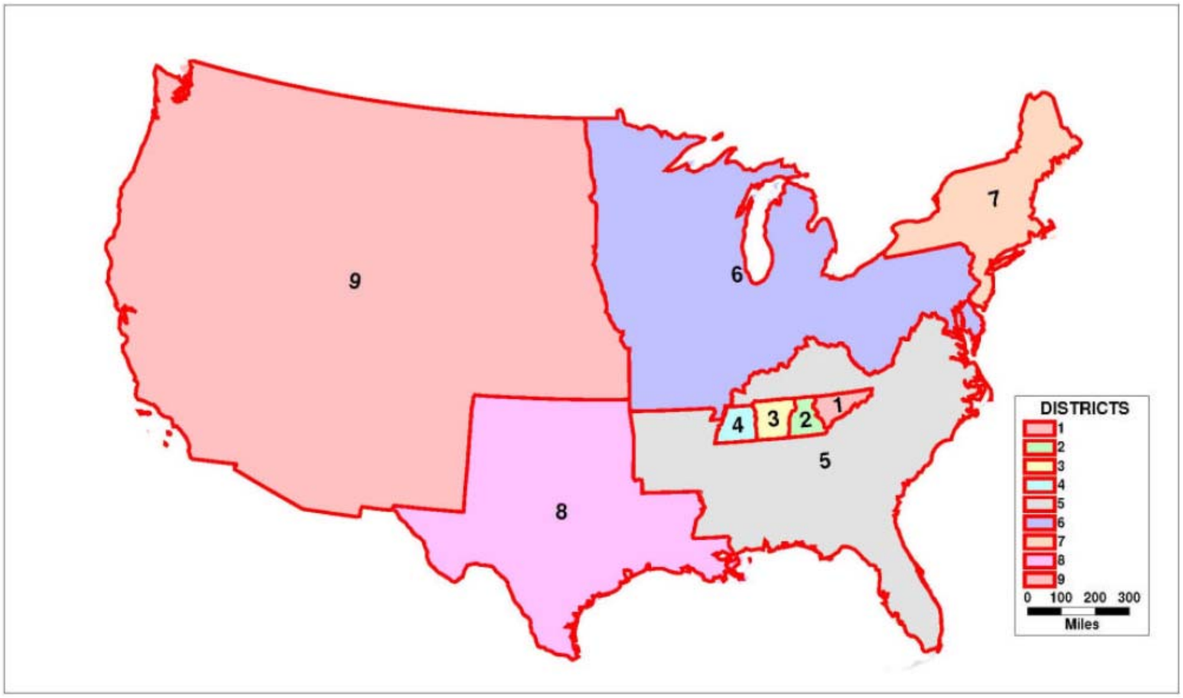
Origin Region	Origin	Destination Region	Destination	STCC4	Commodity Description	Air	Truck Tons	Water	Truckload Loads
01007	Alabama Portion of Birmi	47037	Davidson County, TN	22 51	Knit Fabrics	0	2	0	0
01007	Alabama Portion of Birmi	47037	Davidson County, TN	22 91	Felt Goods	2	0	0	0
01007	Alabama Portion of Birmi	47037	Davidson County, TN	23 11	Mens Or Boys Clothing	0	7	0	0
01007	Alabama Portion of Birmi	47037	Davidson County, TN	23 89	Apparel, Nec	35	0	0	0

The use of a commodity table in place of one developed through a trip-generation and trip-distribution process as described in Section 4.0 does have limitations. These forecasts are not easily modified in response to changes in employment forecast by industry or by specific units of geography. The freight flows will not change in response to changes in the transportation system that might result in new distribution patterns. The use of a fixed table for freight may represent a different paradigm than that used for passenger travel. The use of commodity tables directly for freight flows is often part of a less sophisticated model, where simplifications were for the passenger trip table. The direct use of commodity flow tables in transportation forecasts is typically done in state forecasting, since the internal truck movements that are of interest in urban travel forecasting are not represented in most commodity databases. The direct use of a commodity trip table may be considered for the external portion of the forecasting as described in the Hybrid Approach for metropolitan areas that is discussed in Section 6.0.

5.2 Acquiring Commodity Tables

In order to be useful in freight forecasting, a commodity flow table must represent all of the flows in the geographic area, not be just a sample of selected flows. There are a number of public and private commercial commodity flow databases. The database that best serves as a complete representation of commodity flows will be discussed in more detail in later sections. They are the publicly available Commodity Flow Survey, discussed in Section 5.7; commercially available TRANSEARCH database, discussed in Section 5.9; and the Freight Analysis Framework, discussed in Section 5.9. The publicly available databases are available for no cost but, due to sampling and disclosure agreements, have limited levels of data availability by commodity, mode, and most importantly geography. To be useful in forecasting applications, these data typically need to be disaggregated in some fashion. This effort is labor intensive and requires detailed information for the disaggregated unit of geography that will support the disaggregation process. Most often industry employment that can be related to commodity classifications is used to disaggregate flows. For the commercial TRANSEARCH database, this information is available at smaller units of geography, but supporting information on how flows at smaller units of geography is proprietary and is not available to those acquiring this database. The price of the TRANSEARCH data is related to the number of records delivered. Since the records are uniquely defined by origin, destination, and commodity, additional zones and commodity detail will increase the number of records and the cost of the database. A method to limit the number of zones is to use detailed geography in the study area, for example counties, and to use increasingly less detailed units of geography at increasing distances from a study area, progressing to states and census regions, as shown in Figure 5.2 for Tennessee.

Figure 5.2 Tennessee Freight Model Regions and District Geography



The publicly available databases also are national databases, and without assigning the database to a network, the through traffic for a particular jurisdiction cannot be easily established. For example, from the CFS or FAF2 databases, it cannot be determined what portion of the flows from California to Pennsylvania pass through Illinois. The TRANSEARCH database does include an assignable fixed path network, as described in Section 4.2.9. The inclusion of a network means that TRANSEARCH purchase can exclude external-to-external freight flows that do not pass through a study area.

In summary, the first tradeoff to consider is fixed price for a commercial private database versus labor and data costs to disaggregate a free public database. The second tradeoff to consider is the ability to easily include external through traffic, which are of interests to a study area, in commercial databases versus the lack of a process to include these trips in public free databases. The third tradeoff to consider is the transparency of the process and the ability to modify the processing of the free public database versus the lack of transparency and ability to modify the records in a private commercial database. The final consideration is the use of the databases. The free public databases, the CFS and the FAF2, are linked mode trip tables that easily can provide mode share information on complete trips. However, they cannot be easily routed on modal networks. The unlinked trip table that can be produced from the TRANSEARCH database cannot easily be used to analyze modal share changes for trips that use several modes, but since it identifies the zones where trips change modes as an origin or destination, it is ideally suited for assignment to modal networks.

5.3 Forecasting

Forecasts of the commodity flow tables are produced by applying economic forecasts of the industries consuming and producing freight to the related commodity flows. These forecasts are applied directly to observed base year commodity flows, rather than being used in trip generation and distribution methods. The Georgia Freight Model did not prepare an independent set of forecasts. It applied the growth rates that already had been used in preparing the FAF1 state-to-state commodity flow table by commodity as shown in Table 5.1.

The Tennessee Freight Model applied growth rates for industries available from economic development agencies. It applied those factors differently to industries producing freight than to industries consuming freight. The relationship between commodities and producing industries is shown in Table 5.2. In almost every case 100 percent of the growth in the outbound shipment of commodities is related to the industry producing that commodity. Table 5.3 shows the relationship of the inbound (consumption) shipment of commodities to the employment industry groups used in the model. These will be quite different from the industry producing that commodity. For example, 58 percent of the agricultural shipments are consumed by manufacturing, 19 percent are consumed by populations, and 14 percent are consumed by the agricultural industry, with the balance in service and government. The growth in the outbound shipment of commodities is the application of the growth in each of these industries, weighted by the percentages shown in Table 5.2.

The Virginia Freight Model applies a similar method of applying growth factors. As shown in Figure 5.3, the growth in employment by industry is obtained from a commercial vendor Woods and Poole. These employment forecasts are associated with producing and consuming industries using state provided information and national Input-Output tables and are then related to the STCC commodities. Increases in labor productivity that would account for increases in freight shipment that are greater than the growth in employment are obtained and included in the forecast. The resulting growth rates in commodity consumption and attraction by county are applied to the base year, TRANSEARCH, commodity flow table.

Table 5.1 Georgia Freight Model Freight Analysis Framework Annual Percentage Rate of Growth

STCC2	Commodity Description	Truck APR	Rail APR	Water APR	Air APR	Total APR
01	Farm Products	1.3%	2.0%	4.1%	2.1%	1.4%
08	Forest Products	1.5%	3.0%	N/A	0.5%	1.6%
09	Fresh Fish	4.7%	8.0%	N/A	-0.5%	4.0%
10	Metallic Ores	1.5%	4.9%	N/A	5.1%	4.7%
11	Coal	5.0%	0.9%	N/A	3.2%	1.1%
13	Crude Petroleum	3.1%	0.0%	N/A	4.7%	1.1%
14	Nonmetallic Minerals	1.1%	0.8%	-1.5%	3.8%	1.0%
20	Food Products	4.4%	4.1%	3.0%	3.2%	4.3%
21	Tobacco Products	1.6%	NA	N/A	2.3%	1.6%
22	Textile Mill Products	1.5%	3.4%	N/A	2.7%	1.5%
23	Apparel	4.3%	5.3%	N/A	4.9%	4.4%
24	Lumber or Wood	3.1%	3.2%	5.5%	4.0%	3.1%
25	Furniture or Fixtures	3.8%	6.5%	N/A	4.3%	4.0%
26	Pulp and Paper	2.6%	3.0%	2.8%	2.3%	2.7%
27	Printed Matter	3.7%	3.5%	N/A	2.6%	3.7%
28	Chemicals	2.4%	2.3%	1.5%	2.5%	2.4%
29	Petroleum or Coal	2.3%	1.9%	1.3%	1.8%	2.2%
30	Rubber and Plastics	3.0%	3.7%	N/A	2.6%	3.0%
31	Leather	4.3%	NA	N/A	3.4%	4.3%
32	Clay, Concrete, Glass, Stone	3.8%	3.6%	5.2%	3.2%	3.7%
33	Primary Metal Products	3.2%	3.3%	5.5%	2.8%	3.2%
34	Fabricated Metal	3.5%	3.8%	3.4%	2.7%	3.5%
35	Nonelectrical Machinery	5.9%	4.7%	7.1%	5.2%	5.8%
36	Electrical Machinery	5.1%	6.4%	N/A	5.5%	5.2%
37	Transportation Equipment	3.4%	2.7%	4.8%	3.2%	3.1%
38	Instruments	4.9%	4.1%	N/A	4.4%	4.9%
39	Miscellaneous Manufacturing	3.8%	4.1%	N/A	3.2%	3.8%
40	Waste or Scrap Materials	4.2%	3.1%	2.3%	4.6%	3.0%
41	Miscellaneous Freight Shipment	NA	1.1%	N/A	NA	1.1%
42	Containers Returned Empty	NA	2.9%	N/A	NA	2.9%
43	Mail	4.8%	5.9%	N/A	5.8%	5.2%
44	Freight Forwarder	NA	4.9%	N/A	NA	4.9%
45	Shipper Association	NA	-7.8%	N/A	NA	-7.8%
46	Freight all Kinds	3.4%	3.6%	1.2%	4.0%	3.5%
47	Small Packages	NA	5.0%	N/A	NA	5.0%
48	Hazardous Materials	NA	NA	N/A	NA	NA
50	Secondary and Drayage	5.1%	NA	N/A	NA	5.1%
Total		**3.0%**	**2.4%**	**1.7%**	**4.7%**	**2.9%**

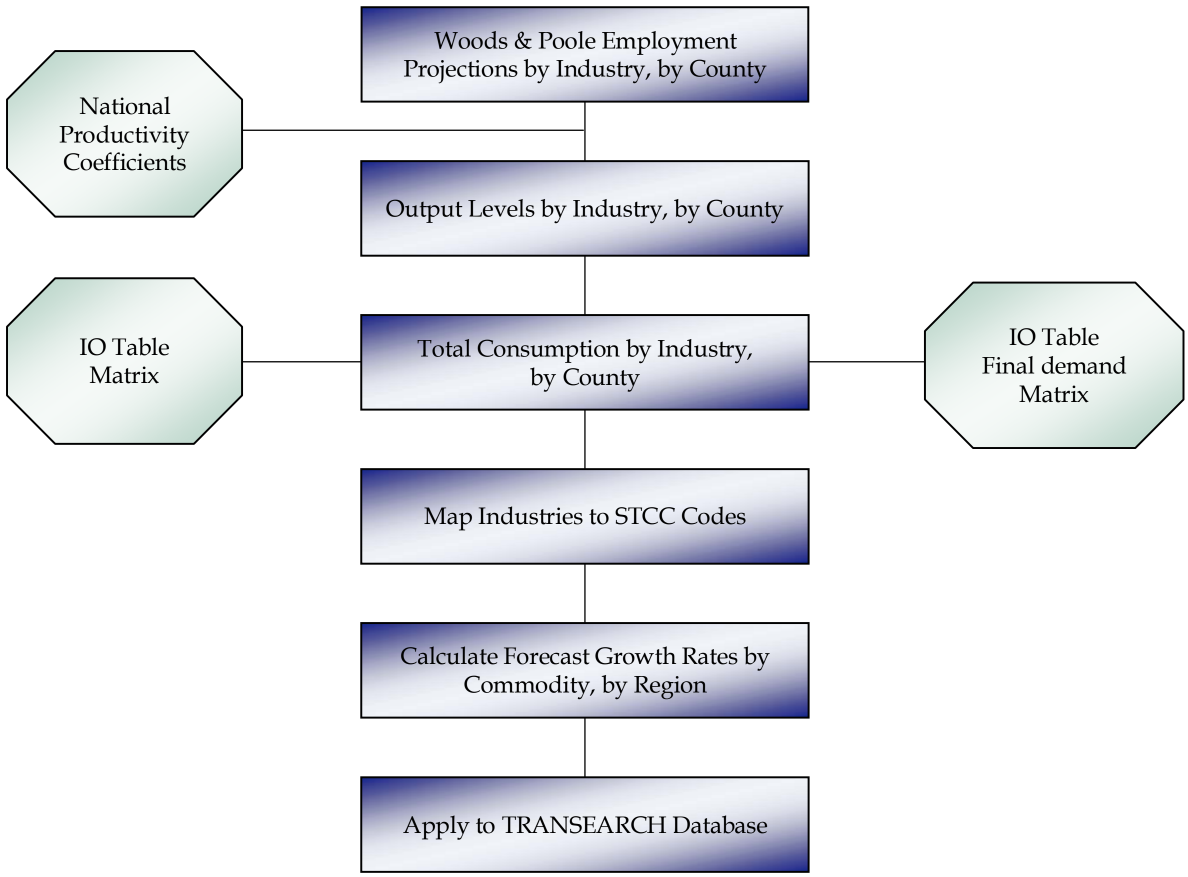
Table 5.2 Tennessee Freight Model Commodity Production to Employment Relations by Model Commodity Group

NAICS Employment Type	Commodity Group: Agriculture	Timber and Lumber	Construction	Food and Kindred Products	Household Goods and Other	Paper Products	Chemicals	Primary Metals	Machinery	Mixed Shipments and Warehouse
Farm	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Agriculture	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Construction and Mining	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Manufacturing	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%
Trade	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transportation and Public Utilities	0%	0%	0%	0%	0%	0%	0%	0%	0%	70%
Service	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Government	0%	0%	0%	0%	0%	0%	0%	0%	0%	30%

Table 5.3 Tennessee Freight Model Commodity Consumption to Employment Relations by Model Commodity Group

NAICS Employment Type	Commodity Group: Agriculture	Timber and Lumber	Construction	Food and Kindred Products	Household Goods and Other	Paper Products	Chemicals	Primary Metals	Machinery	Mixed Shipments and Warehouse
Farm	14%	21%	1%	3%	0%	0%	2%	0%	1%	1%
Agriculture	0%	23%	0%	0%	0%	0%	0%	0%	0%	0%
Construction and Mining	0%	0%	13%	0%	9%	1%	9%	4%	7%	4%
Manufacturing	58%	39%	26%	13%	36%	43%	34%	90%	37%	12%
Trade	1%	0%	3%	1%	2%	5%	2%	1%	4%	3%
Transportation and Public Utilities	0%	0%	1%	0%	1%	1%	3%	0%	3%	1%
Service	6%	9%	19%	14%	14%	34%	14%	2%	8%	18%
Government	1%	0%	13%	4%	4%	6%	6%	0%	7%	3%
Population	19%	8%	23%	64%	33%	9%	28%	1%	34%	60%

Figure 5.3 Virginia Freight Model Commodity Flow Forecast Methodology



■ 5.4 Mode Choice

The use of a commodity table is typically associated with a simplified level of effort. Therefore, it is not surprising to account for mode share in forecasting by simply assuming that the existing mode share, by origin, destination, and commodity, remains the same in the future. Since the relative flow by origin, destination, and mode can change, this simplified constant mode share can result in changes of modes, but only because of changes in the mix of the flow table. The modal shares by commodity used in the Georgia Freight Model, which even though they are applied by origin and destination, are averaged for the state and shown in Table 5.4.

Table 5.4 Georgia Freight Model TRANSEARCH Tonnage Mode Split

STCC2	Commodity Description	Truck	Carload	Intermodal	Water	Air
01	Farm Products	46%	49%	1%	4%	0%
08	Forest Products	0%	23%	77%	0%	0%
09	Fresh Fish	0%	0%	7%	47%	47%
10	Metallic Ores	0%	80%	0%	20%	0%
11	Coal	1%	94%	0%	4%	0%
13	Crude Petroleum	0%	100%	0%	0%	0%
14	Nonmetallic Minerals	0%	86%	0%	14%	0%
19	Ordnance	0%	98%	2%	0%	0%
20	Food or Kindred Products	83%	15%	2%	0%	0%
21	Tobacco Products	98%	1%	1%	0%	0%
22	Textile Mill Products	100%	0%	0%	0%	0%
23	Apparel	94%	0%	4%	0%	2%
24	Lumber or Wood Products	85%	14%	0%	0%	0%
25	Furniture or Fixtures	97%	1%	2%	0%	0%
26	Pulp and Paper	65%	33%	2%	0%	0%
27	Printed Matter	94%	0%	4%	0%	2%
28	Chemicals	64%	30%	1%	5%	0%
29	Petroleum or Coal Products	77%	9%	0%	14%	0%
30	Rubber and Plastics	97%	1%	2%	0%	0%
31	Leather	97%	0%	2%	0%	1%
32	Clay, Concrete, Glass, or Stone Products	78%	22%	0%	0%	0%
33	Primary Metal Products	76%	20%	0%	4%	0%
34	Fabricated Metal Products	94%	0%	1%	5%	0%
35	Nonelectrical Machinery	93%	2%	1%	0%	3%
36	Electrical Machinery	94%	1%	2%	0%	3%
37	Transportation Equipment	60%	39%	1%	0%	1%
38	Instruments	93%	0%	1%	0%	7%
39	Miscellaneous Manufacturing	91%	3%	5%	0%	1%
40	Waste or Scrap Materials	0%	40%	2%	58%	0%
41	Miscellaneous Freight Shipment	0%	41%	5%	54%	0%
42	Containers Returned Empty	0%	4%	96%	0%	0%
43	Mail	0%	0%	25%	0%	75%
44	Freight Forwarder	0%	0%	100%	0%	0%
45	Shipper Association	0%	0%	100%	0%	0%
46	Freight All Kinds	0%	11%	87%	0%	2%
47	Small Packages	0%	0%	100%	0%	0%
48	Hazardous Materials	0%	96%	4%	0%	0%
50	Secondary and Drayage	100%	0%	0%	0%	0%
Grand Total		**70%**	**24%**	**3%**	**3%**	**0%**

Note: Percentages may not sum to 100 percent across rows due to rounding.

Even with this simplified approach, qualitative changes can be made to the mode shares. Target mode shares can be established by commodity. Origin-destination records where the existing mode share falls below this amount can be identified and adjusted upwards towards the target level as sensitivity tests. The qualitatively changed mode shares can then be applied to the forecast to determine how changes in mode share can be reflected through the system. In applying this method, sometimes referred to as "market segmentation" since the target mode share has been applied to segmented origin, destination, and commodity markets, care must be taken to recognize that some modes, for a variety of reasons are virtually captive to certain modes and that no qualitative change should be made. For example in Table 5.4 for Georgia, 93 percent of Precision Instruments (STCC 38) move by truck with the remainder by air. The captive market should be recognized and diversion to other modes, for example to rail, should be considered carefully in forecasting.

5.5 Vehicle Conversion

The methods to convert commodity trip tables are very similar to the methods used to convert freight trip distribution tables to vehicles discussed in Section 4.3.8. The Tennessee Freight Model used payload factors that were purchased as part of the TRANSEARCH database. Payloads across commodity groups were increased since the majority of trucks were multiunit, long-haul trucks. The adjusted payload factors also were compared against Federal regulations for truck weight and size. Those values are shown in Table 5.5.

Table 5.5 Tennessee Freight Model Estimated Payload for Commodity Groups

Commodity Group	Tons per Load
Agriculture	22
Chemicals	21
Construction and Mining	17
Food and Kindred Products	23
Household Goods and Other Manufactures	17
Machinery	15
Mixed Miscellaneous Shipments, Warehouse, Rail Intermodal Drayage, and Secondary Traffic	7
Paper Products	22
Primary Metal	25
Timber and Lumber	26
Waste Materials	N/A

Source: TRANSEARCH 2001, Reebie Associates.

Truck movements were derived from commodity flows and, as such, did not reflect the presence of "empty trucks." Empty trucks, however, contribute to truck VMT and affect consumption of highway capacity. It was assumed that the most efficient truckers operate at 20 percent empty or less. An empty-truck adjustment was made for each type of movement based on its internal-to-internal (I-I), internal-to-external (I-E), and external-to-external (E-E) orientation. Relatively short-haul I-I trips account for the highest proportion of empty truck trips, while E-E trips accounted for the lowest share. These percentages were then applied to each of the loaded movements as an estimate of empty truck trips. An assumption also was made that empty movements were depicted as partial reverse trips dependent on the loaded direction.

Georgia developed payload factors from VIUS in the same manner as Wisconsin and Florida that is shown in Section 4.3.8.

For Virginia, the TRANSEARCH commodity flow tables report annual commodity flows by STCC type by ton, with the origin and destination as a state or BEA. For truck trip flows, only Truck, less-than-load (LTL), and private truck trips were used at this step. The commodity flow tables were first converted into truck trips using truck load factors according to the STCC type. The load factors, as shown in Table 5.6, were borrowed from those developed by Reebie Associates for Texas.

Table 5.6 Virginia Freight Model Truck 1 Load Factors

STCC	Commodity Type	Movement Type		
		Intrastate	Interstate	Through
1	Farm Products	16.1	16.1	16.1
9	Fresh Fish or Marine Products	12.6	12.6	12.6
10	Metallic Ores	11.5	11.5	11.5
11	Coals	16.1	16.1	16.1
14	Nonmetallic Ores	16.1	16.1	16.1
19	Ordinance or Accessories	3.1	3.1	3.1
20	Food Products	17.9	17.9	17.9
21	Tobacco Products	9.7	16.4	16.8
22	Textile Mill Products	15.2	16.1	16.5
23	Apparel or Relented Products	12.4	12.4	12.5
24	Lumber or Wood Products	21.1	21.0	21.1
25	Furniture or Fixtures	11.3	11.3	11.4
26	Pulp, Paper, Allied Products	18.6	18.5	18.6
27	Printed Matter	13.8	13.6	13.9
28	Chemicals or Allied Products	16.9	16.9	16.9
29	Petroleum or Coal Products	21.6	21.6	21.6
30	Rubber or Miscellaneous Plastics	9.1	9.2	9.3
31	Leather or Leather Products	10.8	11.0	11.3
32	Clay, Concrete, Glass, or Stone	14.4	14.3	14.4
34	Fabricated Metal Products	14.3	14.3	14.3

Table 5.6 Virginia Freight Model Truck 1 Load Factors (continued)

STCC	Commodity Type	Movement Type		
33	Primary Metal Products	19.9	19.9	2.00
35	Machinery	10.8	10.8	10.9
36	Electrical Equipment	12.7	12.8	12.9
37	Transportation Equipment	11.3	11.3	11.3
38	Instruments, Photo Equipment, Optical Equipment	9.4	9.4	9.7
39	Miscellaneous Manufacturing Products	14.2	14.4	14.8
40	Waste or Scrap Metals	16.0	16.0	16.0
50	Secondary Traffic	16.1	16.1	16.1

5.6 Assignment

The ability to assign the commodity vehicle tables to modal network will in large part depend on the quality of the modal networks and the ability to consider traffic by vehicles other than those carrying freight. The choice to use a commodity table in freight forecasting in lieu of trip generation and distribution typically is done because a more sophisticated model transportation model is not available. This quite often is accompanied by the lack of an auto highway model. A commodity table can be assigned directly to a highway network, but without the interaction of auto traffic, the response to congestion cannot be considered. For that reason, the use of commodity models is often accompanied by simple auto highway models. For the Georgia and Tennessee Freight Models, auto trip tables were created through an Origin-Destination Matrix Estimation (ODME) process using only observed traffic counts. Although this table does not allow the consideration of behavioral changes, its inclusion at least ensures that the combined impact of auto and truck congestion is considered. Georgia and Tennessee also approached the inclusion of nonfreight trucks in the freight forecasting process differently. Tennessee made the assumption that commodity trucks can be considered the same as large combination tractor trailers and assumes that observed single unit trucks could be considered to be the same as nonfreight trucks. They estimated nonfreight truck trips through an ODME process. Georgia considered freight trucks to be a subset of all trucks. It calculated a total truck table from observed counts in an ODME process and then subtracted the commodity truck table from that total ODME truck table to calculate nonfreight trucks.

Virginia already had included autos in their Virginia State Model (VSM). It assumed that the commodity freight trucks could be considered to be identical to all trucks outside urban areas where the model would be used.

Even with these simplifications, the assignment results for commodity trucks can be produce acceptable results. The results for the validation of freight trucks in the Tennessee Model are shown in Table 5.7.

Table 5.7 Tennessee Freight Model Assignment Validation

	VMT (Multiunit Daily Truck Traffic)	VMT (Assigned Daily Truck Volume)
Daily Truck Vehicle Miles of Travel by TDOT Regions		
1	27%	27%
2	20%	20%
3	33%	30%
4	20%	23%
Total VMT	**100% (13,087,821)**	**100% (14,382,402)**
Daily Truck Vehicle Miles of Travel by Functional Class		
1	49%	57%
2	7%	5%
6	6%	3%
11	27%	31%
12	1%	1%
14	7%	3%
16	2%	0%
Total	**100%**	**100%**
Daily Truck Vehicle Miles of Travel by Interstate Systems		
I 24	18%	16%
I 240	2%	2%
I 40	44%	45%
I 55	1%	2%
I 65	10%	9%
I 75	18%	18%
I 81	6%	8%
Total	**100%**	**100%**

5.7 Commodity Flow Survey (CFS)

The CFS is undertaken as part of the Economic Census through a partnership between the U.S. Census Bureau, U.S. Department of Commerce, and the Bureau of Transportation Statistics (BTS), U.S. Department of Transportation. The survey is undertaken approximately every five years, most recently in 2002. The survey produces data on the movement of goods in the United States. It provides information on commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of shipments of manufacturing, mining, wholesale, and select retail establishments. The commodity classification system used in the CFS has changed over time. The 2002 CFS uses the Standard Classification of Transported Goods (SCTG) commodity reporting system. It provides U.S. national data, data for all 50 states, and data for selected metropolitan areas plus remainder-of-state. The CFS is a "linked" trip table in that records between an origin and a destination report all modes used; for example, "truck-rail" rather than reporting each portion of the trip by mode aggregated to a separate record.

The CFS is available on a CD from the BTS. Because the database is reported in 114 zones (state portion of major metropolitan areas and remainder of states), it is of limited use and would have to be disaggregated to smaller units of geography to be useful. The Indiana Freight Model was disaggregated in this fashion, but that effort was undertaken as a research project using primarily graduate student labor. Since the CFS contains essentially the same information included in the more complete FAF2 that is discussed in Section 5.6, it is not expected to be a common source of commodity adapted for use in freight forecasting.

5.8 TRANSEARCH

TRANSEARCH is a freight database that is available commercially from Global Insight. The databases had previously been available from Reebie Associates before they were acquired by Global Insight, and the database is often referred to as "Reebie" data. TRANSEARCH utilizes a multitude of mode-specific data sources to create a picture of the nation's freight traffic flows on a market-to-market commodity basis. The national database from which purchases of TRANSEARCH are developed has U.S counties as the primary flow unit, although TRANSEARCH can use proprietary data to provide a more disaggregated level of geography. Each record in the TRANSEARCH database records the flow from an origin zone to a destination zone.

TRANSEARCH is created each year using:

- The Annual Survey of Manufacturers (ASM) to establish production levels by state and industry;
- The Surface Transportation Board (STB) Rail Waybill Sample to develop all market-to-market rail activity by industry;
- The Army Corps of Engineers Waterborne Commerce data to develop all market-to-market water activity by industry;
- The Federal Aviation Administration (FAA), Enplanement Statistics; and
- Airport-to-airport cargo volumes …

in conjunction with information on commodity volumes moving by air from the BTS CFS, to create detailed air flows; and the rail, water, and air freight flow data are deducted from the Bureau of Census ASM-based production data to establish preliminary levels of truck activity.

The proprietary Motor Carrier Data Exchange Program provides information on actual market-to-market trucking industry movement activity. The Data Exchange Program includes carriers from both the private and for-hire segments of the industry and both the truckload (TL) and LTL sectors. The truckload sample covers about six percent of the market, and TRANSEARCH's LTL sample is about 40 percent. In total, information is received on over 75 million individual truck shipments. By way of comparison, the government's CFS covers about 12 million shipments, spread across all modes, and the Rail Waybill's sample rate is about 2.5 percent of all rail freight moves.

TRANSEARCH's county-to-county market detail is developed through the use of Global Insight's Motor Carrier Data Exchange inputs and Freight Locator database of shipping establishments. The Freight Locator database provides information about the specific location of manufacturing facilities, along with measures of facility size (both in terms of employment and annual sales), and a description of the products produced. This information is aggregated to the county level and used in allocating production among counties.

Much of the Data Exchange inputs from the trucking industry are provided by zip code. The zip code information is translated to counties and used to further refine production patterns. A compilation of county-to-county flows and a summary of terminating freight activity are used to develop destination assignments.

TRANSEARCH freight traffic flow data has limitations with respect to trucks:

- Primary coverage of truck traffic is limited for nonmanufactured products. Supplemental purchases can provide for agricultural and mining resource extraction shipments from the source to a processing plant that are not ordinarily covered in commodity flow surveys.

- Traffic movements originating in warehouses or distribution centers or drayage movements of intermodal rail or air freight are shown as STCC 5010. 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 are not available.

- The inland or surface movements of import and export traffic volumes to locations outside of North America are included in the data. 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.

Freight carried by trucks, based on the definitions used by the principal agencies collecting data, also typically excludes shipments to or from retail (excluding mail-order and warehousing), offices, service establishments, and residences. These local freight or goods deliveries are significantly different from those freight shipments that are included in terms of the distances traveled, the type of trucks used, the times of movement, and the routing of the shipment, but their exclusion does not detract from the larger freight-related issues.

5.9 Freight Analysis Framework (FAF)

The FAF, available from FHWA, integrates data from a variety of sources to estimate commodity flows and related freight transportation activity among states, regions, and major international gateways. The original version, FAF1, provides estimates for 1998 and forecasts for 2010 and 2020. The new version, FAF2, provides estimates for 2002 and the most recent year plus forecasts through 2035. The original FAF1 based its analysis on county-to-county freight flows; however the publicly available origin-destination database of freight flows was available only as state-to-state movements.

The FAF1 was developed in part from the TRANSEARCH database and uses the Standard Transportation Commodity Code (STCC) classification system at the two-digit hierarchy to report flows. The FAF1 also included a highway network, using the TransCAD format that was created from the National Highway Planning Network, the Highway Performance Monitoring System, and others adapted from state DOTs. The county-to-county freight flows were converted to trucks and assigned to the FAF1 network for 1998, 2010, and 2020. The FAF1 highway network included automobile and total truck counts and forecasts from the state DOTs. For the base year, nonfreight truck volumes were calculated for each link by subtracting the FAF1 freight truck assignment from the observed truck count. The forecast of nonfreight trucks was created by applying the state provided growth rate to this base nonfreight volume. While there was no opportunity to reassign auto or non-freight trucks on the network, those volumes were considered in the capacity restrained assignment of the FAF1 trucks. The publicly available FAF1 highway network provided only totals of all freight truck volumes. These truck volumes were not disaggregated by commodity. Although the lack of a publicly available geography below the state level limited the direct use of the FAF1 origin-destination database, the growth factors provided a consistent set of forecasts for application in freight forecasting. The FAF1 highway network also serves as a valuable resource for developing the highway network portion of freight models for portions outside the primary study area.

The FAF2 was developed to address some of the shortcomings of the FAF1 database. The FAF2 origin destination table estimates commodity flows and related freight transportation activity among states, substate regions defined in the 2002 CFS, 17 additional international gateways, and 7 international regions. It also forecasts future flows among regions and relates those flows to the transportation network. In addition to the origin-destination database of commodity flows among regions, FAF2 includes a network database in which flows are converted to truck payloads and related to specific routes. The FAF2 commodity origin-destination database includes tons and value of commodity movements among regions by mode of transportation and type of commodity. The specific differences between the FAF1 and FAF2 are:

- FAF2 contains projected commodity flow data ranging from 2010 to 2035 in five-year intervals, reported in the STCG commodity classification used in the CFS.
- FAF2 excludes all foreign-to-foreign shipments via the United States.

- The FAF2 2002 base year database is built entirely from public data sources. Key sources include the 2002 CFS; Foreign Waterborne Cargo data, developed by the U.S. Army Corps of Engineers; and a host of other sources. FAF2 statistics should not be compared with original FAF1 data because different methods and coverage are employed.

- The FAF2 estimates commodity movements by truck and the volume of long-distance trucks over specific highways. The county share of truck VMT within a FAF2 region is used to disaggregate interregional flows from the Commodity Origin-Destination Database into flows among individual counties and assign the detailed flows to individual highways. Although the FAF provides reasonable estimates for national and multistate corridor analyses, FAF estimates are not a substitute for local data to support local planning and project development.

6.0 Hybrid Approaches

6.1 Introduction

State-of-the-practice metropolitan truck models are hybrids that blend commodity flow modeling techniques with freight truck modeling techniques. Commodity flow databases tend to be relatively accurate for inter-county flows, but undercount intra-county flows because commodity flow databases rely partly on economic input-output data that ultimately are based on financial transactions between producers and consumers of goods. However, in an urban area, many truck moves are not easily traced to such transactions. Moves from warehouses and distribution centers, repositioning of fleets, drayage moves, parcel delivery, and the like are generally short-distance trips in which there may not be an economic exchange of the goods from one party to another. To compensate for the lack of inclusion of the shorter distance trips in commodity flow data, and to account for types of trucks that do not carry freight, local truck trips are generated based on local employment and economic factors using trip generation rates. These trips are usually generated at the zone level and trip distribution uses methods such as gravity models. The trip rates are calibrated so that the truck traffic volumes that are generated from the combined commodity flow and locally generated truck trips match those from available truck counts. Several terms are used to refer to these two trip types, including commodity-flow trips versus locally generated trips, external versus internal truck trips and long-haul versus local truck trips. Taking advantage of the relative strength of the commodity long-haul approach and the truck short-haul approach within the same model has been called a "hybrid approach." The two modeling frameworks – freight-truck models and commodity flow models – are described briefly in the following sections. These two models form the basis for the freight/truck hybrid forecasting procedures.

6.2 Three-Step Freight Truck Models

Freight truck models develop highway freight truck flows by assigning an O-D table of freight truck flows to a highway network. The O-D truck table is produced by applying truck trip generation and distribution steps to existing and forecast employment and/or other variables of economic activity for analysis zones. This method involves estimating the O-D table directly using trip generation rates/equations and trip distribution models at the TAZ level. This is similar to the four-step passenger models. The mode choice step is eliminated since truck trips are estimated directly without consideration of other possible modes for moving freight. The components required for this modeling technique include existing and forecast zonal employment data, methods to generate zonal freight productions and attractions by using freight truck trip generation rates, methods to generate truck O-D flows by applying trip distribution procedures to truck productions and attractions, and methods to assign the O-D freight truck flows to a highway network.

Freight truck models usually attempt to account for shipment of goods, including local delivery. Because these models are focused exclusively on the truck mode, they cannot analyze shifts between modes. Truck models are usually part of a comprehensive model that forecasts both passenger and freight movement and, consequently will often use a simultaneous assignment of truck trips with automobile trips.

As noted above, freight truck models follow a three-step process of trip generation, trip distribution, and traffic assignment. Trip generation estimates the number of trips either produced in each zone or attracted to each zone and is usually a function of socio-economic characteristics of the zone (employment by industry, population, or number of households). Trip generation is accomplished using truck production and attraction equations whose coefficients are estimated based on local surveys or by using parameters borrowed from other sources such as the *Quick Response Freight Manual* (QRFM). Trip distribution determines the connection between trip origins and trip destinations. Trip distribution is generally accomplished using a gravity model similar to that used in a passenger model. In the gravity model, the number of trips that travel between one zone and another is a function of the number of trip attractions in the destination zone and is inversely proportional to a factor measuring the impedance between the two zones. The gravity model is usually related to the travel time between two zones, i.e., the longer it takes to get from one zone to another, the less attractive trips to that destination zone become. Parameters in the gravity model can be developed from local surveys or borrowed from other sources such as the QRFM. The route that trucks use to get from origin to destination is a function of network characteristics, taking into account traffic conditions on each route. Network assignment of the truck trips is usually based on a multi-class equilibrium highway assignment that includes passenger cars; in other words, the model looks for the shortest time path for all trips simultaneously. Freight truck models can take into account the size of trucks and their impact on congestion compared to automobiles (large trucks cause more congestion because they occupy more space than automobiles). In addition, the networks can be coded so that any prohibited routes are not available for truck trips.

■ 6.3 Four-Step Commodity Flow Models

The four-step commodity flow model is similar in structure to the four-step passenger model. Both the four-step commodity flow models and the four-step passenger models require the development of a network and zone structure. Since a larger percentage of freight trips in an urban area are long haul than is the percentage of passenger trips that are long haul, a skeletal highway network external to the region is usually appended to a local passenger network to allow for assignment of these long-haul freight trips.

Commodity models can analyze the impact of changes in employment, trip patterns, and network infrastructure.

The commodity-based "trip" generation model actually estimates the tonnage flows between origins and destinations. These flows are converted to vehicle trips after the mode choice step in the process. The trip generation models include a set of annual or daily commodity tonnage generation rates or equations by commodity group that estimate annual or daily flows as functions of TAZ or county population and disaggregated employment data. Base year commodity flow data at the zonal level are used to estimate the trip rates or trip generation equations. The O-D tables for these flows are typically estimated using gravity models similar to the trip distribution step in four-step passenger models. Trip distribution models are estimated separately for each different commodity group. The unit of flow in the O-D table is typically tons shipped. The distribution of freight is to a national system of zones, recognizing the large average trip lengths in this class of models. Mode split is a necessary component because O-D patterns are developed for particular commodities rather than for trucks. Quite often the mode-split step simply assumes that the base year mode share of each commodity flow stays the same in the future. The conversion of commodity truck tonnage to daily freight truck trips uses the application of payload factors (average weight of cargo carried per vehicle load). Payload factors can be estimated on a commodity-by-commodity basis using locally collected survey data (e.g., roadside intercept surveys) or national surveys (e.g., the U.S. Census Bureau VIUS). The assignment of truck freight will typically use either a freight truck only or multiclass assignment model.

6.4 Case Studies

The Southern California Association of Governments (SCAG) in Los Angeles, the San Joaquin Valley in Central California, and the Puget Sound Regional Council in Seattle employ the hybrid method for their truck forecasting models. These three models are discussed in the ensuing sections.

6.4.1 SCAG HDT Model – Los Angeles

The SCAG heavy-duty truck (HDT) model is in the process of being updated based on new truck travel surveys and commodity flow data. In the "current" SCAG truck model, the external trip model is based on a commodity flow database and forecast developed by DRI/McGraw Hill and Reebie Associates (now Global Insight). The external model estimates truck trips for which at least one trip end (either origin, destination, or both) occurs outside of the region.

The "new" updated truck model uses the commodity flow data that were originally compiled for the California Intermodal Transportation Management System (ITMS) developed by the California Department of Transportation (Caltrans). This commodity flow data have an original base year of 1995 and these were based on 1993 county-level commodity flow data developed for the SCAG Interregional Goods Movement Study and the original Caltrans ITMS. Caltrans has since updated the ITMS commodity flow data to a 1996 base year with forecasts to 2006 and 2016 based on the FHWA FAF and Caltrans employment forecasts by industry at the county level. Cambridge Systematics has recently estimated 2003 base year commodity flow data, forecasted from the 1996 ITMS database. In addition, the national CFS for 2002 and the data available for the Southern California metropolitan area was used to conduct a limited validation of the 2003 base year estimate developed from ITMS. This provided an important update to a key data input to the external model of the "new" SCAG truck model.

The framework of the "new" external HDT modeling methodology is determined by the direction of flows (inbound/outbound), commodity type (agricultural, manufacturing, mining, etc.), and shipment type (TL/Private Carrier or LTL), since these factors affect the input parameters and the procedure for commodity flow disaggregation from county-level flows in the ITMS database to the SCAG TAZ level. County-level commodity flows in the SCAG truck model were disaggregated to TAZs using zone-level employment data. For outbound truck moves, commodity flows were allocated to TAZs in the origin county based on the employment share of the producing industry in each TAZ. For inbound flows of manufactured goods and farm products by truckload and private truck modes, economic input/output models were used to determine the portion of each commodity that moves to a manufacturing facility and the portion that moves directly to a warehouse for eventual distribution to a retail facility. For commodities carried by less-than-truckload carriers, these flows were disaggregated from county to TAZ level based on the exact locations of LTL facilities in the SCAG region using a list of LTL terminals.

The SCAG truck model converted commodity flows into truck trips using data from a combination of O-D surveys (2002 SCAG Truck Count Study) and data from the Census Bureau's 2002 VIUS.[1] First, the tons were allocated to the three truck classes in the model (light-heavy duty trucks, medium-heavy duty trucks, and heavy-heavy duty trucks) using the data from VIUS. Next, the tons in each of the truck classes were converted to truck trips using the payload data from the intercept surveys and VIUS. Weigh-in-motion data were used to convert annual truck trips to daily truck trips. This disaggregation process converted the annual truck tons in the commodity flow database into a daily zone-level truck trip table for the SCAG region.

The internal component of the SCAG truck model is being updated in 2007 based on new truck travel surveys. This component will estimate truck travel for trips where both the origin and the destination are within one of the six SCAG counties. The "new" internal model will be a three-step freight truck model just like the "current" model.

In the "current" model, the trip rates for internal truck trips were estimated using data on daily truck activity collected from a shipper-receiver survey and zone-level employment data.

---

[1] Note that this data collection effort has been expanded to include all types of vehicles, and the name of the survey has changed to the Vehicle Inventory and Use Survey (VIUS).

The land use/employment categories were agriculture/mining/construction, transportation/communication, wholesale trade, retail trade, financial/insurance/real estate/services, government, and households. Samples for the shipper-receiver survey were drawn by industry group from the American Business Directories' Southern California Business Directory, a listing of 725,000 businesses, their addresses, telephone numbers, seven-digit Standard Industrial Classification (SIC) Code, and sales and employment figures. The sampling frame did not include households or government facilities.

The survey of shippers and receivers divided trips into two major categories: trips that delivered something to a facility (including services) and trips that removed something from a facility. Essentially, the survey distinguished between pickups and deliveries. Respondents estimated the number of truck trips per day made to their facility and noted whether shipments were truckload or partial truckload deliveries. For several of the categories, insufficient survey data were available to estimate trip rates, so rates were borrowed from other metropolitan area models (Phoenix and San Francisco). Special generator models were used to add truck trips to the table from the major sea ports, intermodal transfer facilities, and airports. The final truck trip table was the sum of the external truck trip table, the internal truck trip table and the truck trip table developed from the special generators.

Trip distribution for the "current" internal trips was accomplished through a gravity model based on a limited number of truck trip diaries. The traffic assignment was done by first allocating the truck trips to the four time periods in the SCAG passenger model using truck count data collected by weigh-in-motion equipment at California's weigh stations. A multiclass assignment was then performed using both the passenger car and truck trip tables. The model was calibrated and validated using 11 screenlines in the region.

While state of the art for its time, the SCAG model suffers from four weaknesses:

1. The data used to develop the trip generation and trip distribution elements of the "current" internal model are extremely limited. The "new" model will use the ongoing new truck travel survey data and will try to overcome some of its limitations.

2. The behavioral basis of the "current" internal model is crude and based on a considerable simplification of different types of truck operations. The "new" model is based on stratifying trucks into trip purposes or sectors, and the surveys are being collected by targeting different economic sectors.

3. There is no direct linkage between the external commodity flow model and the internal trips generated in the "current" model, and this will continue to be a problem in the "new" model as well.

4. It is not multimodal.

6.4.2 FASTruck Model – Seattle

The freight action strategy truck (FAST) forecasting model was developed to provide an analytical basis for evaluating the benefits of transportation investments that impact the movement of goods throughout the Puget Sound region. The truck model defines a truck based on relative weight classes and separates light, medium, and heavy trucks for analysis purposes. Medium and heavy trucks are defined to match the definitions used for collecting truck counts by the Washington State Department of Transportation (WSDOT).

The development of the truck model was based on using different forecasting methods for internal and external truck trips because the factors that influence these truck trips are very different. In the case of the external trips, defined as those truck trips that begin and end outside the region, truck trips are affected by economic factors beyond the region borders. In the case of the internal trips, defined as those truck trips that begin and end within the region, truck trips are affected by economic factors within the region borders. Truck trips that have either an origin or destination outside the region and an origin or destination inside the region are affected by both external and internal factors. These three types of truck trips are, therefore, estimated separately using unique methods for each type.

The socioeconomic data used in the FASTrucks Forecasting Model are consistent with those data used in the passenger model, except that the employment data are stratified into more employment categories. This process provides more accuracy for truck travel and allows for a direct relationship between the commodities being estimated in the external trip model and the allocation of these commodities to TAZs within the region.

The trip generation rates for the internal truck model were developed from two primary sources of existing truck models: the QRFM[2] and the Vancouver BC truck model.[3] The QRFM was selected because it provided trip rates based on national averages. The Vancouver trip rates were selected to provide stratifications of trip rates for more employment categories. The QRFM was used to derive trip rates for light trucks, while both the aforementioned sources provided trip rates for medium and heavy trucks, although the QRFM defines these categories as six or more tire trucks and combination trucks, respectively. These trip rates were originally developed using the two primary sources of data, but were adjusted during model calibration.

One additional source of data that was available to use in adjusting the internal model heavy truck trip rates for manufacturing and wholesale sectors was the TRANSEARCH commodity flow dataset. These data were processed to identify internal, county-to-county

---

[2] U.S. Department of Transportation, *Quick Response Freight Manual*, developed by Cambridge Systematics, Inc., with Comsys Corporation and the University of Wisconsin for the Travel Model Improvement Program, September 1996.

[3] Jack Faucett & Associates, *Draft Report for the Lower Mainland Freight Study, for the Greater Vancouver Regional District*, May 2000.

commodity flow and converted to average daily truck flows for comparison with other trip rates. The TRANSEARCH commodity flow dataset did not contain any commodities for internal truck trips other than manufacturing and wholesale trade, so these were the only sectors that were adjusted based on these data.

For the external FASTruck model, three primary types of external trips were represented: 1) trips that begin in Puget Sound region and leave the region; 2) trips that begin outside the region and are destined to someplace within Puget Sound region; and 3) trips traveling through the region. The two sources of data for these trips are the TRANSEARCH commodity flow data, which was converted to truck trips, and the traffic counts at external stations. Both of these sources provided some, but not all, of the data needed to develop comprehensive truck trip tables so some adjustments were made to these sources to fill in the gaps in these data sources.

WSDOT purchased TRANSEARCH data from Reebie Associates (now Global Insight) for commodity flows that traveled into, out of or through the Puget Sound region. The commodity flow data provided tons of goods moved by commodity and truck type (private carrier, less than truckload, and truckload). These data were converted to truck flows by applying payload factors (average tons per truck by commodity category) that were derived from the 2002 VIUS. VIUS is a national database of trucks that was used to derive payloads for all trucks registered in Washington State.

The truck trip tables developed from the TRANSEARCH data were further processed to evaluate the origin and destination of the commodities with respect to the Puget Sound region. These tables were compared to total volumes of truck trips at the external stations and to total internal volumes from the trip generation model. The truck trips for external trips (both internal-external and through trips) compared favorably to the total truck volumes at external stations for heavy trucks. The internal truck trips represent 32 percent of the total internal heavy truck trips estimated in the trip generation model, so these were used to estimate trip rates for manufacturing and wholesale trade, as mentioned in the previous sections.

The TRANSEARCH data identifies the origin and destination of commodity flows for 30 geographic markets. These regions were associated with appropriate external stations and internal Puget Sound counties to disaggregate these data into traffic analysis zones. Modifications to the original dataset were made to eliminate those commodities that would not likely travel through Puget Sound. The TRANSEARCH data provided a direct calculation of external (through) trips. These through trips were subtracted from the total heavy truck counts to provide an estimate of internal-external and external-internal trucks at each station. It was assumed that all TRANSEARCH commodities were moving on heavy trucks. The internal-external and external-internal trucks were distributed to internal zones using the same allocation by industry as the internal truck trips.

Some of the critical issues in the FASTruck model are:

- The internal truck model is entirely based on borrowed trip rates and not on any local survey data.
- The internal model is based only on GVW ratings and not trip purposes or sectors.
- The external trips are derived from TRANSEARCH data that were purchased for years 2000 and 2020. When the model was updated to year 2005, these external data were interpolated using the two years data.
- The external commodity flow data were available only for manufacturing and wholesale inside the four-county Puget Sound region, which enabled cross-checking the internal model heavy truck trips associated with these two categories only.
- It is not multimodal.

6.4.3 San Joaquin Valley Truck Model – Central California

The approximate bounds of the San Joaquin Valley region are the Sacramento metropolitan area to the north, the San Francisco Bay Area and California coast to the west, the Sierra Nevada Forest to the east, and the Los Angeles metropolitan area to the south. The purpose of developing a truck model for the region was to provide an analytical framework for evaluating how changes in the transportation system of the Valley would impact goods movement.

The San Joaquin Valley truck model was developed using the Caltrans road network. The truck model reported truck volumes in two truck classes: medium heavy-duty trucks and heavy heavy-duty trucks. These truck classes are defined based on gross vehicle weight rating and are consistent with the California Air Resources Board truck definitions. The model utilizes a truck trip table that was generated from two separate truck trip tables. The first of the truck trip tables was developed using the Caltrans Intermodal Transportation Management System (ITMS) commodity flow data. These truck trip tables were developed entirely from commodity flow data. The second truck trip table was developed from local socioeconomic data.

An automated procedure was developed to calculate the number of truck trips associated with the ITMS commodity flow data and to assign these truck trips to TAZs. The ITMS database includes O-D detail for freight flows for each of the major modes and each of the major commodities at the county level. The first step towards creating the truck trip table was to convert the truck tons into truck trips. This was done by developing a ton per truck ratio, referred to as the average payload, for the ITMS truck tonnage data. Average payloads were calculated for each commodity using the 1997 VIUS data. The commodity classification used for the payload matrix is the Standard Transportation Commodity Code (STCC) system. Application of the payload matrix to the ITMS data created a county-level truck trip table for the State of California from the truck tonnage data.

The truck trip table generated from the ITMS data was then disaggregated geographically to create relevant regions for the truck model. Internal regions were based on the eight counties that constitute the San Joaquin Valley study area. Regions external to the Valley were developed to correspond to each of the external cordons that can be used for trucks exiting the study area.

Next, the county-level ITMS commodity flow truck trip data were allocated to zip codes. This allocation was performed using Dun & Bradstreet employment data from 2000. These data include the number of employees by zip code for each of the eight counties in the San Joaquin Valley for thousands of different employment categories based on the SIC system at a four-digit level. The truck trips were allocated to zip codes based on matching the STCC codes in the truck trip table with the employment categories in the Dun & Bradstreet database for each STCC and each zip code. For outbound flows, one-to-one correspondences were made between commodity codes in the two databases. For inbound flows, tons were allocated based on employment in the consuming industries for each commodity.

The zip code-level trips were then allocated to the TAZs in the truck model. This allocation was done based on a combination of employment data from the statewide model and the areas of geographic overlap between the zip code and zone boundaries. This process developed the final zone-level truck tonnage table for the 1996 ITMS data. This truck trip table was then projected to the year 2000 based on the freight tonnage growth derived from the FHWA FAF data for the State of California.

The second truck trip tables or the non-ITMS truck trip table was used to supplement the truck trip table developed from ITMS data. It is typical for truck trip tables developed from commodity flow data to underestimate total truck activity because of an underestimation of local truck trips. Therefore, secondary truck trip tables are generated to improve the match between truck volumes generated by truck models and truck count data. These secondary truck trip tables are typically generated from socioeconomic data.

The trip production rates for the secondary truck trip tables were developed primarily from the QRFM.[4] The QRFM provides trip rates based on national averages for medium and heavy trucks. These rates were scaled back during model calibration. Truck trip consumption rates were developed to estimate the relative number of trucks that are attracted to each zone in the Valley. These consumption rates were developed by evaluating the industries that are present in the Valley (based on employment data) and estimating the inputs required for these industries based on input-output data. The input-output data were available at the national level and scaled to represent the input-output characteristics of the State of California. The tables for the State of California were then disaggregated to represent truck trip rates for medium and heavy truck trips.

[4] U.S. Department of Transportation (DOT), *Quick Response Freight Manual*, developed by Cambridge Systematics, Inc., with Comsys Corporation and the University of Wisconsin for the Travel Model Improvement Program, September 1996.

For this model, the socioeconomic data available are stratified into the following 10 industry groups: 1) agriculture/farm/fishing, 2) mining, 3) construction, 4) manufacturing – products, 5) manufacturing – equipment, 6) transportation, 7) wholesale, 8) retail, 9) finance, and 10) education/government. The availability and use of multiple industry groups increases the accuracy for truck travel generation because each industry group can be assigned different truck trip generation rates.

Trip distribution was performed using a standard gravity model. Model calibration was performed using a reasonableness check of the average truck trip lengths estimated by the model.

The truck model is designed to generate truck volumes based on average daily traffic. The truck model output reports truck volumes based on truck classes that the CARB defines as medium-heavy duty and heavy-heavy duty for regulatory purposes (more than 14,000 pounds gross vehicle weight rating (GVWR)). Medium-heavy duty trucks (MHDT) have a GVWR between 14,001 and 33,000 pounds. Heavy-heavy duty trucks (HHDT) have a GVWR of 33,001 pounds or more. A multiclass equilibrium assignment was performed and validated by comparing model truck volume outputs to observed truck counts collected by Caltrans.

Some of the issues in the San Joaquin Valley truck model that are being addressed in the ongoing model update include:

- There were no calibration procedures adopted to validate the ITMS commodity flows to observed truck counts.

- Flows of nonmanufactured commodities (especially farm and mining products), flows between major city pairs (e.g., flows between the urbanized portions of Southern California and the San Francisco Bay Area), and flows disaggregated to the zip code level need more careful scrutiny and adjustment using a variety of other sources.

- The secondary truck trip tables were developed using QRFM trip rates that were found to be too high and needed to be scaled back during calibration. The new model update will derive trip rates from the National Cooperative Highway Research Program (NCHRP) Synthesis Report 298[5] on truck trip generation data.

- It is not multimodal.

[5] Cambridge Systematics, Inc., Truck Trip Generation Data, National Cooperative Highway Research Program Synthesis 298, Transportation Research Board, 2002.

6.5 Issues with Hybrid Approaches

6.5.1 Conversion of Commodity Flows in Tonnage to Truck Trips

After the commodity flows have been distributed or allocated to various TAZs based on socioeconomic data, they need to be converted to truck trips before any assignments can be done. There are a few ways to do the conversion, but using nationally available databases is the most popular, easiest, and cheapest method. These databases include the Truck Inventory Use Survey (TIUS), which is now called the VIUS. The other methods of conversion include conducting external cordon surveys that provide information about truck payloads by commodity type. From all these methods, the information necessary derived to convert flows to trucks are commodity type, number of axles, and weight of trucks. These data are then used to compute average tons per truck by commodity category also known as payload factors.

The major drawback of using national databases, such as VIUS, is that it provides data by state and not by any specific region. So the payload factors are an average of all trucks across the state. Usually adjustments are made to these based on locally available data either from weigh-in-motion (WIM) data or intercept-based cordon surveys.

The truck models in Seattle and San Joaquin Valley used the 1997 VIUS data to estimate the payload matrices. The external truck trips in the Seattle model were recently updated using the observed data on certain key external stations.

In a recent study in Los Angeles, the payload matrices in the new SCAG external HDT model were updated using the 2002 SCAG Goods Movement Truck Count Study. This study was conducted at external cordons that provided new information about truck payloads by commodity. The data from these external surveys suggested that the payload factors in the old model that were derived from the 1992 TIUS data were too high for heavy-heavy trucks. In addition, the data showed that the allocation of tonnage carried by weight class that was used in the model did not allocate sufficient amounts of tonnage to heavy-heavy trucks. This led to an underestimation by the model of the number of heavy-heavy trucks at the external cordons.

6.5.2 Intra-County Flows Are Underrepresented

The commodity flows are usually estimated and available at the county level and are the strongest for county-to-county freight movements. However, the flows within a county are underrepresented in a commodity flow database and it precludes the ability to disaggregate these flows to TAZs that have both the origin and destination within a county. This is, however, not an issue if the intra-county truck movements are captured using travel survey-based trip rates.

The truck model for Seattle did not use the TRANSEARCH-based commodity flow data for flows within the four-county region but instead used a land use-based trip rate method to generate truck trips internal to the region. The commodity flow data were used only for flows that traveled into, out of, or through the Puget Sound region. A similar approach also was used in the San Joaquin Valley truck model and the SCAG HDT model where the Caltrans ITMS data was used for the external freight movements.

Another drawback of intra-county commodity flows is that it does not include trucks that do not carry freight such as trucks related to the service industry. A significant portion of the truck movements within a county are attributed to this sector that encompasses safety, utility, public service, and business and personal service vehicles.

6.5.3 Overlap of Commodity- and Truck-Based Estimates of Truck Trips

In a hybrid model, both the commodity- and truck-based models predict truck trips in a certain region but it is very difficult to separate the two estimates from each other. That is, commodity-based estimates already might be picking up the trucks in the region that the truck-based estimates include, and vice versa. This overlap is crucial and needs to be dealt with in those models that do not define the study area by the county boundaries. Usually, the commodity-based truck trips are used for those trips with at least one external trip end that is outside the study area. Since the commodity-based truck trips are county-to-county, and if the study area includes partial counties, then the overlap of truck trips from the two estimates can result in overestimation of truck trips. This is, however, not an issue if the study area is defined by its counties' boundaries.

6.5.4 Lack of Correlation of Truck Trip Purposes or Sectors between Commodity- and Trip Rate-Based Models

In a hybrid model, after the commodity- and truck-based estimates are developed, they are all added together irrespective of what commodity type or sector they belong to. This happens after the trip distribution stage. The only stratification that is carried through the assignment process is the truck class which is either in GVW ratings or number of axles such as the FHWA classes. However, this becomes an issue if the external truck trips from the commodity-based estimates need to be included in the trip distribution stage where distributing truck trips by economic sector is a necessity. The reason for this is the poor correlation between the commodity type carried by trucks from the commodity-based approach and the economic sector of truck trips derived from the truck-based model.

6.5.5 Hybrid Approaches Are Not Multimodal

The commodity-based approaches estimate flows by different modes of travel such as surface, rail, air, and water, whereas the truck-based approaches estimate truck trips only. Therefore, the hybrid approaches are appropriate only for trucks, and as a result, planning and policy analyses needed for multimodal studies are not possible. The freight flows carried by nonsurface modes (rail, air, water) need to be modeled and forecasted through other modeling tools.

6.5.6 Limitations in Validating Multimodal Commodity Flow Models

The commodity flow models are usually developed based on commercially and nationally available databases such as the TRANSEARCH and the CFS. Once the trip tables are developed from these databases, they are added into the model either during or after trip distribution. These trip tables are assumed to be accurate and normally validation of these trips are not done. Moreover, there is very limited data collected to validate these trip tables and their trip distribution patterns. Even if observed data need to be gathered, it has to be through external cordon surveys to get O-D information on truck flows coming into, going out of, and passing through the region. Vehicle classification counts at certain key locations or corridors also can be used to validate the entire truck flows passing through those locations but there is no way to separate the trucks that are external to the region from the internal truck trips.

6.5.7 Commodity Flow Databases Are Expensive

The commercially available commodity flow databases such as TRANSEARCH and Claritas are very expensive. They could cost up to $50,000 for one year of commodity flows in a particular state or region. The nationally available databases such as CFS data and FAF data are produced by the U.S. Bureau of Census and are free of cost. However, these have many drawbacks and are not very comprehensive. A series of checks and adjustments need to be made to these data before they can be used and applied to a region. The ITMS data that was used for the SCAG external HDT model development, was thoroughly reviewed and preprocessed before actually using it to develop external trip tables. The preprocessing involved calibrating and validating the flows at certain key external stations which had vehicle classifications counts from the Caltrans Traffic Count book.

6.5.8 Mode Choice Models Are Required to Separate out Truck Flows from the Rest (Air, Water, Rail)

A mode choice analysis needs to be done in order to separate out truck flows from other modes of travel as the hybrid models predict the truck flows or trips in a region. These mode choice models can be done in a couple of ways and are usually data intensive. The market segmentation-based mode choice model is simple and inexpensive, but it does require detailed commodity flow and length of haul information. However, this approach does not consider modal characteristics and, hence, is not policy-sensitive.

An alternate and more robust method that is behaviorally sensitive is the logit choice method which is the most comprehensive. These models examine the characteristics of each individual shipment and the available modes. However, a number of data items need to be gathered to develop these models such as the travel-time data by mode, price of shipment through different modes, schedules and routings, and reliability data of various modes. Surveys can be done to gather these data but they are expensive and time-consuming.

6.5.9 Commodity Flow Forecasts Are Required/Purchased

The hybrid model that uses commodity flows to represent the external truck movements also needs future year flows to forecast future year tuck volumes. These forecasts are usually purchased for a certain year in the future and growth factors are developed based on the base and future year flows to develop trip tables for any interim years. The forecasts for the SCAG external HDT model were derived from growth factors that were developed using different years of ITMS flow data. These data are available for every 10 years from 1996 to 2026. In the case of the hybrid truck model in Seattle, base and future year TRANSEARCH databases were purchased.

If the future year forecasts are not available or purchased, then relationships among external truck flows and socioeconomic data need to be developed using the base year trip tables. The future year socioeconomic data can then serve as the input to the forecasting model and external truck trips can be forecasted.

6.5.10 Special Generators (Ports/Airports) Not Well Represented in Commodity Flow Models

The commodity flows are developed based on the economic activity, consumption rates, and the input-output characteristics in a region. However, these flows do not adequately capture the freight/truck flows related to certain special generators such as airports and seaports. The reasons for this are the nonlinear relationships or a lack of relationship or hard to establish relationships at these special facilities among the freight/truck flows and the corresponding economic activity.

In the SCAG HDT model, two separate models were developed, one for the air cargo shipments and the other for the port truck flows. Separate surveys were conducted at these two facilities and they have different inputs and networks to capture the truck flows coming into and going out of these generators. In the LAMTA Cube Cargo model, surveys were conducted at various intermodal terminals to capture the trip chaining of truck trips.

6.5.11 Issues with Logistic Nodes

Logistic nodes are used in supply chain/logistic chain models that use economic input-output characteristics to calculate supply and demand for each economic sector with an assignment of goods to logistics families to determine the spatial patterns of supply and demand. The logistic nodes are used as means to distribute or disseminate the external movements to internal zones. These nodes are places such as major goods yards, multi-modal terminals, railway stations, and distribution centers where trip chaining of long-distance flows occurs.

The LAMTA freight forecasting modeling process involves the representation and modeling of the long-distance logistics system in the Transport Logistics Node model (TLN). The TLN model is only applied on the long-distance flows. These are defined as flows from the internal area (for example, in the Los Angeles study, this was defined as the greater southern California area) to the external area (in the Los Angeles study, this was defined as the remainder of the United States as well as entry points to/from Mexico and Canada) and flows from the external area to the internal area. Data on TLNs was collected through a shipper survey conducted for 131 locations in Southern California combined with rail operator data obtained at six intermodal terminals.

The following are some of the critical issues that need to be addressed before using such an approach for modeling external freight/truck flows:

- The commodity flows that move wholly within the internal area are not modeled or captured using the logistic nodes approach, unless they are flows that move from one node to another. These are referred to as short-haul movements.
- Although the concept of using logistic nodes is well established in industrial engineering processes, it has not been applied until recently to the truck flows in a travel demand model.
- The long-haul commodity flows are split at the logistic nodes by mode, commodity type, and direction. So a lot depends on the placement of these nodes in the internal parts of the region and the right logistic nodes need to be picked to ensure precise distribution of flows among modes and zones.
- Shipper/receiver surveys need to be conducted in as many logistic nodes as possible to ensure proper representation of the distribution points in the region. This can lead to the whole process being very expensive.

7.0 Economic Activity Models

Economic activity models can be thought of as the freight equivalent of the integrated economic, land use, and transportation models used in passenger travel demand modeling. Economic activity models have two main components which work together: an economic/ land use model and a freight transportation demand model. Before delving into the specifics of the modeling framework, data inputs, and modeling outputs of economic activity models, it is important to understand the interrelationships between the economy, land use, and freight transportation, in order to appreciate the relevance and importance of economic activity models for freight forecasting and to develop robust models to accurately predict future freight flows. The following sections describe these interrelationships and the different ways in which these components interact with each other. Due to the complex relationships and the unique details of a regional economy considered by these models, parameters are not readily transferred and the development and application of these models can hardly be considered a "Quick Response." They are discussed here to provide a better understanding of the methods discussed in previous sections.

As discussed in Section 2.0 of this manual, freight transportation is an essential component of economic activity. Economic activity, which is typically measured in terms of the production of goods and services in a region, generates demand for freight transportation. For example, economic relationships between industries engaged in production and consumption of goods translate into spatial freight movements. These economic interrelationships between industries are described by economic input-output models in terms of the value of different commodities consumed by industries to produce industrial outputs. These economic input-output relationships, coupled with industrial land use patterns, are essential inputs for the spatial analysis of freight movements associated with economic activities in a region.

Freight demand associated with personal consumption is another important component of the impact of economic activity on freight transportation. Increased economic activity in a region fuels personal consumption, which leads to increased freight transportation activity associated with retail trade. Economic input-output models also describe commodity and service consumption activity of households, in terms of the value of goods and services used for final (household) consumption, which can serve as essential inputs to predict total freight demand associated with personal consumption in a region.

The interrelationships between economic activity and land use are important to understand, particularly in developing freight forecasts, since land use defines the spatial distribution of economic activity, and economic activity has a significant impact on the location and types of land uses in a region. For example, increased port economic activity may impact the development of new warehousing/distribution center land use and their location patterns. In addition, new land uses/development also can fuel economic activity in a region, which underscores the importance of integrating land use forecasts with predicting economic activity and associated freight demand. For example, the development of a new intermodal terminal in a region can instigate the development of logistics parks and warehouse/distribution centers, resulting in increased economic activity and associated demand for freight transportation.

Another important component in the interrelationships between the economy, land use, and transportation is how the performance of the transportation system impacts the economy, as well as industry land-use patterns in a region. Delays in the transportation system due to congestion can lead to significant costs for shippers, which are eventually passed on to the consumer. It is estimated that congestion on the transportation system is costing the United States economy more than $200 billion a year. Transportation service availability and system performance are critical factors that impact industry location choice decisions. For example, the development of an intermodal terminal may attract significant industrial investment in a region due to increased transportation system capacity and reliability, and lower costs compared to trucking.

Last, but not the least, is the consideration of the impacts of land use on freight transportation. Industrial and other freight facility land-use patterns in a region essentially define the spatial distribution of freight flows, since a large fraction of freight traffic moves to and from these land uses (excepting through traffic). Consequently, any future variations in the land use patterns of these facilities resulting from land use regulations or new land use developments instigated by economic growth, have a direct impact on the spatial distribution of freight flows. For example, the development of new warehousing/distribution center land use may result from increased port economic activity, and their development location patterns (impacted by land use regulations), can have significant impacts on the distribution of truck trips generated by the port.

■ 7.1 Modeling Framework

This section provides a more in-depth look at the two essential components of economic activity models, namely the economic/land use model, and the freight demand model. The economic/land use component of the model generates socioeconomic forecasts at the zonal level of detail, based on considerations of the structure of the economy and the locations of industrial and household activities in the region in the future. These socioeconomic forecasts along with industrial activity location and economic interrelationships information are used interactively with the freight travel demand model to develop freight trip generation and distribution estimates. The travel demand model component then performs the mode split and network assignment steps to predict freight flows on the network by each mode of transportation.

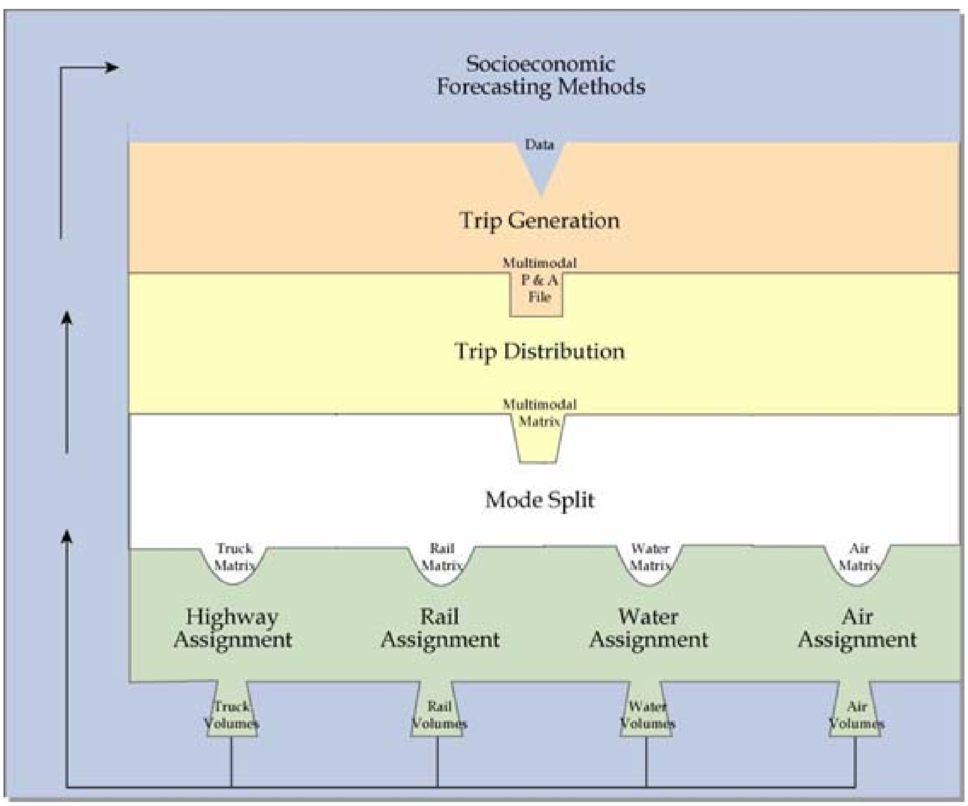
Changes in land use may have a negative impact on freight transportation, especially with regard to facilities in densely developed urban areas. The economic land use model should be able to replicate the observed shift of freight facilities to areas distant from urban centers which have cheaper land in the large parcels often required by modern logistical and freight centers.

7.1.1 Spatial Input-Output Model

The modeling framework of economic activity models (integrated modeling of the economy, land use, and freight demand) is often referred to as a spatial input-output (I-O) model. A spatial I-O model involves an economic component that defines household and economic activity and industry economic relationships in the region, a land use component that distributes household and economic activity across zones, and a spatial transportation component that defines the links and nodes of the network connecting the zones, and computes transportation flows on the network. All of these components are integrated together for freight flow forecasting.

Figure 7.1 depicts the steps involved in the modeling framework of economic activity models. The first step is the running of the economic/land use model which generates zonal socioeconomic forecasts. The model then performs the trip generation, trip distribution, mode split, and traffic assignment steps to estimate future freight flows on the transportation network by each transportation mode.

Figure 7.1 Steps Involved in Economic Activity Modeling Framework



Source: NCHRP 8-43 – Methods for Forecasting Statewide Freight Movements and Related Performance Measures.

However, there are some key features of economic activity models, which differentiate them from traditional four-step travel demand models, which are described below:

- Unlike traditional travel demand models, socioeconomic data (such as zonal employment and industrial economic activity) are not directly supplied to the model, but created internally by applying an economic/land use model. Additionally, in order to estimate economic activity, the generation and distribution of freight flows may be forecast within the economic/land use model component. The forecasts of freight flows, converted into vehicle flows on modal network, are then assigned to the transportation networks.

- At the end of each model run, the resulting performance on the transportation system, converted into costs, are used as feedback to the economic/land use component, which then updates the socioeconomic forecasts based on the predicted transportation system performance. The model then reruns the freight forecasting process with the new socioeconomic forecasts to reestimate modal freight trips on the transportation network. This iterative process continues until there is no further update in the socioeconomic forecasts generated by the economic/land use component of the model, from the predicted freight flows on the network and the resulting transportation system performance.

Since the performance of the freight transportation system, particularly on the highway network, is governed by its interaction with passenger vehicles, economic activity models are usually integrated with passenger travel demand forecasting models so that the predicted performance of the transportation system and the subsequent update of the socioeconomic forecasts are as accurate as possible.

The key feature of economic activity models is the integrated modeling of the dynamic interactions between economic activity, land use, and transportation. A conceptual framework of how these interactions are modeled is presented in Table 7.1. The feedback of model results to the economic/land use model accounts for any changes in economic activity and/or land use that would result from future variations in transportation system performance. These changes in economic activity and land-use patterns in turn impact the magnitude and distribution of freight flows on the transportation network and associated transportation system performance. Due to the considerations of these dynamic interdependencies between transportation system performance, economic activity, and land use, economic activity models also offer capabilities to accurately model induced freight demand impacts of new transportation or industrial investments.

Table 7.1 Dynamic Interactions in Integrated Economic Activity Modeling Framework

Economy and Land Use	Integrated Model Application	Transportation Component
Structure of the Economy	Trip Generation →	Network (links and nodes)
Industry Economic Relationships and Household Consumption Activities	← Trip Distribution	Mode split
	Socioeconomic Forecasting	Network assignment
Location of Household and Economic Activities		Performance (reliability, costs, etc.)

Source: NCHRP 8-43 – Methods for Forecasting Statewide Freight Movements and Related Performance Measures.

■ 7.2 Data Requirements

The following data elements are essential inputs required to develop economic activity models for freight forecasting.

7.2.1 Socioeconomic Data

Base year socioeconomic data are key inputs that feed into the economic/land use component of the model. Specific data elements in this category include base year population and employment by different industry sectors, for each zone, which are used to develop intrinsic socioeconomic forecasts within the framework of the economic activity model. Sources for socioeconomic data include the U.S. Census, MPOs, and state and regional economic development agencies.

7.2.2 Economic Activity Data

I/O data are the main economic data inputs for the spatial I-O modeling framework of economic activity models. These data describe the economic relationships between different industry sectors in terms of the values of the various types of goods and services consumed to produce outputs. I-O data also describe final consumption activity in terms of the total value of goods and services consumed by households. In addition to I-O data, information on values per ton for each commodity are essential inputs in order to translate economic I-O data into equivalent shipment tons. Also, I-O data may be only available at the county level of detail, which are disaggregated by the model to zones for trip generation using the population and employment data inputs described in an earlier section.

Sources of I-O data include IMPLAN™ and RIMS-II™, which track the buying/selling interrelationships between industries within a given region. They reflect forward and backward linkages in the flow of money associated with business suppliers and consumer spending. They can, thus, capture the full economic impacts (including multiplier effects) derived from changes in demand or output in a given industry.

7.2.3 Land Use Data

Data concerning the availability of land, industrial land use patterns, and the rules and regulations governing the development of land uses in the future are critical inputs that are used by the economic/land use component of the model to generate socioeconomic forecasts. Some key issues with respect to land use data that are important to consider as inputs to the model include an understanding of industry location choice decisions as a function of transportation system performance, as well as a better representation of the interdependencies between land use and economic activity (for example, how increased economic activity in one industry sector may fuel the development of land uses associated with other industry sectors, and vice versa. This tendency, for example the location of automobile parts and accessory firms near automobile assembly plants, is often called clustering of industries).

7.2.4 Transportation Network Information

Like traditional travel demand models, transportation network information is a key input for economic activity models in order to assign the freight flows, by mode, to each modal transportation network. The network is represented in terms of links and nodes that provide connectivity between zones. Following are some key network attributes to consider in the model:

- Capacity;
- Size and weight regulations;
- Hazardous material regulations;
- Road closures; and
- Speed limits.

■ 7.3 Oregon Statewide Passenger and Freight Forecasting Model

The first integrated statewide transportation and land use model for Oregon (Oregon Statewide Model) was developed through the establishment of the Transportation and Land Use Model Integration Program (TLUMIP) by the State of Oregon in 1996. An update of this model was initiated by ODOT in 1999, leading to the development of the second generation integrated statewide model that simultaneously models economic activity, land use, transportation supply, and travel demand. The main purpose of developing the integrated land use and transportation model was to analyze and support land use and transportation decisions by making periodic long-term economic activity, demographic, passenger, and freight flow forecasts at the statewide and substate levels. A key objective of the integrated statewide model is to analyze the potential effects of transportation and land use policies, plans, programs, and projects on travel behavior and location choices.

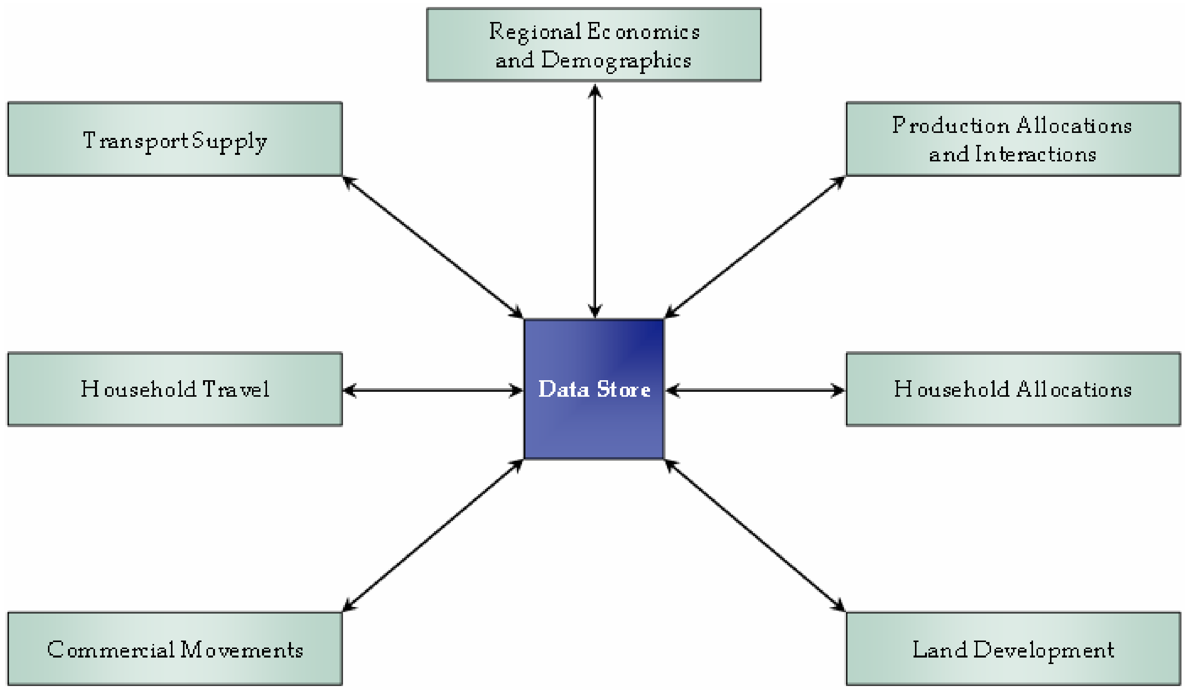
Key characteristics of the Oregon Statewide Model include the following:

- Single geographic scale for the statewide region;
- Complete integration of economic, land use, and transportation components;
- Modeling of dynamic interactions between the economy, land use, and transportation;
- Hybrid equilibrium (for economic and transportation markets), and disequilibrium (for activity and location markets) formulations; and
- Activity-based modeling formulation.

7.3.1 Modeling Framework

The Oregon Statewide Model belongs to the class of economic activity models designed for forecasting both passenger and freight movements. The modeling framework consists of a set of seven stand-alone but highly integrated modules, which are depicted in Figure 7.2.

Figure 7.2 Modules in the Oregon Statewide Model



Source: J.D. Hunt et al., *Design of a Statewide Land Use Transportation Interaction Model for Oregon*, 2001.

Descriptions on each of these modules are presented below:

- **Regional Economics and Demographics –** Key data components in this module include annual productions by economic sector, employment by industry sectors, and in-migration and payroll by economic sector. Besides economic production and industry employment data, this module also includes four sectors for final demand, which include exports, household consumption, investment, and government (state or local).

- **Production Allocations and Interactions –** The production allocations and interactions module determines the distribution of production activity among zones and the consumption of space by these production activities in each zone. The module also reflects the flows of goods and services and labor from production locations (zones) to consumption locations (zones), as well as the exchange prices for goods and services, labor, and space each year.

- **Household Allocations –** In this module, household allocations to zones reflect the same distributions as the allocations from the previous year. The labor flows originating from these households are allocated to the production (exchange) locations based on the production allocations to zones determined from the production allocations and interactions module. Similarly, distribution of freight demand associated with household consumption activity is modeled by allocating the flows of commodities consumed by the households to zones based on zonal production (exchange) allocations.

- **Land Development –** The land development module estimates the year-to-year changes in available space in each zone in the region. The primary task of the land development module is to adjust the quantity of space over time in the region in response to changes in price. Other modules in the model determine a price for each category of space in each zone using a highly disaggregate process (one grid cell at a time), based on the fixed supply of space available in each zone for that particular year. The model uses the zoning patterns and does not forecast how the political process can change zoning patterns.

- **Commercial Movements –** A key output of the commercial movement module is the average annual growth estimates for weekday truck traffic volumes. In order to determine truck traffic growth rates, the module synthesizes a fully disaggregated list of individual truck shipments. For each truck movement, the synthesized data include the type of vehicle (light single-unit, heavy single-unit, articulated), starting link, ending link, starting time, commodity hauled, and transshipment organization. The module uses truck shipment sizes consistent with the CFS. Activity-based truck tours are generated by the module using activity interaction matrices, which contain aggregate freight flows between activity centers. These flows are first translated into discrete shipments by commodity, and then combined into truck tours. The module also considers empty truck movements, O-D distribution patterns for which are derived from the patterns for loaded vehicles.

- **Household Travel –** The household travel module estimates specific individual passenger trips made by households during a particular representative workday for each year, with information on starting link, ending link, starting time, tour mode, vehicle occupancy, utility attribute coefficients, and nonnetwork-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.

- **Transportation Supply –** The transportation supply module is a hybrid of macroscopic and microscopic techniques. The module computes equilibrium travel times by loading a conventional O-D trip table to a network. These equilibrium travel times, derived from a macroscopic perspective (total vehicles), are then used in a microscopic assignment, which works at the level of individual vehicles, determining the network loadings from synthesized commercial vehicle and household travel demands.

- The data store is the database in which all the information input and output from the modules is stored. Also, all information flowing between modules passes through the data store.

7.3.2 Geographic Coverage

The Oregon model has three geographic components:

1. A statewide model for assessing broader statewide policy options;

2. A substate model for regional analysis along major intercity transportation corridors; and

3. An urban model for a more detailed analysis of local impacts associated with policy and investment decisions.

7.3.3 Modes

The Oregon Statewide Model is an integrated passenger and freight forecasting model, with simultaneous assignments of future passenger and freight movements on the transportation network. The modes involved in the model include two-axle truck, three-or-more-axle truck, rail, automobile and van, water, and air cargo.

7.3.4 Data Requirements

Table 7.2 presents the data elements used to develop the Oregon statewide model. The transport supply and demand data elements, which include network information, modes, modal split parameters, user charges, and vehicle operating costs, are comparable to those required to develop traditional travel demand forecasting models. Excepting the development of factors to translate flows in dollars to equivalent person and freight truck trips, the same holds true for the land use-transportation interface data.

7.3.5 Freight Forecasting Process

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. 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. Since 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 a direct effect on land use patterns, which will in turn impact the magnitude and distribution of freight demand in a region.

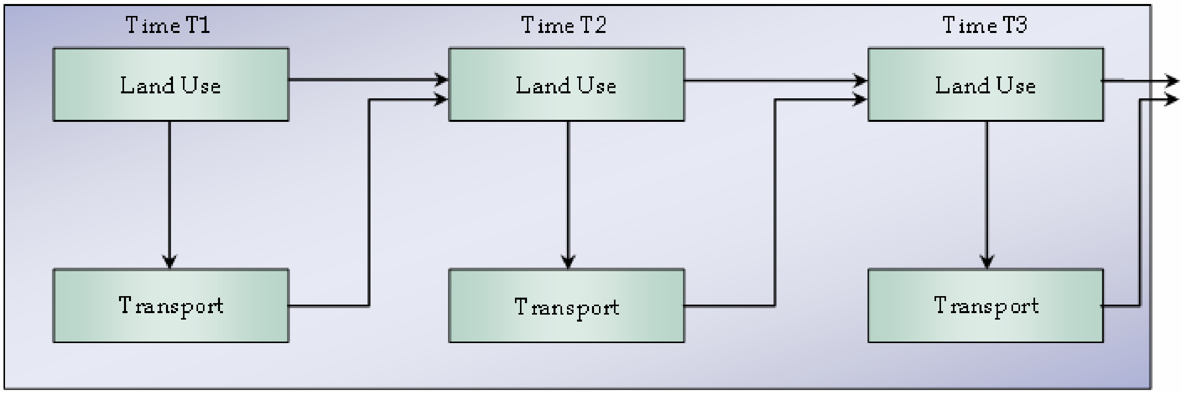
Table 7.2 Data Inputs for Oregon Statewide Model

Category	Data Elements
Land Use and Socioeconomic Data	• Base year input-output accounts, induced production, etc. • Exports by sector • Imports by sector • Restrictions on internal production by zone and sector • Location utility function parameters • Demand function parameters • Demand substitutions • Attractors of exogenous demand • Attractors for induced production • Global increments of exogenous production and consumption • Increments of exogenous demand, production, and external zone exports and imports • Increments of endogenous location attractors, production restrictions, and value added to production
Land Use and Transport Interface Data	• Time and Volume conversion factors, directionality of flows • Intrazonal costs • Exogenously defined trips
Transport Supply and Demand Data	• Network information (links, nodes, length, capacity, etc.) • Transit lines • Trip characteristics (mode, travel times, value of time, etc.) • Trip generation and mode split parameters (elasticity, dispersion, and scaling factors) • Energy and Operating Costs • Vehicle Operating Characteristics • User charges (fares, tariffs, etc.) • Speed-flow curve parameters

Source: *The Oregon Statewide and Substate Travel Forecasting Models*, Rick Donnelly and Pat Costinett, Parsons Brinckerhoff Quade & Douglas, Inc., William J. Upton, Oregon Department of Transportation, TRB on-line publications (onlinepubs.trb.org), 1999.

Figure 7.3 shows the dynamic interactions between land use and transportation over time that are modeled in the TRANUS framework. The model simulates the interactions between land use and transportation for each time period, by predicting the impacts of transportation on new land use, as well as modeling the associated transportation demand impacts of changing land use patterns. Under each temporal iteration process, the new land use is dependent on the land use in the previous iteration, as well as transportation system and demand characteristics at the end of the previous iteration step.

Figure 7.3 Dynamic Interactions in an Integrated Land Use-Transportation System



Source: NCHRP 8-43 – Methods for Forecasting Statewide Freight Movements and Related Performance Measures.

The first step in the model involves generating a set of paths connecting origin and destination pairs by each transport mode (freight, private automobile, public transport, etc.). Second, the model transforms the potential travel demand estimated by the activity/transport interface into actual trips at particular times of the day (peak, off-peak, 24 hours, etc.). Trips for each category are distributed to modes by means of a multinomial logit (MNL) model, in which the utility function is determined by the composite cost of travel by mode. Third, the model 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, also using an MNL modeling approach. The combination of the MNL modal split and assignment models is equivalent to the two-level hierarchical modal split model.

The goods and services shipments flows are estimated using the spatial distributions of activities and population, following the path from the production locations to the exchange locations and then to the consumption locations. A notable aspect is the absence of a separate trip distribution step in the model, as is the case in traditional four-step travel demand models.

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 transportation, which include two-axle trucks, three-or-more-axle trucks, rail, automobile and van, water, and air cargo.

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 household travel and commercial movement demands.

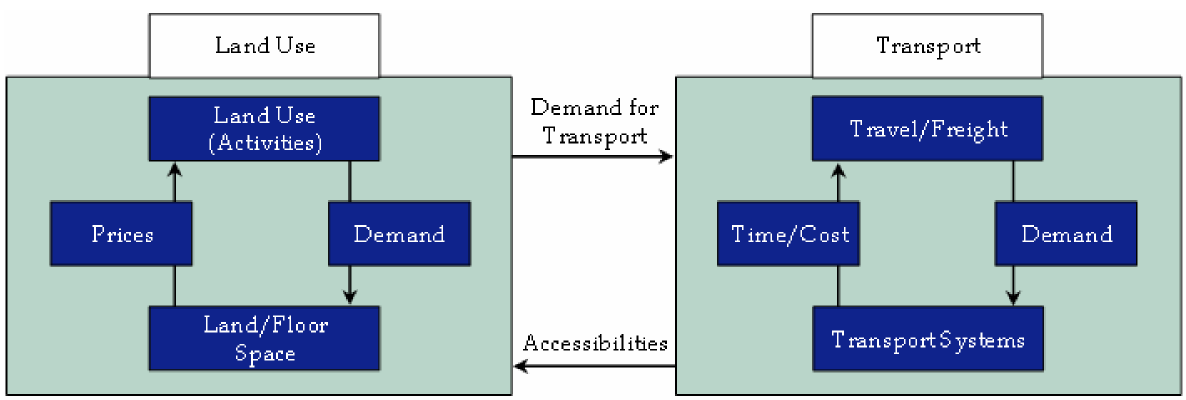
The commercial movement module determines the growth of freight movements during a representative workday in each year. In fact, the model steps through time in a series of one-year steps that allow the entire system to evolve. The representation for year T+1 is influenced in part by the conditions determined for year T. These yearly freight movements are then converted to a representative weekday.

7.4 Cross-Cascades Model

7.4.1 Modeling Framework

The Cross-Cascades model incorporates the spatial I-O modeling framework for passenger and freight forecasting, involving a household and economic activity component (household consumption activity and economic interrelationships between industries for production and consumption), a land use component (spatial distribution of household and economic activity), and a transportation component (physical and operational transportation network attributes). Using the spatial input-output modeling approach, the model simultaneously develops forecasts, generated iteratively, of modal passenger and freight traffic volumes on the corridor network, mode splits, population, and employment. Figure 7.4 depicts the spatial input-output modeling approach of the Cross-Cascades model.

Figure 7.4 The Cross-Cascades Corridor Spatial Input-Output Approach



Source: *Cross-Cascades Corridor Analysis Project Summary Report*, Washington Department of Transportation, 2001.

7.4.2 Geographic Area

Since the model was developed to specifically analyze passenger and freight travel demand along the Cross-Cascades corridor, the market area of the model is limited. The model is comprised of 61 zones, with 54 in Washington, 1 in Idaho, and 6 external zones. The internal zone structure includes 25 subcounty zones within the corridor (24 in Washington, and 1 in Idaho), and 30 other county-level zones in Washington. The external zones in the model include Western Canada; Canada (east of Cascades); Northern Idaho, Montana, and East; Eastern Oregon, Southern Idaho, and Southwest; West Oregon and California; and non-United States.

7.4.3 Modes

The Cross-Cascades model is an integrated passenger and freight forecasting model, with simultaneous assignments of passenger and freight traffic volumes on the corridor network. Freight travel modes considered in the model include medium truck, heavy truck, rail, and air freight, while passenger travel modes include automobile (private), automobile (work), coach (bus), Amtrak (rail), and air.

7.4.4 Data Requirements

Following are some key data inputs to the Cross-Cascades model:

- **Household Data –** 1998 county-level household data from the Washington State Population Survey (data disaggregated to subcounty zones and income groups based on 1990 U.S. Census distributions).

- **Employment Data –** 1998 county-level employment data derived from BEA data on total industry employment, and Labor Market Economic Analysis (LMEA) studies on covered and noncovered employment.

- **MEPLAN Model Coefficients –** Economic activity in Washington State was modeled through the use of MEPLAN model coefficients. These coefficients define the amount of each type of employee or personal activity required to generate a single unit of economic activity for a particular industrial or household sector.

- **Modal Networks –** Transportation networks incorporated in the model include all the major Washington highways, Burlington Northern & Santa Fe (BNSF) rail lines across Stevens Pass and Stampede Pass, and airways connecting the cities of Seattle, Wenatchee, Yakima, Moses Lake, the Tri-Cities area, and Spokane. In addition, truck, rail, and air cargo terminals are explicitly coded into the network for the identification of access routes, and assignment of traffic volumes.

- **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). 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.

7.4.5 Freight Forecasting Process

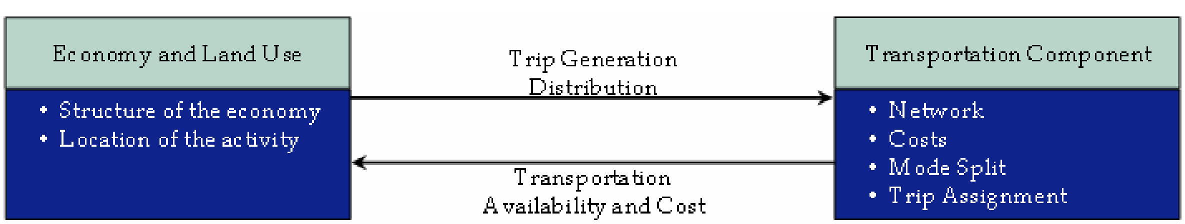
The Cross-Cascades model is implemented in the MEPLAN software, developed and distributed by ME&P of Cambridge, England. MEPLAN is based on the concept that, at any geographic level, land use and transportation affect one another. The location of households in turn create demands for industrial land, retail floor space, 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.

Trip Generation

The Cross-Cascades model as implemented in MEPLAN, uses an I-O structure of the economy to simulate economic transactions that generate transportation activity. A spatial I-O 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 transportation network in previous years. Together, the land use/economic components and the location of the transportation network affect transportation flows. Transportation costs, including the costs of congestion created by increasing travel demands, also influence the location of households and businesses.

Figure 7.5 shows the schematic of the interactions between the economic/land use and transportation model components for the trip generation and trip distribution steps in the model. Trade-to-trip ratios translate economic activity into transportation flows, which are developed using the TRANSEARCH freight flow data. Similarly, household trip rates are applied to estimate equivalent trips associated with households, using information on the number of household units. These rates are developed primarily using Nationwide Personal Transportation Survey (NPTS) travel data. The trade-to-trip ratios and household trip rates are exogenous inputs to the model.

Figure 7.5 Trip Generation and Distribution in the Cross-Cascade Model



Source: *Special Input-Outputs, Cross-Cascades Corridor Analysis Project, Summary Report*, Washington State Department of Transportation, 2001.

Trip Distribution

The Cross-Cascades model handles trip generation and trip distribution in a single step, as depicted in Figure 7.5.

Mode Split

As discussed earlier, the Cross-Cascades model is an integrated passenger and freight forecasting model. The freight transportation modes in the model include air, rail, medium trucks, and heavy trucks. 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 which include air, Amtrak (rail), coach (bus), private automobile, and work automobile. 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.

Traffic 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.

A key feature of MEPLAN is the ability of the transport model to provide feedback to the economic/land use model. At the end of each iteration, the transport model generates travel disutility (costs) for each zone pair, which in turn influence business and household location decisions. In future year iterations of the model, a nested logit model is used to determine the changes in business and housing location patterns in response to changing transportation costs.

8.0 Model Validation

■ 8.1 Introduction

Model validation involves testing the model's capability to predict current travel demand so that it can be used effectively to predict future travel demand. In other words, freight travel models need to be able to replicate observed conditions within a reasonable range before they can be used to produce future year forecasts. As metropolitan areas continue to refine and improve their travel demand forecasting processes, the credibility of the process with decision-makers will depend largely on the ability of analysts to properly validate procedures and models used. Also, the travel demand models have become more complex, resulting in complex procedures needed to validate them. Often there are trade-offs between increasing confidence in the level of accuracy of the models and the cost of data collection and effort required to validate models. Tests or checks used to evaluate the reliability of models can range from a simple assessment of the reasonableness of model outputs to sophisticated statistical techniques.

The model validation and reasonableness tests involve a two-part procedure – calibration and validation. The term "model calibration" is the process of adjusting parameter values until predicted travel matches observed travel demand levels in the given region. The term "model validation" is the process of comparing the model predictions with information other than that used in estimating the model. Model calibration and validation data should be obtained from different sources than the data used in estimating model parameters. As a result, one needs to identify unique sources of data that can support model calibration and validation. For the purpose of this report, calibration and validation data are those data that can be used to compare with model predictions to determine the reasonableness of the model parameters. Model calibration and validation data also are used as a means to adjust the model parameter values so that model predicted travel match observed travel in the region. This is especially important when applying nationally derived model parameters to a specific region.

The focus of this section is to provide various model calibration and validation techniques necessary for each of the freight and truck modeling components. The methodology and the data required are described in detail in the following sections. This section comprises numerous data sources with case studies relevant to the validation of various freight and truck modeling techniques.

■ 8.2 Trip Generation Validation

The trip generation model estimates the number of truck trips to and from each TAZ in the study area. In this step of the travel forecasting process, socioeconomic data are used to estimate the daily truck trips within the study area, i.e., internal-internal, and with origins or destinations outside the study area, i.e., external-internal or internal-external. The trip generation model estimates trip productions and trip attractions.

Trip production and attraction models have been based primarily on one of two basic structures – linear regression models and land use-based trip rate models. The regression models for trip generation are generally developed when origin-destination surveys are conducted for relatively large sample sizes. The regression equations explain the variation in the truck trips based on one or more independent or explanatory variables such as employment and households. Two sets of regression equations are required, one each for the production end and the attraction end. The production models predict the truck trips produced based on variables at the production end, while the attraction models predict the trips being attracted based on variables at the attraction end. Therefore, these models estimate the coefficients for each explanatory variable and the robustness of the models are determined based on a range of statistics. These include the t-statistic associated with the standard error of the coefficient estimate for each variable and the R-square for the model that indicates how well it fits the data.

A major drawback with the linear regression models is that the explanatory variables are often interrelated and correlated with each other. It also assumes that the relationship between the explanatory variables, typically employment for freight and truck models, and the truck trips generated are linear.

The land use-based trip rate models are developed based on information on land uses at trip ends and the household and employment data at the zonal level. The trip rates are computed as a ratio between the total study area truck trips to a particular land use and the total study area employment for that particular land use. This approach is used for the trip ends, both production and attraction. The performance of this approach lies in the ability to stratify the employment into many categories and correlate it with the correct land use types. One or more types of employment can influence the truck trip generation on a particular land use type. The main disadvantage of this approach is the need to forecast the various types of employment. This approach also necessitates the data collection effort to be more informative in terms of land use types at trip ends.

There are a number of sources of error in the development of freight/truck trip generation models. The sampling error and bias in the travel survey affect the trip generation rates. Also, the models may not be specified correctly with the relevant explanatory variables. So, the validation procedure must include tests that involve the examination of total and land use-specific trip rates. These tests can be aggregated as well as disaggregated as described below.

8.2.1 Total Truck Trip Productions and Attractions per Employee

Objective – Compare estimated trip rates against national average rates.

One of the biggest issues in the internal model methodology is the data availability and methods of estimating trip generation. In 2002, the National Cooperative Highway Research Project (NCHRP) published Synthesis Report #298 on truck trip generation. This report critiques all of the available methods for estimating truck trip generation models and rates and presents data from numerous studies in North America. This report can be used to evaluate the reasonableness of the trip rates estimated from the trip generation model and can provide guidance on techniques for improving estimation of these rates.

The QRFM that provides truck trip rates by land use category from a number of different studies also can be used as a means to validate and adjust the trip rates computed from the trip diaries during model calibration. Other sources of validation data for trip generation can include previous version of travel models, local studies on truck trips at various business facilities, and dispatch logs of truckers that some motor carriers maintain.

8.2.2 Total Truck Trips by Purpose or Business Sector

Objective – Compare estimated truck trips by business sector against other local models/reports/data and studies from other regions and agencies.

Due to the varying trip-making behavior of trucks across different business sectors, different trip generation models are usually estimated by business sector that are analogous to trip purpose in a passenger travel model. The typical sectors include manufacturing, warehouses/distribution centers, retail, local pickup and delivery, and service industry. The model results from other regions and agencies can be used to compare the estimated trips or percentage of total trips by business sector to do a reasonableness check.

8.2.3 Observed versus Estimated Truck Trips

Objective – Compare estimated truck trips against observed data by sector, geography, and truck type.

The best validation test is to compare the estimate truck trips against observed data. This test should usually be done by different sectors, geographical area, and truck type. Just like the travel characteristics of truck trips are different across sectors, they also vary by geographical location and truck type. The distribution of land uses and employment in a region drives the variability of truck travel behavior by geography, and the nature of freight flows and the commodity being shipped influences the travel behavior of trucks of different weight classes.

The observed data is gathered either by traditional truck surveys for the entire region which are then expanded to the entire truck population. This expanded data gives the O-D truck trip data at the zonal level for the region or study area. Another source of data is truck intercept surveys at certain key locations in the region. Vehicle classification counts also can be used to develop validation targets for truck trip generation models at those locations where counts are collected.

The differences between observed and estimated trip totals may be due to either error in the trip generation model, or the sampling error in the truck travel survey. These differences need to be reduced to an acceptable range during model calibration that could involve many steps. These include adjusting the trip rates, re-estimating models with different set of explanatory variables, regrouping sectors, and reclassifying truck types.

8.2.4 Coefficient of Determination (R-Square)

Objective – Check the model for its predictive power.

The coefficient of determination, or R-square, measures the proportion of variability in the survey data that is accounted for in the trip generation model. If the value is closer to 1.0, then the model is considered statistically a good model with good predictive power. If the R-square is low, then it could be either the variables specified are not the right kind, or they are correlated to one another. This also is attributed to low sample sizes with large variances.

8.2.5 Plot of Observed versus Estimated Trips (or Trip Rates)

Objective – Check the model for geographical biases.

This validation test is usually done at the district level to see how well the estimated trip or trip rates compare with the observed data. This is a good indicator of model performance and also can help in detecting in any geographical biases, which will need specific attention during calibration.

8.2.6 Disaggregate Validation – Observed versus Estimated

Objective – Apply model to survey records.

A simple and common method of validating the model estimated is to apply it to the survey data that was used in the estimation. That is, applying the trip generation model to the survey records to estimate the productions and attractions. The comparison of the estimated trip end totals to that of the survey totals can be done at any desired level, from very disaggregate to aggregate.

8.3 Trip Distribution Validation

Trip distribution links the trip productions in the region with the trip attractions to create matrices of interzonal and intrazonal travel, called trip tables. The critical outputs of trip distribution are trip length and travel orientation (suburb to CBD, CBD to suburb, etc.), and the resulting magnitude of traffic and passenger volumes. The most common form of model used for trip distribution is the gravity model. The inputs for gravity model-based trip distribution models are productions and attractions for each zone and a matrix of interzonal and intrazonal travel impedances. The productions and attractions are derived from the trip generation model while the travel impedances are obtained from determining the path of least resistance between each pair of zones.

Travel impedances reflect the spatial separation of the zones based on shortest travel-time paths for each zone-to-zone interchange. Some models use a generalized cost approach which converts highway travel time to cost and combines the time cost with other highway costs, including operating expenses (i.e., gas, wear-and-tear), parking, and tolls. Regardless of the procedure used to estimate travel impedances, several types of reasonableness checks can be performed to ensure that the highway skims contain realistic values. The first is a simple determination of implied speeds for each interchange. The second might be a simple frequency distribution of speeds on all interchanges. Another aggregate network-level check is of terminal times. These represent the time spent traveling to/from a vehicle to/from the final origin or destination within the TAZ. Terminal times are generally determined using the area type of the TAZ. The terminal times may be adjusted as part of the trip distribution model calibration process in order to make the average trip lengths produced by the model more closely match the observed average trip lengths. If terminal times are used to adjust impedances, then these will tend to shift the friction factor curve to the right making the distribution of trips from that zone less sensitive to impedance.

During calibration of trip distribution models, the observed and estimated trip lengths are both calculated using network-based impedance. Most travel demand modeling packages automatically calculate average trip length for all trip interchanges. In effect, it is finding the average travel time from the skims matrix weighted by the trip matrix. Some of the truck travel surveys like the trip diary approach do ask truckers to report travel times for their trips. However, these times are not considered as reliable as the origin and destination information obtained from the survey. The reported times are used only to provide an approximate estimate of truck trip lengths in the model validation.

Another source of trip length data is the 2002 VIUS, which consists of trip summaries of commercial vehicles in the entire country. The VIUS data also can be summarized by state or metropolitan areas within a state and also can be done by industry sector and truck type.

8.3.1 Compare Average Trip Lengths

The most standard validation checks of trip distribution models used as part of the calibration process are comparisons of observed and estimated truck trip lengths. The modeled average trip lengths should generally be within five percent of observed average trip lengths. This is typically done by truck type or weight class, and also can be extended to include the sector type stratification, if data permits.

If a generalized cost is used as the measure of impedance, average trip lengths and trip length frequency distributions should be checked using the individual components of generalized cost (e.g., time and distance).

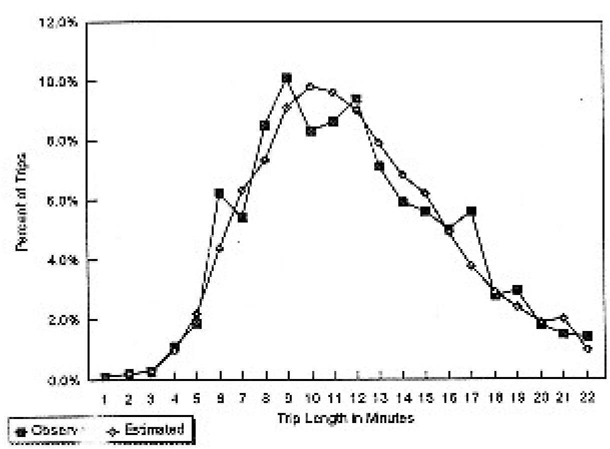
8.3.2 Compare Trip Lengths for Trips Produced versus Trips Attracted

Another way of calibrating the gravity model is by comparing truck trip lengths for trips produced against the trip attracted by sector and area type. This will indicate if the model is performing well at both trip ends and if it is reflecting the observed distribution of truck flows by sector and area type. The average trip lengths sent (produced) and received (attracted) by district also could be mapped using GIS to examine the model performance.

8.3.3 Plot Trip Length Frequency Distributions

The plot of trip length frequency distribution shows how well the model can replicate observed trip lengths over the range of time. The visual comparison of distributions such as shown in Figure 8.1 is an effective method for calibration and validation. A quantitative measure which can be used to evaluate distribution validation is the coincidence ratio.

Figure 8.1 Trip Length Frequency Distribution



Coincidence Ratio

The coincidence ratio is used to compare two distributions. In using the coincidence ratio, the ratio in common between two distributions is measured as a percentage of the total area of those distributions. Mathematically, the sum of the lower value of the two distributions at each increment of X is divided by the sum of the higher value of the two distributions at each increment of X. Generally, the coincidence ratio measures the percent of area that "coincides" for the two curves.

The procedure to calculate the coincidence of distributions is as follows:

$$\text{Coincidence} = \text{sum}\{\min(\text{count}_{+X}/\text{count}_{+}, \text{count}_{-X}/\text{count}_{-})\}$$

$$\text{Total} = \text{sum}\{\max(\text{count}_{+X}/\text{count}_{+}, \text{count}_{-X}/\text{count}_{-})\}$$

Calculate for X = 1, maxX

Coincidence Ratio = coincidence/total

where,

count_{+T} = value of estimated distribution at time T

count_{+} = total count of estimated distribution

count_{-T} = value of observed distribution at time T

count_{-} = total count of observed distribution

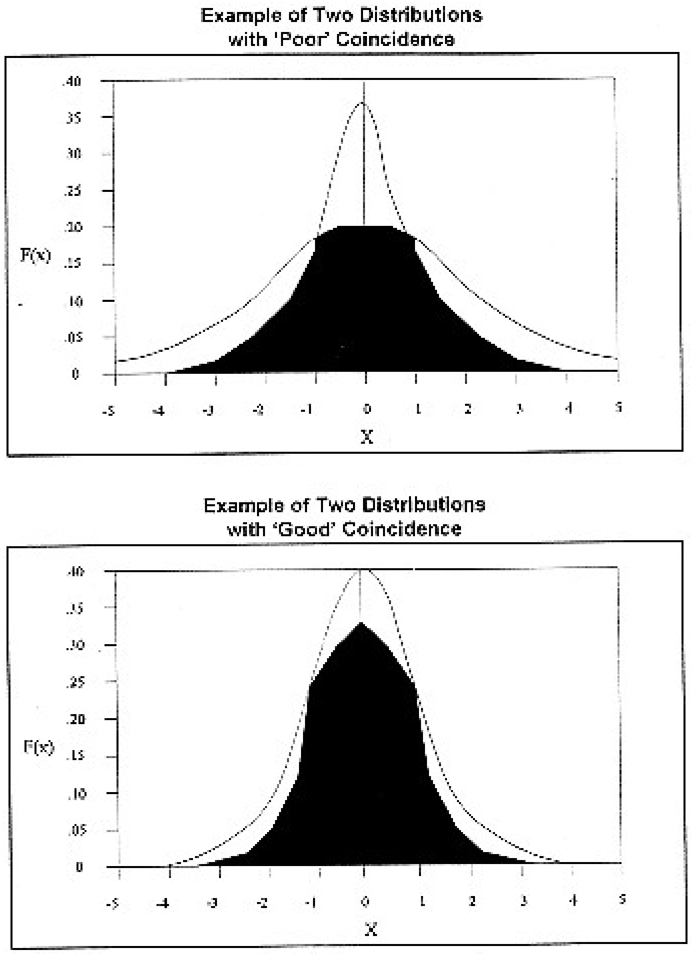
The coincidence ratio lies between zero and one, where zero indicates two disjoint distributions and one indicates identical distributions. An example is presented in Figure 8.2, where the shaded areas represent how well the distributions match or coincide. The top chart has a much smaller shaded portion than the bottom chart, which indicates a better match in the distributions in the bottom chart. Thus, the coincidence ratio will be higher for the bottom chart.

8.3.4 Plot Normalized Friction Factors

If a gravity model is used for trip distribution, then it also is worthwhile to plot the calibrated friction factors (scaled to a common value at the lowest impedance value). Such a plot provides a picture of the average trucker's sensitivity to impedance by truck type or sector, and can be compared to friction factors from other regions. For example, certain types of truck trips might be less sensitive to travel time since these trips must be made every day and can usually not be shifted to off-peak conditions or to different locations. This phenomenon can be observed from the plot where the friction factors show gradual change as travel time increases.

If there are significant differences between observed and estimated trip lengths, then this may be due to either inadequate closure on production/attraction balancing or travel impedances may be too high or too low. After validating the trip distribution model at a regional level, the model results should be checked for subgroups of trips and segments of the region.

Figure 8.2 Coincidence Ratio for Trip Distribution



8.3.5 Compare Observed and Estimated District-to-District Trip Interchanges and Major Trip Movements

Although comparing trip lengths provides a good regional check of trip distribution, the model can match trip lengths without distributing trips between the correct locations. In order to permit easier review of the truck trip tables, zonal interchanges can be summarized into counties, districts, or groups of zones. Trips to the major employment area in the region (i.e., CBD) should be reviewed. Major trip movements to various special generators such as ports, airports, and intermodal facilities should be summarized as well.

K-Factors

K-factors are usually district-to-district factors that correct for major discrepancies in trip interchanges. These factors are computed as the ratio between observed and estimated trip interchanges. K-factors are typically justified as representing economic activity that affect truck trip making but are not otherwise represented in the gravity model.

The use of K-factors is, however, generally discouraged and seen as a major weakness f traditional gravity models when used to correct for intangible factors. Since K-factors represent characteristics of the economic activity and population which change over time, the assumption that K-factors stay constant in the future can introduce a significant amount of error in predictions of future trip distributions.

8.4 Mode Split Validation

Mode split models are unique to studies that deal with multimodal facilities; that is, besides roadways for trucks, they involve railways for trains carrying freight, water transportation at ports, and by air at airports. These studies often deal with commodity-based freight flows (in tonnage) that are split into different transportation modes based on the characteristics of the shipment being carried, destination, cost, and delivery time associated with the shipments. The treatment of modal choice can vary a great deal by region and the availability of various facilities. For regions with limited or no rail, water and air transportation, it may be sufficient to apply a fixed mode split factors to determine the percentage of freight moved other than by trucks.

Mode split is usually based on a logit mode choice model and historical mode split percentages. Most statewide models utilize qualitative estimates varying observed mode shares. The reason behind this is because mode choice for freight does not follow strict probabilistic rules because the magnitude of freight flows in tons is determined by only a few shipper or carrier decision-makers.

8.4.1 Comparison of Mode Split Model Coefficients with Other Studies

The basic validation test for a mode split model is to compare the estimated model coefficients with other studies that deal with similar modes and under similar conditions. This gives an indication if the model is performing within reasonable expectations. The important things to look for are the signs and magnitudes of the level of service variables such as cost and time. These should always be negative and within acceptable range of values. The values of time associated with each mode also should be computed to determine the reasonableness of the coefficients.

The comparison of model coefficients and derived variables can be considered both a validation check and a sensitivity check. Typically, when mode choice models are estimated, not only the model coefficients, but also derived ratios and model elasticities are compared to those from other regions. If model coefficients (and constants) and derived ratios are in the range of what has been reported elsewhere, the model sensitivity should be similar to models used in other regions. Tests on sensitivity are described in the following section.

8.4.2 Sensitivity Tests – Elasticity of Demand to Supply Relationship

A common sensitivity test for mode choice models is the direct or cross elasticities of the model. Elasticities can be used to estimate the percent change in demand given a percent change in supply. As with the values of the model coefficients and derived ratios, elasticities can be considered as both validation and sensitivity tests. Sensitivity tests can be made on model elasticities for costs and travel-time attributes. Sensitivity tests are performed by applying the model with unit changes in variables, e.g., a $0.25 increase in cost or a 10 percent increase in travel time.

8.4.3 Observed versus Estimated Shares of Freight Flows

An aggregate validation test is to compare the estimated shares to that of observed shares of freight flows by different modes of travel such as trucks, rail, ship, and air. This test can be used as a calibration procedure which involves adjusting the modal constants until the shares match well within acceptable ranges.

■ 8.5 Assignment Validation

Trip assignment is the fourth and last step of the traditional four-step process. This includes both passenger and commercial vehicle assignment carrying people and goods respectively. The assignment of trips to the network is the final output of the modeling process and becomes the basis for validating the model set's ability to replicate observed travel in the base year as well as to evaluate the transportation improvements in the future years. Depending on the level of analysis being done, the assignment can be to a regional highway network for systemwide planning or to a detailed network for a subarea or corridor study.

The calibrated commercial vehicle trip tables are assigned to a network along with passenger vehicle trip tables to produce estimates of total traffic on network links. There are, however, some special considerations that may affect the assignment of commercial vehicle trips. These include the larger impact of trucks on congestion than passenger vehicles on a per VMT basis, existence of truck only lanes, and the prohibition of trucks on certain corridors in a region.

The Highway Capacity Manual provides "passenger car equivalence" (PCE) factors that can be used to quantify the relative impact of different types of vehicles on congestion. For example, a PCE value of 2.0 indicates that the vehicle in question has the same effect on congestion as 2.0 passenger cars. Specifically, the HCM recommends a PCE value of 1.5 for trucks and buses on level terrain, with trucks defined as commercial vehicles with six or more tires. Hence, to reflect the effect of heavier vehicles on congestion, the trip tables for single-unit trucks with six or more tires and combinations can be multiplied by 1.5 and 2.0, respectively, before being assigned to the network. The resulting assignment volumes will then be expressed in PCEs, not number of vehicles. No adjustments to PCE values are needed for four-tire commercial vehicles, since these vehicles are generally similar to passenger cars in terms of acceleration and deceleration capabilities. Though usually not considered as a major factor, the grade of roadway facilities also plays a significant role in determining the actual PCE value of a truck. In some applications, a variable PCE methodology also is adopted to increase the performance of the assignment model. Adjusting the PCE values also is considered a calibration techniques to better match the observed truck traffic counts by weight class.

If trucks are prohibited from using key network links, then the truck prohibitions must be enforced in the basic network description. Usually, four-tire commercial vehicles such as pickup trucks and vans are not considered to be trucks for the purpose of enforcing truck bans, so that such vehicles would be combined with passenger cars in the assignment process. In some areas, truck-only lanes also are considered to better regulate the traffic flows during congested time periods and areas. So this also should be properly accounted for when developing the roadway network attributes.

The validation tests for truck assignments are presented at three levels: systemwide, corridor, and link specific. There are several systemwide or aggregate validation checks of the assignment process. The checks are generally made on daily volumes, but it is prudent to make the checks on volumes by time of day as well. Systemwide checks include VMT, cordon volume summaries, and screenline summaries.

8.5.1 Vehicle Miles Traveled

Objective – Compare model VMT against HPMS VMT estimates by functional classification and area type.

The validation of a truck model using VMT addresses all major steps in the travel model system, including trip generation (the number of trips), trip distribution (the trip lengths), and assignment (the paths taken). Using observed data such as traffic counts and roadway mile, a regionwide estimate of VMT can be developed to be used for validating the base year assignment of commercial vehicles produced by a travel demand model. These traffic counts are collected in most urban areas as part of the ongoing transportation planning process and are used to validate the passenger portion of urban travel demand models. In addition to any counts that might be undertaken for planning purposes, state DOTs are required to include Annualized Average Daily Traffic Counts and mileage for all roadways, based on a statistical sample, for each urban area as part of their annual Highway Performance Monitoring System (HPMS) submittal. The HPMS VMT can be summarized by functional classification of highways and by area type and compared to the urban area model volumes by functional classification and area type. When using HPMS estimates of VMT, it is important to understand that VMT is for all roadways, including local roads. Travel demand models, in contrast, generally do not include these local roads so this comparison should consider an adjustment for them to allow for a comparison of the total observed and estimated VMT.

Generally, traffic counts are collected and VMT is calculated either for all vehicles or for vehicles classified by axle configuration. Traffic count information is predominately collected by Automatic Traffic Recorders (ATR) and, thus will rarely include any other classification of commercial vehicles. This information will typically be based on a visual identification of commercial markings on the vehicle or a visual observation of the commercial registration plate.

HPMS estimates of percentages of single unit and combination trucks, based on ATRs, can be used to develop VMT for these types of trucks. Not all commercial vehicles are included in these classes and intercity freight trucks that are excluded from the definition of urban commercial vehicles are responsible for a considerable portion of the truck travel on higher functional classes. Nevertheless, HPMS estimates of truck VMT can be used to validate commercial vehicle models. It should be noted, however, that the HPMS values for trucks are based on statistical samples. Thus, the “observed” truck VMT is in reality an estimate.

Based on accepted standards for model validation, modeled regional VMT should generally be within 5 percent of observed VMT.[1] When the regional models are used to track VMT for air quality purposes, the Environmental Protection Agency requires that estimates be within 3 percent. However, these estimates are for the total of all vehicles irrespective of vehicle type. If commercial vehicles generally represent 13 percent of total VMT, and if a travel demand model’s estimate of commercial VMT is within 5 percent of that value, it would be consistent with the overall validation standards.

The mix of commercial vehicles by functional class will, however, vary considerably by vehicle category. For example, school buses travel almost exclusively on local or collector roads, while urban freight vehicles travel principally on the arterial system. Thus, commercial vehicles cannot be expected to have the same distribution by functional classification as that of other vehicles. However, the variability of usage of the functionally classified roads by urban area size can be expected to occur for commercial vehicles.

In addition to validating modeled VMT to observed VMT by functional class, it is customary to use measures such as VMT per person or per household to assess the reasonableness of urban models. Reasonable ranges of total VMT per household are 40 to 60 miles per day for large urban areas and 30 to 40 miles per day for small urban areas (Barton-Aschman, 1997). If one applies the 13 percent of total VMT that is estimated for commercial VMT to these household ranges, then the VMT per household for commercial vehicle demand would represent 5 to 8 miles per day for large urban areas and 4 to 5 miles per day for small urban areas.

[1] Barton-Aschman Associates and Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking Manual*, Travel Model Improvement Program, FHWA, 1997.

There are many useful statistics that can be calculated for the systemwide-level validation of VMT. These include both the absolute and relative (percent) difference. Another measure is to compare current estimates of regionwide VMT with the historical trend and rate of growth from HPMS. The absolute difference is the simple difference between observed and modeled VMT. The difference is typically large for high-volume links and low for low-volume links, so the size of the numerical difference does not reliably reflect the true significance of error. Percent difference is often preferred to absolute difference since its magnitude indicates the relative significance of error. Modeled regional VMT should generally be within five percent of observed regional VMT. This five percent difference is particularly important in light of the accepted error that EPA allows for VMT tracking using the HPMS data.

8.5.2 Vehicle Classification Counts

Objective – Compare modeled truck traffic volumes against observed truck traffic counts – screenlines, area type, volume group, and facility type.

Travel demand models are validated by comparing observed versus estimated traffic volume on the highway network and by comparing summations of volumes at both cordons and screenlines. Vehicle classification counts have been used to validate automobile and truck volumes, but this is not directly useful to validate commercial vehicles by category, since many categories contain both automobiles and trucks. Nonetheless, it is one of the only sources to verify the reasonableness of traffic volumes based on the inclusion of commercial vehicles into the transportation planning models.

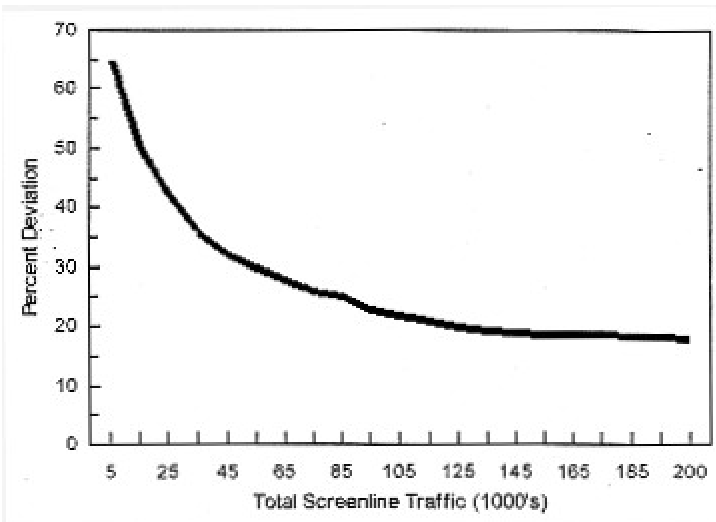
The vehicle classification count data, which classifies vehicles according to the 13-axle-based classes of the FHWA, is generally available from state departments of transportation for sampled sets of streets and highways. For the 13 classes, the information includes counts by location, hour of the day, and date. In summary format, this information generally presents truck volumes (defined as FHWA Classes 5 through 13, six tires and above) and occasionally includes buses (FHWA Class 4). Four-tire pickup trucks, vans, and sport utility vehicles (FHWA Class 3), are almost always included with passenger cars.

After assignments of commercial vehicles by type (automobile and truck at a minimum), the vehicle classification counts can be used to compare the observed automobile and truck counts (and shares by vehicle type) with the estimated automobile and truck volumes (and shares) produced by the travel demand model. These vehicle assignments will include both personal and commercial vehicles, derived from both personal and commercial models, so calibration adjustments deemed necessary from these comparisons may be required for either the personal or commercial models or both. The validation summaries also are usually summarized by functional class, area type, and screenlines.

Compare Observed versus Estimated Volumes by Screenline

The validation targets can vary for screenlines depending upon the importance of the screenline locations in the study area. Figure 8.3 shows the maximum desirable deviation in total screenline volumes according to the observed screenline volume.

Figure 8.3 Maximum Desirable Deviation in Total Screenline Volumes



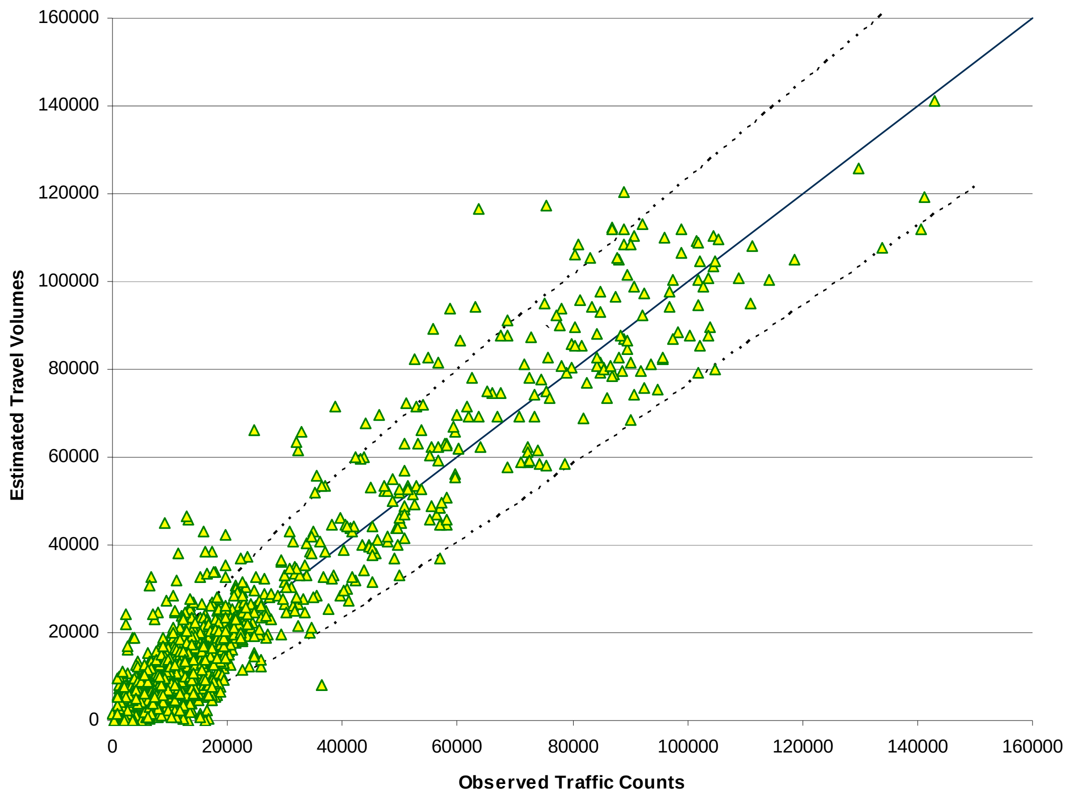
Compare Observed versus Estimated Volumes for All Links with Counts

With the use of the on-screen network editors and plots of network attributes, the checking of link level counts visually is relatively simple. In addition to visually checking the correlation of the counts to volumes, as shown in Figure 8.4, it also is useful to compute aggregate statistics on the validity of the traffic assignment. There are two measures computed widely during model validation, and these are the correlation coefficient and the percent root mean square of the error (RMSE).

R^2 (Coefficient of Determination)

R^2 is computed to determine the performance of the model predictability. It is used to compare the regionwide observed traffic counts to that of the estimated volumes regionwide. A value closer to 1.0 indicates a better model. Another useful validation tool is to plot a scattergram of the counts versus the assigned volumes (as shown in Figure 8.4). Any data points (links) that lie outside of a reasonable boundary of the 45-degree line should be reviewed.

Figure 8.4 Assigned versus Observed Average Daily Traffic Volumes



RMSE

The RMSE is computed using the following formula:

$$\%RMSE = \frac{(\sum_j (Model_j - Count_j)^{2/} (NumberofCounts - 1))^{0.5} * 100}{(\sum_j Count_j / NumberofCounts)}$$

The acceptable RMSE ranges vary based on the facility type; it should be as small as 5 percent for freeways and expressways, and as large as 40 to 50 percent for local and minor arterials.

Model Parameters

There are a number of parameters in an assignment model that are potential sources of error. Although the actual parameters and calculation options involved depend on the modeling software and assignment methodology being used, other possibilities include:

- Assignment procedures, including number of iterations, convergence criterion, expansion of incremental loads, and damping factors;
- Volume-delay parameters such as the BPR coefficient and exponent;
- Peak-hour conversion factors used to adjust hourly capacity and/or daily volumes in volume-delay function;
- PCE factors for commercial vehicles;
- Scaling or conversion factors to change units of time, distance, or speed (miles/hour or kilometer/hour);
- Maximum/minimum speed constraints;
- Preload purposes (HOV, through trips, trucks, long/short trips); and
- Toll queuing parameters (diversion, shift constant, etc.).

8.5.3 Registration Records

Objective – Comparison of model fleet sizes against observed fleet sizes by sector and district/county/region.

State vehicle registration databases often indicate whether registered vehicles are used for commercial purposes. These databases typically show vehicle weight classes, but not service use. Service use can be inferred based on vehicle make/model, weight class, owner, and possibly other data. However, this requires considerable data processing. Many states databases also do not include odometer readings. It also should be recognized that motor carriers and private fleet operators may register their trucks in states with based not on operations but on consideration of state taxes and regulations and adjustments and thus state truck registrations may underestimate or overestimate the actual size of a state's active truck fleet.

In a recent Federal research effort, Cambridge Systematics came up with an approach to compute and compare the modeled truck fleet sizes against the observed fleet sizes derived from local DMV registration data. Vehicle registration databases that are maintained by a state can yield useful information on the number of commercial vehicles existing within a particular geographic area. For example, the California Energy Commission has been working with the California DMV and other agencies since the late 1990s in an effort to clean, organize, and analyze the State's vehicle data. The California DMV employed all key words from the 120-character owner field of each record in the database that reveal any potential business use information. The Energy Commission divided the DMV data into two main groups: 1) light vehicles and 2) medium and heavy vehicles. It further divided the light vehicle category by use, and the medium and heavy vehicle category by body type.

Based on use and body-type subcategories, the registration data was mapped to the 12 categories of commercial vehicles, as shown in Table 8.1. No vehicle types in the California DMV database correlate to the following commercial vehicle categories in this study: Shuttle Service: Airports, Stations; Private Transportation: Taxi, Limos, Shuttles and Paratransit: Social Services, Church Buses.

Table 8.1 California DMV Vehicle Types by Commercial Vehicle Category

Commercial Vehicle Category	California Light-Duty Vehicles	California Medium- and Heavy-Duty Vehicles
1 School Bus		Bus
5 Rental Cars	Daily Rental	
6 Package, Product and Mail Delivery: USPS, UPS, FedEx, etc.		Parcel Delivery
7 Urban Freight Distribution, Warehouse Deliveries		Automobile Carrier, Beverage Cargo Cutaway, Dromedary, Logger, Multiple Bodies, Refrigerated, Stake or Rack, Tandem, Tank, Tractor Truck, Tractor Truck Gas
8 Construction Transport		Boom, Concrete Mixer Crane, Cutaway, Dump, Flat Bed/ Platform, Motorized Cataway
9 Safety Vehicles: Police, Fire, Building Inspections, Tow Trucks	Government – District – Fire Government – District – Police	Ambulance Fire Truck Tow Truck Wrecker
10 Utilities Vehicles (Trash, Meter Readers, Maintenance, Plumbers, Electricians, etc.)	Government – District – Utility Government – District – Water/ Irrigation	Garbage Utility
11 Public Service (Federal, State, City, Local Government)	Government – City Government – County Government – State Government – Federal Government – District – School Government – District – College Government – District – Transit Government – District – Other	
12 Business and Personal Services (Personal Transportation, Realtors, Door-to-Door Sales, Public Relations)	Other Commercial	Armored Truck, Panel, Pickup, Step Van, Van
Not Categorized	Personal	Chassis and Cab, Conventional Cab, Forward Control, Gliders Incomplete Chassis, Tilt Cab, Tilt Tandem, Unknown, Motorized Home

Source: California Department of Motor Vehicles registration data processed by the California Energy Commission, 2002.

The California DMV data has a large category of "other commercial" light duty vehicles that was assigned to the business and personal services categories. Since not all "other commercial" vehicles are being used for commercial purposes, this category can be factored to exclude the business and personal service vehicles used for personal activities, based on the VIUS estimates of the use of these vehicles. The VIUS Business and Personal Services category vehicles was then cross-tabulated by business use and personal use, and it was determined that in California, 22 percent of total vehicles (both personal and commercial) are used for commercial purposes. Accordingly, "other commercial" vehicles in the California DMV data were multiplied by 0.22 to obtain the numbers of Business and Personal Services vehicles as shown in Table 8.2.

Table 8.2 Business and Personal Services Vehicles in California Cities

	San Francisco	Los Angeles	San Diego	Sacramento
"Other Vehicles" from California DMV Database	687,169	1,474,911	242,156	210,271
Factors from VIUS Database	0.22	0.22	0.22	0.22
Business and Personal Services Vehicles	152,263	321,445	50,488	43,984

Source: *Accounting for Commercial Vehicles in Urban Transportation Models*, FHWA, 2003.

Registration data, such as that collected by the California DMV, is the best source of fleet size statistics. Table 8.3 presents the California DMV data on fleet size for four California urban areas that could be used for calibration or validation of urban area commercial vehicle models.

Table 8.3 Fleet Sizes across Select Cities in California

Commercial Vehicle (CV) Category	San Francisco		Los Angeles		San Diego		Sacramento	
	Number of CV	Percent	Number of CV	Percent	Number of CV	Percent	Number of CV	Percent
School Bus	1,510	0.03%	5,259	0.05%	1,267	0.06%	1,011	0.07%
Rental Car	89,805	1.78%	88,217	0.83%	12,107	0.61%	9,913	0.69%
Package, Product, Mail	470	0.01%	449	0.00%	41	0.00%	42	0.00%
Urban Freight	22,484	0.44%	69,617	0.65%	8,510	0.43%	10,651	0.74%
Construction	22,561	0.45%	36,318	0.34%	6,939	0.35%	8,798	0.61%
Safety Vehicles	5,090	0.10%	11,149	0.10%	3,364	0.17%	7,090	0.49%
Utility Vehicle	7,552	0.15%	19,488	0.18%	2,729	0.14%	5,108	0.36%
Public Service	38,094	0.75%	83,219	0.78%	13,111	0.66%	36,710	2.56%
Business and Personal Services	152,263	3.01%	321,445	3.01%	50,488	2.55%	43,984	3.07%
Total Commercial Vehicles	**885,120**	**17.50%**	**1,806,460**	**16.90%**	**292,652**	**14.80%**	**291,849**	**20.34%**
Total Vehicles	**5,057,355**	**100%**	**10,688,810**	**100%**	**1,977,794**	**100%**	**1,434,670**	**100%**

Source: *Accounting for Commercial Vehicles in Urban Transportation Models*, FHWA, 2003.

Vehicle registration data for New York State are available at their web site.[2] These data are not as detailed as the California DMV data. Vehicle registration and new vehicle data also may be purchased from R.L. Polk & Co., a privately owned consumer marketing information company. Polk develops custom reports for customers, providing data by ZIP code, Metropolitan Statistical Area, county, state, or for the entire United States. The numbers of vehicles by type are summarized for five cities in Table 8.4.

Table 8.4 Fleet Sizes across Select Cities

	New York City (Bronx Only)		San Francisco		Los Angeles		San Diego		Sacramento	
Commercial Vehicle (CV) Category	**Number of CV**	**Percent**	**Number of CV**	**Percent**	**Number of CV**	**Percent**	**Number of CV**	**Percent**	**Number of CV**	**Percent**
Bus	624	0.2%	2,101	0.4%	19	0.3%	230	0.1%	72	0.0%
Taxi	5,394	2.0%	11,844	2.5%	175	2.5%	6,720	2.6%	325	0.2%
Trailer	1,561	0.6%	2,424	0.5%	57	0.8%	932	0.4%	8,981	4.2%
Ambulance	63	0.0%	642	0.1%	2	0.0%	135	0.1%	42	0.0%
Motorcycle	2,395	0.9%	4,831	1.0%	77	1.1%	5,374	2.1%	4,465	2.1%
Moped	80	0.0%	253	0.1%	4	0.1%	887	0.3%	146	0.1%
Rental Vehicles	334	0.1%	2,246	0.5%	78	1.1%	207	0.1%	2,236	1.0%
Total Commercial Vehicles	17,317	6.4%	38,420	8.2%	662	9.3%	21,885	8.5%	39,430	18.2%
Total Vehicles	**269,577**	**100%**	**470,290**	**100%**	**7,086**	**100%**	**257,531**	**100%**	**216,133**	**100%**

[2] New York State Department of Motor Vehicles, 2001.

9.0 Existing Data

This section presents an overview of existing freight transportation data sources that can be used in the planning process. It covers Commodity O-D Tables, Mode-Specific Data Sources, Employment/Industry Data, and Performance Data. A brief overview of the most common data sources is presented, including a summary of the methodology as well as the major drawbacks and positive aspects of each.

9.1 Commodity O-D Tables

There are several public and private sources for freight origin-destination data in the United States. This section discusses the four most commonly used ones: Global Insight's TRANSEARCH Data, the Federal Highway Administration's (FHWA), FAF1 and FAF2, and the U.S. Census Bureau's Bureau of Transportation Statistics' (BTS) Commodity Flow Survey (CFS). The discussion covers the general methodology used for each database as well as some of the major limitations.

9.1.1 Global Insight TRANSEARCH

TRANSEARCH is a privately maintained comprehensive market research database for intercity freight traffic flows compiled by Global Insight, formerly Reebie Associates. The database includes information describing commodities (by Standard Transportation Commodity Classification (STCC) code), tonnage, origin and destination markets, and mode of transport. Data are obtained from Federal, state, provincial agencies, trade and industry groups, and a sample of motor carriers. Forecasts of commodity flows for up to 25 years also are available.

TRANSEARCH data are generally accepted as the most detailed available commodity flow data and are commonly used by states, metropolitan planning organizations (MPO), and FHWA in conducing freight planning activities. However, it should be noted that there are some limitations to how this data should be used and interpreted:

- **Mode Limitations –** The Rail Waybill data used in TRANSEARCH are based on data collected by Class I railroads. The waybill data contain some information for regional and short-line railroads, but only in regards to interline service associated with a Class I railroad. This is important to Maine, as it does not have any direct service from a Class I railroad. The rail tonnage movements provided by the TRANSEARCH database, therefore, are conservative estimates.

- **Use of Multiple Data Sources –** TRANSEARCH consists of a national database built from company-specific data and other available databases. To customize the dataset for a given region and project, local and regional data sources are often incorporated. This incorporation requires the development of assumptions that sometimes compromise the accuracy of the resulting database. Different data sources use different classifications; most economic forecasts are based on SIC codes while commodity data are organized by STCC codes. For example, the U.S. Bureau of Census' VIUS has its own product codes that must be assigned to STCCs to convert truck commodity flows to truck trips. These and other conversions can sometimes lead to some data being miscategorized or left unreported.

- **Data Collection and Reporting –** The level of detail provided by some specific companies when reporting their freight shipment activities limits the accuracy of TRANSEARCH. If a shipper moves a shipment intermodally, for example, then one mode must be identified as the primary method of movement. Suppose three companies make shipments from the Midwest United States to Europe using rail to New York then water to Europe. One company may report the shipment as simply a rail move from the Midwest to New York; another may report it as a water move from New York to Europe; the third may report the shipment as an intermodal move from the Midwest to Europe with rail as the primary mode. The various ways in which companies report their freight shipments can limit the accuracy of TRANSEARCH.

- **Limitations of International Movements –** TRANSEARCH does not report international air shipments through the regional gateways. Additionally, specific origin and destination information is not available for overseas waterborne traffic through marine ports. Overseas ports are not identified and TRANSEARCH estimates the domestic distribution of maritime imports and exports. TRANSEARCH data also do not completely report international petroleum and oil imports through marine ports. This is a concern to a state like Maine, which receives large amounts of petroleum through its major marine ports from Canada. Finally, TRANSEARCH assigns commodity data only to the truck, rail, air, and water modes, though a large percentage of foreign imports (by weight) consist of oil and petroleum products – commodities that are frequently shipped via pipeline to storage and distribution points.

9.1.2 FHWA Freight Analysis Framework

In order to better understand freight demands, assess implications for the surface transportation system, and develop policy and program initiatives to improve freight efficiency, FHWA developed a Freight Productivity Program. The first generation of FAF1 was developed by FHWA as part of that program to document the magnitude and geography of freight moving within the United States; analyze changes in freight flows and networks; highlight mismatches in national and regional freight demand and supply; and understand the regional significance of freight corridors and nodes.

FAF1 is essentially a modified version of Global Insight's TRANSEARCH database. Two important enhancements from the "off-the-shelf" TRANSEARCH database were included in FAF1. First, FAF1 provided better coverage of agricultural products, particularly in the truck mode. Second, freight rail movements in FAF1 reflect additional work that was done to better identify rail export volumes. The resulting county-to-county movements were summarized at the state level for release to state DOTs and MPOs.

The FAF1 data provide flows of specific commodities by mode (truck, rail, air, and water) for a base year (1998) and forecasts of freight movement by mode for 2010 and 2020. Forecasted freight movements were developed using forecasts of specific industries. While these data do not provide the level of geographic detail to be useful for detailed statewide or metropolitan freight planning, they are useful in identifying key transportation corridors and how those corridors are expected to grow in the future.

In 2006, the FHWA published the second generation of FAF (FAF2), which improved on the first version by providing more geographic regions that cover substate areas (FAF2 includes 114 zones, while FAF1 displayed only interstate flows); providing international freight flows to Canada, Mexico, Latin and South America, Asia, Europe, the Middle East, and the rest of the world through more than 75 international gateways in the country; providing seven mode classifications (truck, rail, water, air, pipeline, intermodal, and others) instead of the traditional four provided by FAF1 (truck, rail, air, water); and providing commodity data using the two-digit Standard Classification of Transported Goods (SCTG) scheme in order to match the 2002 CFS.

The FHWA notes that FAF2 is based entirely on public data sources and transparent methods and has been expanded to cover all modes and significant sources of shipments. Because the scope and methods changed significantly since FAF1, statistics from FAF2 and the original FAF should not be compared. Furthermore, the same limitations that apply to Global Insight's TRANSEARCH data apply to both FAF1 and 2.

The FHWA has recently published forecasts for FAF2 that extend to 2035, the complete database and documentation are available on-line for download at: http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm.

9.1.3 Census Bureau Commodity Flow Survey

The 2002 CFS is undertaken through a partnership between the U.S. Census Bureau, U.S. Department of Commerce, and the BTS, U.S. Department of Transportation. This survey produces data on the movement of goods in the United States. It provides information on commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of shipments of manufacturing, mining, wholesale, and select retail establishments. The data from the CFS are used by public policy analysts and for transportation planning and decision-making to assess the demand for transportation facilities and services, energy use, and safety risk and environmental concerns.

Industry Coverage

The 2002 CFS covers business establishments with paid employees that are located in the United States and are classified using the 1997 North American Industry Classification System (NAICS) in mining, manufacturing, wholesale trade, and select retail trade industries, namely, electronic shopping and mail-order houses. Establishments classified in services, transportation, construction, and most retail industries are excluded from the survey. Farms, fisheries, foreign establishments, and most government-owned establishments also are excluded.

The survey also covers auxiliary establishments (i.e., warehouses and managing offices) of multi-establishment companies, which have nonauxiliary establishments that are in-scope to the CFS or are classified in retail trade. The coverage of managing offices has been expanded in the 2002 CFS, compared to the 1997 CFS. For the 1997 CFS, the number of in-scope managing offices was reduced to a large extent based on the results of the 1992 Economic Census. A managing office was considered in-scope to the 1997 CFS only if it had sales or end-of-year inventories in the 1992 Census. However, research conducted prior to the 2002 CFS showed that not all managing offices with shipping activity in the 1997 CFS indicated sales or inventories in the 1997 Economic Census. Therefore, the 1997 Economic Census results were not used in the determination of scope for managing offices in the 2002 CFS.

Shipment Coverage

The CFS captures data on shipments originating from select types of business establishments located in the 50 states and the District of Columbia. The data do not cover shipments originating from business establishments located in Puerto Rico and other U.S. possessions and territories. Shipments traversing the United States from a foreign location to another foreign location (e.g., from Canada to Mexico) are not included, nor are shipments from a foreign location to a U.S. location. Imported products are included in the CFS at the point that they left the importer's domestic location for shipment to another location. Shipments that are shipped through a foreign territory with both the origin and destination in the United States are included in the CFS data. The mileages calculated for these shipments exclude the international segments (e.g., shipments from New York to Michigan through Canada do not include any mileages for Canada). Export shipments are included, with the domestic destination defined as the U.S. port, airport, or border crossing of exit from the United States.

Availability

The 2002 CFS documentation and reports are available on the BTS site at: http://www.bts.gov/publications/commodity_flow_survey/.

■ 9.2 Mode-Specific Freight Data

This subsection covers publicly available data that deal with specific modes, such as the VIUS, the Carload Waybill Sample, and the U.S. Army Corps of Engineers' (USACE) Waterborne Commerce Statistics Database. As with the previous subsection, the discussion covers the general methodology used for each database as well as some of the major limitations.

9.2.1 U.S. Census Bureau's Vehicle Inventory and Use Survey (VIUS)

The VIUS provides data on the physical and operational characteristics of the nation's truck population. Its primary goal is to produce national and state-level estimates of the total number of trucks. The first survey was conducted in 1963. It was then conducted every five years beginning in 1967 and continuing to 2002. Prior to 1997, the survey was known as the Truck Inventory and Use Survey (TIUS). VIUS has not been included in the budget for the 2007 Economic Census, and the 2002 VIUS may be the last survey available.

VIUS data are of considerable value to government, business, academia, and the general public. Data on the number and types of vehicles and how they are used are important in studying the future growth of transportation and are needed in calculating fees and cost allocations among highway users. The data also are important in evaluating safety risks to highway travelers and in assessing the energy efficiency and environmental impact of the nation's truck fleet. Businesses and others make use of these data in conducting market studies and evaluating market strategies; assessing the utility and cost of certain types of equipment; calculating the longevity of products; determining fuel demands; and linking to, and better utilizing, other datasets representing limited segments of the truck population.

Public use microdata files are available for years 1977 and later. Publications are available for all years. Visit http://www.census.gov/svsd/www/vius/products.html to access these files and publications.

Methodology and Limitations

The VIUS is a probability sample of all private and commercial trucks registered (or licensed) in the United States. The sample size for each year is:

Year	Sample Size
2002	136,113
1997	131,083
1992	153,914
1987	135,290
1982	120,000
1977	116,400
1972	113,800
1967	~ 120,000
1963	~ 115,000

The VIUS excludes vehicles owned by Federal, state, or local governments; ambulances; buses; motor homes; farm tractors; and nonpowered trailer units. Additionally, trucks that were included in the sample but reported to have been sold, junked, or wrecked prior to the survey year (date varies) were deemed out of scope.

The sampling frame was stratified by geography and truck characteristics. The 50 states and the District of Columbia made up the 51 geographic strata. Body type and gross vehicle weight (GVW) determined the following five truck strata:

1. Pickups;
2. Minivans, other light vans, and sport utilities;
3. Light single-unit trucks (GVW 26,000 pounds or less);
4. Heavy single-unit trucks (GVW 26,001 pounds or more); and
5. Truck-tractors.

Therefore, the sampling frame was partitioned into 255 geographic-by-truck strata. Within each stratum, a simple random sample of truck registrations was selected without replacement. Older surveys were stratified differently: for the 1963-1977 TIUS the survey was stratified by "small trucks" and "large trucks."

9.2.3 Surface Transportation Board's Carload Waybill Sample

The Carload Waybill Sample (Waybill Sample) is a stratified sample of carload waybills for terminated shipments by rail carriers. A waybill is a document issued by a carrier giving details and instructions relating to the shipment of a consignment of goods. Typically, it will show the names of the consignor and consignee, point of origin of the consignment, destination, route, method of shipment, and amount charged for carriage.

Railroads may file waybill sample information by using either: 1) authenticated copies of a sample of audited revenue waybills (the manual system); or 2) a computer-generated sample containing specified information (the computerized system or MRI). The waybill submissions from these two methods are combined in a 900 byte Master Record File containing a movement-specific Confidential Waybill File and a less detailed Public Use Waybill File. The content of waybill requests are described in 49 CFR 1244.9.

The Waybill Sample is a continuous sample that is released in yearly segments. For the past several years, the sample contained information on approximately 600,000 movements. It includes waybill information from Class I, Class II, and some of the Class III railroads. The STB requires that these railroads submit waybill samples if, in any of the three preceding years, they terminated on their lines at least 4,500 revenue carloads. The Waybill Sample currently encompasses over 99 percent of all U.S. rail traffic.

Data from the Waybill Sample are used as input to many STB projects, analyses, and studies. Federal agencies (U.S. Department of Transportation, U.S. Department of Agriculture, etc.) use the Waybill Sample as part of their information base. The Waybill Sample also is used by states as a major source of information for developing state transportation plans. In addition, nongovernment groups seek access to waybill sample data for such uses as market surveys, development of verified statements in STB and state formal proceedings, forecast of rail equipment requirements, economic analysis and forecasts, academic research, etc.

Access to the Files

Because the Master Waybill File contains sensitive shipping and revenue information, access to this information is restricted to railroads; Federal agencies; states; transportation practitioners, consultants, and law firms with formal proceedings before the STB or State Boards; and certain other users. Rules governing access to Waybill Data are described in 49 CFR 1244.9.

Anyone can access the nonconfidential data in the Public Use File by sending a written request to: OEEAA, Surface Transportation Board, 1925 K Street, N.W., Washington, D.C. 20423-0001.

9.2.4 U.S. Army Corps of Engineers' Waterborne Commerce Statistics Database

The USACE publishes every year the Waterborne Databanks and Preliminary Waterborne Cargo Summary reports, which contain foreign cargo summaries, including value and weight information by type of service on U.S. waterborne imports and exports. These statistics are based on the U.S. Bureau of the Census trade data matched to the U.S. Customs vessel entrances and clearances.

The Waterborne Commerce Dataset presents detailed data on the movements of vessels and commodities at the ports and harbors and on the waterways and canals of the United States and its territories. Statistics are aggregated by region, state, port, and waterway for comparative purposes. Data on foreign commerce are supplied to the USACE by the U.S. Bureau of the Census, U.S. Customs, and purchased from the Journal of Commerce, Port Import Export Reporting Service.

Domestic Commerce

Contiguous and noncontiguous states and territories constitute the geographical space upon which domestic commerce may be transported. This includes Hawaii, Alaska, the 48 contiguous states, Puerto Rico and the Virgin Islands, Guam, American Samoa, Wake Island, and the U.S. Trust Territories.

The waterborne traffic movements are reported to the USACE by all vessel operators of record on ENG Forms 3925 and 3925b (or equivalent) approved by the Office of Management and Budget under the Paperwork Reduction Act (44 U.S.C. 3510(a)). 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. Cargo moved for the military agencies in commercial vessels is reported as ordinary commercial cargo; military cargo moved in Department of Defense vessels is not collected.

In summarizing the domestic commerce, certain movements are excluded: 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.

Beginning in 1996, fish are excluded from internal and intraport domestic traffic. The fish landing data in Tables 4.3 and 5.3 are furnished by the National Marine Fisheries Service.

In tables containing domestic tonnage totals for the United States, the commodity "Waterway Improvement Materials" is not included. "Waterway Improvement Materials" tonnage is included in domestic ports, waterways, and waterway systems. This is the same procedure that has been used in years prior to 1990; therefore, the tonnages for years 1990 and later are comparable to tonnages in years prior to 1990.

Foreign Commerce

Foreign commerce is waterborne import, export, and in-transit traffic between the United States, Puerto Rico and the Virgin Islands, and any foreign country. These statistics do not include traffic between any foreign country and the United States Territories and Possessions (American Samoa, Guam, North Mariana Islands, and U.S. outlying islands).

Beginning with the calendar year 2000 publication, foreign waterborne import, export, and in-transit cargo statistics are derived primarily from data purchased from the Port Import Export Reporting Service, a division of the Journal of Commerce and supplemented by data furnished to the USACE by the U.S. Bureau of the Census and the U.S.

Customs Service. Foreign cargo is matched to the vessel moves to improve geographic specificity.

Although the Republic of Panama is a foreign country, individual vessel movements with origin and destination at U.S. ports traveling via the Panama Canal are considered domestic traffic. Alaskan crude oil (origin at Valdez, Alaska) shipped via the Panama pipeline (west to east) and destined for gulf and east coast ports also is considered domestic commerce.

Import and export shipments for use of the United States Armed Forces abroad are not reported to the Waterborne Commerce Statistics Center (WCSC). Beginning with calendar year 1989, shipments under the military assistance program of the Department of Defense are included in the statistics under the appropriate commodity code. In prior years, these cargoes were given as commodity code 9999.

9.2.5 Federal Highway Administration's Vehicle Travel Information System (VTRIS)

The VTRIS system validates, facilitates editing, summarizes, and generates reports on vehicle travel characteristics. It also maintains the permanent database of the Station description, Vehicle Classification, and Truck Weight measurements in metric units. It allows repetitive data averaging and report generation with different options without additional source data processing. It allows input of ASCII traffic data as well as import of state-submitted data in internal VTRIS formats. The reports and graphs – final products of VTRIS functionality can – be created in both metric and English units.

The VTRIS software was developed by Signal Corporation together with the FHWA Office of Highway Policy Information (HPPI). It is distributed among all state agencies and FHWA field offices.

The information is presented in VTRIS W-Tables, which are designed to provide a standard format for presenting the outcome of the Vehicle Weighing and Classification efforts at truck weigh sites. Tables list the characteristics of each weight station as well as summary of vehicles counted, vehicles weighted, average weight, and truck classification amongst other things based on user input regarding state, year, and station or roadway classification.

The VTRIS database and documentation can be accessed on-line at: http://www.fhwa.dot.gov/ohim/ohimvtis.htm.

■ 9.3 Employment/Industry Data

Employment and wage data, as well as population and income data, are used to analyze and judge the economic development contributions that may result from a transportation improvement project. This can include analysis of job trends, the types of industries creating new jobs in the region, a description of how existing businesses would be affected by the transportation project, and whether the local labor pool is sufficient to fill new jobs created by the project. High unemployment and low relative wages would indicate an available labor pool, both in terms of people seeking jobs and "underemployed" people willing to change jobs for higher wages.

Wage and payroll data by region can be used to analyze the differences in pay levels in one area compared to another, by occupation or by industry and, often in conjunction with unemployment rates, can indicate whether a region is in relative "economic distress." These data can be a reflection of the overall health of a region, especially if mean pay levels are significantly above or below state averages. When viewed over time, wage and payroll data can show whether a region is gaining or losing ground relative to the state.[1] For poorer regions, a measure of economic progress can be wage levels that are progressively converging with the state. As an economic development strategy, transportation investment can be used to reduce disparities among subregions in employment and wage growth. Economic development outcomes emanating from a transportation project may include relative increases in employment growth rates and relative reductions in unemployment rates.

This section provides an overview of the most common sources for employment, wage data, and income data.

9.3.1 Sources of Employment and Wage Data

Bureau of Labor Statistics

The Bureau of Labor Statistics (BLS) is the principal fact-finding agency for the Federal government in the broad field of labor economics and statistics. The BLS is an independent national statistical agency within the U.S. Department of Labor that collects, processes, analyzes, and disseminates essential statistical data to the public, the U.S. Congress, other Federal agencies, state, and local governments, business, and labor.

---

[1] See Section 8.0 for a description of a study on New York's North Country which included a time series analysis to determine the extent of regional deficiencies in infrastructure and economic development. The study found that the rate of business expansions and industry growth (especially in tourism) significantly lagged state averages.

The BLS works with state-level employment agencies throughout the country to collect data on employment, unemployment, and wages. Statistics can be obtained from the Bureau's web site at http://www.bls.gov/.

State Department of Labor

States Department of Labor tend to be the chief collector of data on industry and regional employment trends in the state. Agencies usually collect data through several distinct programs, in cooperation with the Bureau of Labor Statistics (BLS). Employment, wage, and payroll data also are produced by the Census Bureau of the U.S. Department of Commerce. Information for all State Departments of Labor can be found on the U.S. Department of Labor web site at: http://www.dol.gov/esa/contacts/state_of.htm.

Current Employment Statistics (CES)

CES data are collected through a monthly survey of about 160,000 business and government agencies representing approximately 400,000 individual work sites and provides detailed industry data (industry-level details are available at a four-digit NAICS code for some, generally larger, metropolitan areas) on nonfarm employment, hours, and earning estimates based on payroll records. Current data on employment are available for most industries. Because comparable data are collected for all states and metropolitan areas, CES data is an excellent source for evaluating and comparing the economic health and composition of these larger geographic areas; however, CES data is generally not available at the county level. CES data at the state and metropolitan levels may be obtained at http://www.bls.gov/sae/home.htm while nationwide data is available at http://www bls.gov/ces/home.htm.

Local Area Unemployment Statistics (LAUS)

These monthly figures provide labor force estimates, the number of persons employed, the number of persons unemployed, and the unemployment rates for areas in the country. Information is available for states, metropolitan statistical areas, counties, and some cities, towns, and villages. The data from the LAUS are particularly useful if "high unemployment rates" (as a proxy for "economic distress") are a selection criteria for evaluating the economic development component of a transportation project.

One very significant difference between the LAUS data series and the other employment sources (ES-202 and Current Employment Statistics) discussed in this section is that it is based on a household survey rather than an employer survey. Because the LAUS is a household survey, it reflects where employed and unemployed people *live*, not where they *work*.

LAUS data are available from the Department of Labor's web site at the following address: http://www.labor.state.ny.us/html/laus/search.htm.

The following definitions for *civilian labor force* and *employment* are used in the Local Area Unemployment Survey:

- **Civilian Labor Force –** That portion of the population age 16 and older employed or unemployed. To be considered unemployed, a person has to be not working but willing and able to work and actively seeking work.

- **Employment (Total) –** The estimated number of people in an area who were working for pay or profit during a period, or who had jobs from which they were temporarily absent, or who worked 15 hours or more as unpaid family workers.

Occupational Employment Statistics

Occupational Wage Data are produced by the BLS with cooperation with each state's Department of Labor. The program produces employment and wage estimates for over 800 occupations. These are estimates of the number of people employed in certain occupations, and estimates of the wages paid to them. Self-employed persons are not included in the estimates. These estimates are available for the nation as a whole, for individual states, and for metropolitan areas; national occupational estimates for specific industries also are available.

Data are generated through a voluntary survey of employers. From the responses, wage data for the regions is produced. The data are available at the following site: http://www. bls.gov/oes/.

U.S. Census Bureau's County Business Patterns

County Business Patterns (CBP) is an annual series from the U.S. Census Bureau that provides subnational economic data by industry.[2] The series is useful for studying the economic activity of small areas and analyzing economic changes (employment, number of business establishments, and payroll by industry) over time.

CBP data for the United States, individual states, metropolitan areas, and zip code can be accessed using a menu-driven web site maintained by the Census Bureau: http://www.census.gov/epcd/cbp/view/cbpview.html.

Economic Census Industry Data

The Census Bureau conducts the Economic Census every five years, in those years ending in "2" and "7," to provide data on the national economy by major industry sector. The advantage of the Economic Census is that it is comprehensive and presents detailed

[2] The County Business Patterns program defined industries under the Standard Industrial Classification (SIC) system through 1997. However, beginning with the 1998 CBP program (published in 2000) data were tabulated using the North American Industrial Classification System (NAICS).

industrial data at the state, metropolitan area, and community levels. A disadvantage of the Economic Census is that it is released only once every five years, with a lag time of several years between the time the data is gathered and the time it is published.

Industry reports for each state can be downloaded in Adobe Acrobat's PDF format directly from the Census Bureau site at http://www.census.gov/econ/census02/. Each industry report contains data on establishments, sales, and payroll at the state, metropolitan area, county, and community levels.

The Economic Census of Manufactures, a subset of the Economic Census,[3] provides data by NAICS code on manufacturing establishments that is unavailable from other public sources. Manufacturing data is included by industry and geographic location for total shipments, annual and first quarter payroll, number of employees, capital expenditures, cost of materials, and value added.

These data can illustrate several points about manufacturing in the local economy by providing a snapshot for comparing metropolitan areas, counties, and communities in a number of ways, including: 1) how much manufacturers invested in their facilities (new capital expenditures); 2) the dollar value of goods being shipped from the area's manufacturing facilities (value of shipments); and 3) the value-added by manufacture for the area's industries. The report also includes wage data such as total payroll and production worker wages at the state, county, metropolitan area, and community levels. Using the data provided for value-added by manufacture, the *productivity* of a region's or area's manufacturing industries can be determined by calculating value added per production worker wage dollar.

Productivity Measures

Productivity is a measure of the value added during the manufacturing process as it relates to the wages earned, the hours worked, and the number of people employed. It is a reflection of the education and skill level of the workforce, the application of advanced processes, and the efficient use of capital and equipment (such as production machinery and computers). Transportation infrastructure enhances productivity by allowing businesses to use their capital more efficiently. For example, the use of just-in-time (JIT) production processes, enabled by an efficient transportation system, abets productivity by reducing inventory and lowering costs.

Productivity is measured by showing the *value added* per unit of input (usually labor) in the production process. Using a motor vehicle plant as an example, the value added that is reported for a facility puts into dollar terms, the value of production that is actually taking place at the plant. Value added is the difference between the value of goods being shipped out of the plant (for example, finished pickup trucks) minus the materials (such

[3] Beginning with the 1997 Census, all sectors are covered under the title Economic Census (with the exception of agriculture and government), and are no longer treated as if each sector had a separate census, such as the Census of Manufacturers.

as paint, plastics, metal parts, electronics, and glass) that were required to build the finished good.

9.3.2 Sources of Income Data

Bureau of Economic Analysis

The U.S. Department of Commerce's Bureau of Economic Analysis (BEA) is the best source for income data. The BEA's mission is "to produce and disseminate accurate, timely, relevant, and cost-effective economic accounts statistics that provide government, businesses, households, and individuals with a comprehensive, up-to-date picture of economic activity." BEA data offer the opportunity to analyze trends going back to 1969. Income data can be downloaded from the BEA's web site and is available at the state, metropolitan area, and county levels. Historic information on employment and population also is presented on the BEA web site.

Basic profiles, explaining the growth of per capita and personal income by county, are available from the BEA's BEA Regional Facts at http://bea.gov/bea/regional/bearfacts/. This site allows users to select any state, county, or MSA for a short-profile chronicling the area's personal income using current estimates, growth rates, and a breakdown of the sources of personal income. Users can compare their year of choice (1979–2004) with a year that falls 10 years prior, for example 2004 compared to 1994.

Personal income and per capita income data currently are available by county, metropolitan area, and state for the 1969-2004 period on the BEA web site at http://bea.gov/bea/regional/reis/. The data on this site can only be downloaded at predefined, geographic levels.

■ 9.4 Performance Data

This section covers two publicly available data source that deal with highway performance: the FHWA's Highway Performance Monitoring System and the Texas Transportation Institute's Urban Mobility Report.

9.4.1 FHWA's Highway Performance Monitoring System (HPMS)

The Highway Performance Monitoring System (HPMS) provides data that show the extent, condition, performance, use, and operating characteristics of the nation's highways. It was developed in 1978 as a national highway transportation system database. It includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information. HPMS replaced numerous uncoordinated annual state data reports as well as biennial special studies conducted by each state. These special studies had been conducted to support a 1965 congressional requirement that a report on the condition of the nation's highway needs be submitted to Congress every two years.

The HPMS data form the basis of the analyses that support the biennial Condition and Performance Reports to Congress. These reports provide a comprehensive, factual background to support development and evaluation of the Administration's legislative, program, and budget options. They provide the rationale for requested Federal-aid Highway Program funding levels and are used for apportioning Federal-aid funds back to the states under TEA-21; both of these activities ultimately affect every state that contributes data to the HPMS.

These data also are used for assessing highway system performance under FHWA's strategic planning process. Pavement condition data, congestion-related data, and traffic data used to determine fatality and injury rates are used extensively by the Administration to measure FHWA's and the state's progress in meeting the objectives embodied in *The Vital Few*, FHWA's Performance Plan, and other strategic goals.

In addition, the HPMS serves the needs of states, MPOs and local governments, and other customers in assessing highway condition, performance, air quality trends, and future investment requirements. Many states rely on traffic and travel data from the HPMS to conduct air quality analyses and make assessments related to determining air quality conformity, and they are now using the same analysis models used by FHWA to assess their own highway investment needs, HERS-ST. As a result of these uses, states have an additional stake in ensuring the completeness and quality of these data.

Finally, these data are the source of a large portion of information included in FHWA's annual *Highway Statistics* and other publications. They are widely used in both the national and international arenas by other governments, transportation professionals, and industry professionals to make decisions that impact national and local transportation systems and the transportation dependent economy.

Further information about the HPMS and its methodology can be obtained on-line at: http://www.fhwa.dot.gov/policy/ohpi/hpms/index.htm.

9.4.2 Texas Transportation Institute's Urban Mobility Report

The Urban Mobility Report, published on an annual basis, contains over 20 years of data which are used to identify trends and examine issues related to urban congestion. The 2007 study includes information for 85 U.S. urban areas from 1982 to 2005. The measures presented in the report provide a basis for discussion about the significance of the mobility problems and the need for solutions.

The TTI study ranks areas according to several measurements, including:

- Annual delay per peak-period (rush hour) traveler, which has grown from 16 hours to 44 hours since 1982;
- Number of urban areas with more than 20 hours of annual delay per peak traveler, which has grown from only 5 in 1982 to 57 in 2005;
- Total amount of delay, reaching 4.2 billion hours in 2003; and
- Wasted fuel, totaling 2.9 billion gallons lost to engines idling in traffic jams.

The 2007 study is available on-line in PDF format at: http://mobility.tamu.edu/ums/.

10.0 Freight Data Collection

This section provides a detailed discussion on data collection for freight planning and forecasting. The subsections in this section include a discussion of the need for freight data collection, the common types of data collection supporting freight planning and forecasting, and key issues associated with collecting freight data pertaining to costs, sample sizes, and implementation processes.

10.1 Need for Freight Data Collection

Section 9.0 of the QRFM provided a detailed description of the various existing freight data sources available at national and regional levels for freight planning and forecasting applications. These included commodity origin-destination databases (such as FAF2 and TRANSEARCH), modal flow databases (such as the Carload Waybill Sample), vehicle data (for example VIUS), and employment/industry data (for example County Business Patterns). Although these data sources provide comprehensive information on base year and forecast freight demand, transportation supply, and economic characteristics in a region, there are often a host of other critical data needed for freight planning/forecasting that are beyond the scope and coverage of these standard data sources. For example, truck volume data on the highway network is a critical need for MPOs and other regional planning agencies for the validation of the regional truck models. Understanding time-of-day characteristics of truck traffic is another important need for planning agencies to understand peak-hour interactions between passenger and freight traffic, and plan for congestion alleviation measures during peak hours. These data elements can only be compiled from a local freight data collection effort. Also, in many cases, the data available from standard freight data sources may not be representative of the actual freight traffic characteristics in the planning region under consideration. For example, truck payload factors derived from the VIUS database are only available at the state level of detail and cannot always be applied to an urban area. Clearly, local data collection efforts can provide more representative and accurate data in such cases to support the freight demand analysis and planning process.

Although local freight data collection efforts require additional resources in terms of time and costs, they provide much needed data for a planning agency to conduct a comprehensive analysis of freight traffic flows in a region and develop more accurate freight forecasts for planning applications. Some critical factors that impact the time, costs, and level of effort associated with local freight data collection programs include the following:

- The level of availability and comprehensiveness of existing data;
- Type and volume of data/information needed;
- Time needed to conduct data collection;
- Desired level of accuracy and detail in the collected data; and
- Types of equipment and resources (manual, etc.) required to perform data collection.

10.2 Local Freight Data Collection

Though there are a host of local freight data collection methods, this section covers the most important methods from a freight planning and forecasting application perspective. In addition to presenting the essential concepts associated with each data collection method, some key issues pertaining to costs, sample sizes, and implementation for each type of data collection, also are discussed.

The following types of local freight data collection methods are covered in this section:

- Vehicle classification counts;
- Roadside intercept surveys;
- Establishment surveys; and
- Travel diary surveys.

10.2.1 Vehicle Classification Counts

Introduction

Collecting vehicle classification counts is a common local freight data collection method, which involves counting traffic for each vehicle class (based on a particular vehicle classification system) for a certain duration of time at key locations on the highway network. Typically, the counts are collected during weekdays and may be collected for more than one day to get average weekday traffic volumes at the count location. Collecting counts by vehicle class is important in order to differentiate between automobile and truck traffic volumes, as well as analyze truck traffic volumes by truck type (the applications of vehicle classification counts are discussed in detail in a subsequent section).

The four primary methods of collecting vehicle classification counts are:

1. **Manual Observation –** Manual counting procedure involves a trained observer collecting vehicle classification counts at a location based on direct observation of vehicles. This procedure is generally used for short durations of count data collection (for example, peak hour), and in cases where available resources do not justify the use of

automated counting equipment. Typical equipment used in manual counting for recording observed traffic include tally sheets, mechanical count boards, and electronic count boards.

2. **Pneumatic Tubes –** This data collection approach involves placing pneumatic tubes across travel lanes for automatic recording of vehicles. These tubes use pressure changes to record the number of axle movements to a counter placed on the side of the road. They can record count data for 24-hour periods or more and are easily portable.

3. **Loop Detectors –** This data collection approach involves embedding one or more loops of wire in the pavement, and connecting to a control box, excited by a signal (typically ranging in frequency from 10 KHz to 200 KHz). When a vehicle passes over the loop, the inductance of the loop is reduced, indicating the presence of a vehicle. One of the main benefits of this approach is the reliability of count data under all weather conditions. Loop detectors are mainly used as permanent recorders, at locations where counts are required for a longer-time duration.

4. **Videography –** Videography involves collecting vehicle classification counts using video tape recorders and tallying them manually by observing vehicles on the video. Similar equipment, as described under the manual observation data collection approach above, can be used for tallying the data. A primary advantage of videography is the ability to stop time and review data, if necessary.

The vehicle classification system used for the count program can vary depending on the need, as well as the type of method used for counting vehicles. Classifying vehicles by the number of axles is the most basic vehicle classification scheme. However, this has some limitations with respect to applications for freight planning; for example, the inability to differentiate between automobiles and two-axle trucks, which is an important piece of information for freight planning applications in urban areas. The FHWA 13-group vehicle classification system is a common and efficient scheme for classifying vehicles (trucks are classified based on number of axles and number of units). This system is described in detail at the following web site: http://www.fhwa.dot.gov/ohim/tmguide/tmg4.htm#chap1. However, some data collection methods such as pneumatic tubes are only based on counting the number of axles and cannot classify vehicles based on the FHWA 13-group system. The key to classifying vehicles in count programs, and using them for freight planning applications, is to understand how the different classification schemes relate to one another. For example, translating length-based classification from loop detectors to axle-based classification and vice versa.

Applications of Vehicle Classification Counts

Vehicle classification counts are useful in freight planning and forecasting. Some applications are described below.

Model Calibration and Validation

One of the most important applications of vehicle classification counts is in performing model calibration and validation. Truck counts by truck type can be used to calibrate input origin-destination (O-D) trip tables of regional truck models using an Origin-Destination Matrix Estimation (ODME) process, if the collected counts provide a good geographic coverage of key truck traffic locations in the region. The ODME process iteratively updates the input O-D trip table of the model so that model truck volume results match with observed truck counts. Truck counts also are used for validation of regional truck models by comparing model results with observed truck traffic volumes at screenline locations. By collecting classification counts, this validation process can be performed by truck classes in the truck model. However, model calibration and validation processes cannot be conducted simultaneously because if an ODME process is conducted for model calibration, the model results are matched with observed truck counts, resulting in redundancy of a model validation process.

Time-of-Day Analyses

Another important application of vehicle classification counts is in performing time-of-day analyses of truck traffic volumes. Hourly counts collected over a 24-hour period can be used to develop time-of-day distributions of truck traffic volumes to analyze peaking periods for truck traffic. Classification counts also allow for the simultaneous comparisons of time-of-day distributions between automobile and truck traffic to understand peak-period interactions between passenger and freight traffic, and to plan for the efficient movement of traffic during the peak period. Classification counts also can be used to analyze time-of-day truck traffic characteristics by truck class, as well as by highway facility type (freight access routes versus major freight corridors).

Trip Generation

Vehicle classification counts also are used to develop truck trip generation models. For example, counts by truck class on access routes to major freight facilities provide inputs for developing regression models by truck class for truck trip generation. Truck counts also can be used to develop truck trip generation rates for freight facilities as a function of economic variables such as employment. Directional counts on access routes around freight facilities can be used to develop separate trip generation rates for production and attraction trips. However, the application of counts for trip generation analysis entails the availability of freight facility economic or land use data.

Identification of Major Freight Corridors and Access Routes

If the vehicle classification count program provides a good geographic coverage of sites on the highway network, then it can be used to identify major freight corridors and freight access routes in the region, based on an analysis of locations with high truck traffic volumes. This information serves as an essential input for defining the regional highway freight system of a region, which can be used for highway freight planning purposes.

Implementation Issues

Site Selection

The success of a vehicle classification count program in terms of its applicability for freight planning in a region is to a large extent determined by the selection of sites for collecting counts. The best approach to site selection is an initial assessment of the truck count data needs in the region and selecting sites based on a prioritization of needs. This approach not only ensures that the most critical data needs in the region are satisfied by the count program, but also is useful for the optimal utilization of resources available for conducting the count program. Some examples of critical freight planning data needs that feed into the site selection process include the following:

- Truck volumes on truck model screenline locations;
- Truck volumes on major freight corridors;
- Truck volumes on major freight access routes; and
- Truck volumes to meet specific jurisdiction truck traffic data needs.

An important consideration in the site selection process is the geographic coverage of the region, particularly if a primary application of the count data is for performing an ODME process for input truck trip table calibration.

Costs

The costs of collecting vehicle classification counts are primarily governed by the type of method used for collecting counts, as well as the number of sites selected for the count program. To reduce the overall costs of compiling traffic volume information on the regional highway network, the planning agency must consider availability of count data from existing count programs, in order to avoid duplication of count data collection efforts. For example, vehicle classification counts are collected by state departments of transportation at key locations on the highway network as part of their requirement to report traffic data to the FHWA for the Highway Performance Monitoring System (HPMS). Similarly, existing count programs of regional jurisdictions (for example, counties) and authorities (for example, sea and air ports) can provide traffic volume information by vehicle classes.

For each type of data collection, the actual costs will vary significantly depending on the efficiency of operation of the data collection firm, the accuracy sought from the data collection effort, as well as the characteristics of the site for ease of count data collection. Based on a review of previous count data collection efforts, the unit costs (per site) for conducting 24-hour vehicle classification counts by manual and video counting methods are approximately $650 and $500, respectively. In addition to these costs, there are typically costs associated with data synthesis and analysis that vary depending on the extent of the count data collected, as well as the tabulations associated with the analysis.

Data Variability Issues

Data variability is an important concern that needs to be addressed by any vehicle classification count program. In addition to time-of-day variations, truck volumes can have significant day-of-week and seasonal variations, which have not been as well established as time-of-day truck traffic distributions. For example, how seasonal changes in industrial shipment characteristics translate into seasonal variations in truck traffic volumes on the highway network. Thus, truck counts that are typically collected on a specific day of the year cannot be representative of average annual truck traffic volumes at the location and need to be adjusted to account for seasonal variations. These seasonality factors are typically derived from permanent traffic recorders that collect continuous counts. However, these locations are not typically distributed across the region with sufficient coverage of all relevant areas (for example, there is usually very little coverage on state highways and no coverage on arterials). Thus, vehicle classification count programs designed to capture seasonal variations especially on these road types can significantly increase the understanding of temporal variability in the region.

Advantages

Vehicle classification counts have many advantages, which are presented below for each method of data collection.

Manual Observation

Some advantages of manual counts are presented below:

- There is no disruption of traffic during data collection.
- There is minimum risk to individual observers collecting vehicle classification counts, as they do not have to interact with the traffic flows.
- They may be more accurate than automatic vehicle classification counting methods and can count vehicles based on both axle group and number of units, thus enabling vehicle classification by the FHWA 13-group classification system.

Automated or Electronic Data Collection

Some advantages of automated or electronic counts are presented below:

- There is no disruption of traffic during data collection, even though automatic vehicle recording equipment are placed on the pavement to count vehicles.
- They are particularly useful when classification counts are needed at many sites, due to the higher efficiency in data collection with minimum labor requirement.

Video Surveillance

Some advantages of video surveillance-based counts are presented below:

- There is no disruption of traffic during data collection.
- They offer the ability to stop time and review data for quality checking.
- They can provide better information on type of truck (and consequently, the type of commodity hauled) compared to automated counting methods.

Limitations

Some key limitations of vehicle classification counts are presented below for each method of data collection.

Manual Observation

Following are some key limitations of collecting vehicle classification counts by manual observation:

- There is a high personnel requirement, as well as training, for conducting manual counts.
- Manual vehicle classification counts have the potential for human error, especially under heavy traffic conditions.
- They are not a good approach for counting vehicles during the nighttime period, as visibility can cause a problem in effective counting of vehicles by vehicle classes.

Automated or Electronic Data Collection

Following are some key limitations of automated/electronic vehicle classification counts:

- There is a potential for equipment failure, which will impact the accuracy of the collected counts.
- They are relatively more expensive compared to manual counting methods, especially for a larger geographic coverage area.
- They can count vehicles only based on a particular classification system (for example, number of axles), and consequently, there is a potential for error when converting counts from one classification system to the other.

Video Surveillance

Following are some key limitations of collecting vehicle classification counts based on video surveillance:

- They are associated with high equipment costs, especially for larger geographic coverage areas.
- Weather can have a serious impact on video count programs, due to the potential for equipment failure or reduced visibility.

10.2.2 Roadside Intercept Surveys

Introduction

Roadside intercept surveys belong to the category of primary truck trip data collection, which involve intercepting trucks on the road and interviewing truck drivers to get information on their truck trip characteristics. The surveys are administered through the use of survey questionnaires that are completed by the interviewer based on information provided by the driver from the personal interviews. Typically, the interviewer makes visual observation of the vehicle to gather information about configuration and number of axles. There are many key steps involved in developing and implementing a roadside intercept survey, which include preparation of the survey questionnaire, site selection, site preparation, recruiting and training of survey personnel, sampling frames, survey administration, and survey data synthesis and analyses.

Depending on the types of freight modeling and planning applications, roadside intercept surveys can gather comprehensive information about truck travel characteristics in a region. The key data attributes that can be collected through roadside interviews include O-D locations (state, city, zip code), routing patterns, type of commodity, vehicle and cargo weight, shipper and receiver information (business name, contact, type of facility, etc.), trucking company information (business name, contact, type of carrier – truckload, LTL, or private, etc.), and type of truck (number of axles and number of units).

The locations for conducting roadside intercept surveys depend on the O-D truck travel patterns that are being analyzed. To gather truck trip characteristics of internal-external, external-internal, and external-external (through) trips, the most common approach is to conduct surveys at external cordon locations. External cordons are the external highway gateways that are used by trucks to enter and exit the study area. Collecting roadside intercept surveys within concentrated urban areas for internal-internal trips can be prohibitive because of the need to conduct surveys at many locations (due to the complex internal distribution patterns of trucks), as well as traffic congestion and/or limited space availability at survey sites. Some common locations for conducting roadside intercept surveys include weigh stations, toll plazas, and border crossing locations.

Terminal gateway surveys are a special class of roadside intercept surveys, wherein trucks entering and exiting terminal gateway facilities (seaports, airports, and intermodal rail yards) are intercepted and surveyed to get information on O-D locations, routing, commodities, payloads, truck types, types of carriers, O-D facilities used, etc., for trucks using terminal gateways.

Applications

Data collected from roadside intercept surveys are useful for freight modeling and planning applications, which are discussed in the following sections.

Origin-Destination (O-D) Freight Flow Matrix

A primary application of roadside intercept surveys is in the development of O-D freight flow matrices for a region. Depending on the extent of data available and the level of accuracy of the geocoding process for the O-D locations, a TAZ-level O-D freight flow matrix can be developed from the survey data. However, only the external gateway surveys offer the ability to develop accurate O-D matrices, since surveys conducted at internal locations are typically inadequate for developing a comprehensive O-D matrix and incorporating all the possible O-D flow combinations in a region. The O-D matrix developed from external gateway surveys contains truck freight flows between external cordons and internal regions (TAZs or districts), and can be in terms of commodity flows (in tons) by trucking submodes (truckload, LTL, and private), or truck trips by truck class. These O-D matrices serve as key inputs in the development of external truck models for urban areas. Commodity-specific flows from these matrices also can be used to validate the TAZ-level disaggregation procedures in existing urban truck models for production and attraction trips.

Trip Distribution

Truck O-D information collected from terminal gateway surveys are essential inputs for developing truck trip distribution tables for terminal facilities. These tables can be developed by type of commodity and/or truck classes to understand the variations in terminal gateway truck O-D distributions as a function of these parameters.

Payload Factors

Roadside intercept surveys collect information on the type of commodity, weight of cargo, and type of truck that can be used to develop weighted average payload factors by commodity group and truck classes. These factors can be used in the development of commodity-based urban truck models (which involve conversion of commodity flows to equivalent truck trips by each truck class), or validation of payload factors in existing truck models to improve the accuracy of predicted truck trips.

Commodity Tonnage Distribution to Truck Classes

The type of commodity, weight of cargo, and type of truck information collected from the surveys can be used to develop tonnage distributions for each commodity group carried by each truck class, at each external cordon location. This information is a key input in commodity-based urban truck models to distribute total commodity flows to each truck class, in order to predict truck trips by truck classes.

Empty and Through Truck Factors

Empty truck trip fractions at external cordons are key inputs in commodity-based urban truck models in order to account for empty truck trips. Collecting through truck traffic information is a key requirement for developing robust truck models. Some of the key include the fraction of total trips that are through trips at each external cordon, and through truck traffic distributions (the distribution of through trips at each external cordon through all the other external cordon locations).

Market Research

Roadside intercept surveys can be used for market research and have been applied successfully in many studies, particularly related to cross-border movements. Using intercept surveys at border crossing locations, information can be collected on major shippers and receivers involved in cross-border trade, as well as major carriers performing cross-border shipping operations.

Advantages

Following are some key advantages of performing roadside intercept surveys for gathering truck travel information:

- They offer the best statistical control and reliability, since sample is from known traffic population.
- They have high response rates compared to mail or telephone surveys, due to direct one-on-one interview with the driver.
- Surveys at external stations provide a good statistical representation of trucks entering, exiting, and passing through the study area.
- They have low investment costs, if managed and administered properly.
- They offer the ability to gather comprehensive truck trip information in a single interview pertaining to O-D, routing patterns, commodities, shipment sizes, truck types, and facilities used.

Limitations

Following are key limitations of performing roadside intercept surveys:

- There are only a limited number of locations where intercept surveys may be implemented in a region. This can lead to sampling bias in the truck travel characteristics determined from the survey.

- There is potential disruption of traffic, especially when surveys are conducted by roadside pull-offs.

- There is potential risk for survey personnel, related to safety risks from traffic and security risks from direct contact with interviewees.

- They can only capture truck traffic characteristics of trucks passing through survey sites. They are not particularly effective for collecting information on internal-internal truck traffic characteristics because of the limitations in the number of sites, and the complexities in distribution patterns of internal-internal trips.

Roadside intercept surveys generally focus on "last stop-next stop" origins and destinations since questions involving multiple stops (trip-chaining activity) can be confusing to the driver and may yield less reliable data. This can be a potential limitation if last/next stops of the surveyed trip involve activities that are not related to goods movement such as fueling and rest areas.

Implementation Issues

Sampling Rates

Because of the impracticality of intercepting all the trucks passing through the survey site, sampling rates are typically developed to select a sample of the total truck traffic for the surveys. These rates can vary based on the total truck traffic volumes at the location, as well as the type of truck. The sampling rates also can depend on the rate of processing of surveyed trucks at the site, which is a function of the number of interviewers, as well as slot space available at the site for the surveys. Typically, roadside surveys at the site are accompanied by vehicle classification counts in order to determine total trucks passing through the location for expanding the survey sample data.

Three questions need to be answered when performing sampling analyses for roadside intercept surveys, which are as follows:

1. Where to sample (which sites to be selected for performing surveys)? Key parameters that help answer this question include the major locations for entry and exit of truck traffic in a region locations of existing truck stop sites such as weigh stations, rest areas, toll plazas, and border crossing.

2. Who to sample (which trucks to be selected for surveys, and how many)? Key parameters that help answer this question include the types of trucks passing through the site and the volume of traffic by each truck type.

3. When to sample (which day of week and seasons to be selected to account for weekly and seasonal variations in truck traffic patterns)? Key parameters that help answer this question include the volume of truck traffic in the region by day of week and seasonal truck traffic volumes. These data can be typically collected from Weigh-in-Motion (WIM) sites and permanent traffic recorders.

There are no specific guidelines for arriving at sampling frames for the surveys, since each region has unique truck traffic characteristics in terms of total traffic volumes, types of truck, site characteristics, time-of-day truck traffic distributions, and weekly and seasonal traffic variations.

Costs

The cost of conducting roadside intercept surveys for a region depends on many factors, including the number of survey sites, time period of data collection, site preparation, costs of equipments such as cones, signs, etc., as well as the efficiency of the data collection firm, and the quantity and quality of data collection desired. Based on an analysis of previous roadside intercept studies, the average cost of conducting a 24-hour intercept survey is estimated to be around $5,000 per site. However, actual costs of data collection can vary significantly based on the characteristics of the sites, the quantity and quality of data collected, and the data collection firm employed for conducting the surveys.

Personnel Training and Other Operational Issues

Recruiting and training personnel to conduct interviews of truck drivers is a critical component in the design and implementation of a roadside intercept survey program. There are, however, many data collection firms specializing in roadside intercept surveys that can be hired to conduct roadside interviews, but this approach can be potentially more expensive. An alternate and less expensive approach is to recruit personnel from local organizations and/or volunteer groups (community service clubs), comprised of individuals with good knowledge of local roads, and understanding of general traffic patterns in the region. Typical components of personnel training for roadside intercept surveys include instruction in personal interviewing techniques, accurate identification of different truck and tractor-trailer combinations (along with number of axles), and procedures and requirements for ensuring personal and third-party safety at the survey site. Other operational elements to be considered for the survey include the provision of accessories such as clipboards and pens, as well as reflective safety vests, headlamps, and hats to survey personnel and equipment of each site with survey crew signs and traffic cones. Additionally it is advisable to deploy a Commercial Vehicle Enforcement officer at the site to ensure safety of survey personnel, as well as effective direction of selected trucks to the survey site, in order to ensure a high degree of compliance, which leads to high response rates.

10.2.3 Establishment Surveys

Introduction

Surveying establishments engaged in freight activity is an important element of a local freight data collection effort for a region, since they generate a large fraction of local, and long-haul (internal-external and external-internal) freight flows. This data collection method involves surveying owners, operators, or fleet managers of key establishments, which may include manufacturing facilities, warehouses, retail distribution centers, truck terminals, and transload facilities. These surveys may include terminal gateway facilities like seaports, airports, and intermodal yards. However, the utility of establishment surveys for terminal gateways is generally limited to getting information on economic characteristics of the facility (such as number of employees), since the extent of truck traffic volumes and patterns associated with terminal facilities make terminal gateway intercept surveys more optimal compared to establishment surveys for collecting information on truck traffic characteristics. The use of business directories, such as Dun & Bradstreet, may be useful in identifying personnel contacts who can provide the required information.

The primary methods of conducting establishment surveys include telephone interviews, mail-out/mail-back surveys, and combined telephone and mail surveys. Establishment surveys can be used to collect comprehensive information regarding economic, land use, and modal freight (trucking, rail, etc.) activity characteristics of freight facilities, which may provide key inputs for freight modeling and planning applications. Specific data attributes that can be collected include facility hours of operation, number of employees, facility land area, fleet size, fleet ownership, types of trucks in fleet (straight, tractor-trailers), commodities handled, average payloads by commodity and type of truck, types and share of trucking services used (parcel, truckload, and LTL), average daily inbound and outbound truck shipments, average trip lengths, truck trip-chaining activity, truck O-D distribution patterns, types of facilities used, etc. In addition, establishment surveys also can be used to understand how key transportation performance variables such as transportation costs, travel times, reliability, highway regulations, and roadway closures impact shipment decisions.

Applications

Following are some key freight forecasting and planning applications of the data collected from establishment surveys.

Trip Generation

Data collected from establishment surveys on number of employees, land area, and average daily truck trip productions and attractions can be used to develop truck trip generation estimates. These data elements can serve as inputs to the two common approaches for trip generation, which include trip generation rates, and regression equations. Establishment surveys may be more feasible compared to collecting traffic counts for trip generation since daily trucking activity information for the facility can be collected at a fairly reasonable level of accuracy using limited resources, compared to conducting traffic counts that might prove to be more expensive. In addition to providing data for the estimation of trip generation rates and regression equations, establishment surveys can collect forecast economic data (future employment and labor productivity) for the facility, which are key inputs for facility freight forecasting and planning.

Truck Trip-Chaining Analysis

Establishment surveys generally provide better data for understanding truck trip-chaining activity compared to other types of data collection, such as terminal/facility gate surveys. Gate surveys of truck drivers are most effective when collecting only the last stop-next stop activity information, since drivers tend to get confused about questions related to multi-stop trip-chaining activity and may not provide reliable information. In the case of establishment surveys, however, the interviewee can provide information for each commodity group handled by the facility on the fraction of total truck trips performing multi-stop tours. This information, combined with the types and locations of facilities used by truck trips of each commodity group, is key to understanding and modeling truck trip-chaining activity associated with specific freight facilities. Establishment surveys of motor carrier terminal facilities are useful for understanding truck trip-chaining behavior based on the type of carrier (truckload, LTL, or private), and the type of commodity hauled.

Payload Factors

Establishment surveys offer a resource efficient and optimal approach for collecting payload data for truck shipments by commodity and type of truck. An alternative approach is through gate surveys, but they are not only more cost- and time-intensive to implement but only capture a sample of the truck shipments that can potentially lead to statistical bias in the estimates. A facility/fleet operator can provide more reliable information, with relatively lower data collection effort, on average payload factors by commodity and truck classes, using records/logs of daily truck shipment activity at the facility. Data collected from facility/fleet operators on average payload factors for different trip length categories (long- versus short-haul/local distribution), also can be used to understand the impacts of market area on payload factors for different commodity groups.

Other Applications

Other key applications of the data collected from establishment surveys include the following:

- **Time-of-day analysis to understand variations in trucking activity at a facility by time of day –** This is useful for site/facility planning, to understand time-of-day interactions between trucks and automobiles, and to plan for the efficient movement of freight during peak periods.

- **Analysis of the types of facilities used by trucks generated by a facility for different commodity groups –** This can be useful for developing trip distribution models (for example, truck traffic disaggregation models), as well as land use planning associated with large freight generators such as seaports. Establishment surveys of trucking terminals also can yield useful data on the types of facilities used by type of carrier (truckload, LTL, or private) to validate trip distribution patterns based on truck trips by carrier type.

Implementation Issues

Type of Data Collection

Deciding on the type of data collection (telephone, mail-out/mail-back, or combined telephone and mail) is a primary issue in the implementation of establishment surveys. Each of these methods has advantages and limitations associated with the type and volume of data collected, and the time and costs associated with the data collection effort. Generally, mail surveys have been the commonly used method for establishment surveys, particularly due to the relative ease of implementation compared to telephone or combined telephone and mail surveys. The investment costs and personnel requirements associated with mail surveys also are typically the lowest. However, mail-out/mail-back surveys have many limitations, most notable being their low response rates, as well as the inability to clarify responses to specific questions. Telephone surveys have relatively higher response rates compared to mail-out/mail-back surveys; however, they may be less effective in getting comprehensive trucking activity information, since identifying and reporting specific trip detail about all shipment types can be prohibitive in a telephone conversation. Telephone interviews also require the availability of accurate data on telephone numbers and interviewees (owners, operators, fleet managers, etc.), and compiling that data can be a time-consuming and costly undertaking. Combined telephone and mail surveys offer high response rates, since the establishments are notified beforehand through telephone contact about the mail survey. However, this survey approach typically has the highest cost of implementation. Table 10.1 presents the advantages and limitations associated with each type of data collection, pertaining to implementation, investment, statistical reliability, data attributes, and geographic coverage.

Sample Selection

Sample selection is an important element in the design of an establishment survey data collection effort. The larger the sample size, the more reliable and comprehensive the data collected from the survey. However, it would be practically impossible and cost prohibitive to survey the universe of establishments located in a region. Thus, attention to developing appropriate sampling frames is critical not only for minimizing the overall cost of the data collection effort, but also for ensuring that the sample surveys provide unbiased and reliable data on the economic, land use, and freight activity characteristics of establishments in the region.

Table 10.1 Advantages and Limitations of Mail-Out/Mail-Back, Telephone, and Combined Telephone and Mail Surveys

Method	Advantages	Limitations
Mail-Out/ Mail-Back Survey	• Ease of implementation • Low investment costs, and minimal personnel requirement • Generally good information and data detail from survey respondents	• Low response rates • Limited ability to clarify responses to specific questions • Difficulty finding the appropriate person at the establishment to complete the survey
Telephone Survey	• Ease of implementation • Quicker turnaround compared to mail-out/mail-back surveys • Low investment costs • Ability to clarify responses • Better success rates for follow-up surveys compared to mail-out/mail-back surveys	• Compiling phone numbers and contact person information can be difficult and time-consuming • Surveys can only be conducted during normal business hours • Higher personnel requirement compared to mail-out/mail-back surveys • Inability to collect comprehensive trucking activity information during a telephone conversation
Combined Telephone and Mail Surveys	• Quicker turnaround that mail-out/ mail-back surveys • Improved ability to clarify intent of data collection, and explain questions, leading to better detail and accuracy in collected data • Relatively higher response rates compared to mail-out/mail-back surveys	• Compiling phone numbers and contact person information can be difficult and time-consuming • Higher personnel requirement compared to mail-out/mail-back surveys

It is important to note that there is no definitive methodology for arriving at the sample size. In the case of establishment surveys, the primary factor impacting sample size is the method of data collection since each method is associated with different response rates. For example, in the case of a mail-out/mail-back survey, the generally low response rates would entail the selection of a larger sample size compared to a telephone interview survey with relatively higher response rates. Other factors which will impact the sample size are the costs of data collection (tied to the method used), as well as the reliability and accuracy of the available contact information.

In the case of establishment surveys of freight facilities such as manufacturing plants, warehouses, and distribution centers, the usual sampling approach involves selecting establishments based on their employment size or land area. Standard privately owned data sources such as Dunn & Bradstreet are available for purchase and provide the universe listing of establishments in a region for sampling, along with their economic (number of employees, etc.) and land use (floor acreage, etc.) characteristics. Additionally, there may be publicly available data, compiled by state economic development departments, MPOs, or other organizations (such as port authorities) on major freight establishments in a region, which can be used to develop sample sizes.

In the case of establishment surveys of trucking terminals, the sampling strategy would typically depend on the trucking characteristics in the region. For example, the predominance of local distribution activity in large metropolitan areas (captured in the VIUS database) would imply that the sampling approach should focus on capturing a larger fraction of motor carrier establishments involved in short-haul local distribution activity compared to long-haul trucking, to perform a statistically reliable and unbiased analysis of trucking activity in a metropolitan area.

Costs

The costs involved in conducting establishment surveys vary depending on the method of data collection. Based on historical information available on establishment surveys, the average costs of conducting mail-out/mail-back (with a 10 percent response rate) and telephone (with a 20 percent response rate) surveys are estimated to be $100 per survey and $250 per survey, respectively. Historical cost information on combined telephone and mail-out/mail-back surveys is not available since this survey method is not very common due to the relatively higher level of effort involved in data collection. The cost of conducting combined telephone and mail surveys is expected to be higher than telephone surveys.

10.2.4 Travel Diary Surveys

Introduction

Travel diary surveys are a useful method of data collection, particularly for understanding internal-internal (local) truck trip activity in an urban area. The basic approach of data collection involves selecting a representative sample of trucks operating in the region, and obtaining travel diaries from truck drivers for a certain time duration. The usual time period for data collection is 24 hours; however, depending on the willingness of truck drivers to complete trip diaries, the surveys can be conducted for time periods extending more than a day (typically, three days or a week). The most common approach to providing travel diaries is through forms completed manually by the driver listing the truck trip characteristics for the time period of the survey. Typically, drivers are asked to record information on the truck trip regarding origin, destination, trip mileage, routing, travel time, trip time of day, commodity-hauled and size of shipment, truck type, and land use and activity (pickup, delivery, refueling, rest area, etc.) at trip end. Additionally, they may be asked to report their type of carrier operation (truckload, LTL, or private), if this information cannot be deduced from the source data.

An alternative and more advanced approach of travel diary surveys is the use of Geographic Positioning Systems (GPS) receivers, which are fit in trucks to trace individual truck trip activity. However, GPS-based data collection in itself cannot provide key truck trip characteristics pertaining to commodity hauled, shipment size, and activity at trip end. The maximum utility of GPS-based data collection for a travel diary survey is realized when combined with other data sources and methods of data collection. For example, origin, destination, and routing information received from GPS receivers can be used to validate and improve the information provided by truck drivers in manually completed travel diaries. Also, combining GPS truck trip information with GIS-based land-use data, for example, can yield useful information on truck activity characteristics at trip ends.

Applications

Some key freight forecasting and planning applications of the data collected from travel diary surveys are listed below.

Trip Chaining

As discussed earlier, travel diary surveys are particularly useful for understanding internal-internal truck trip activity in a region and perhaps the most important application in this regard is truck trip-chaining analysis to develop more robust and accurate urban truck travel demand models. Travel diaries capture the entire trip making activity of each individual truck over a 24-hour period, which can be used to trace the occurrence of trip chaining. For example, a trip diary entry for a trip starting from home base to a pickup location, proceeding to a drop-off location, and then proceeding to another drop-off location indicates the presence of trip chaining (such trips are common in urban areas, particularly local distribution trips related to retail activity). Trip-chaining activity from travel diaries, coupled with information on type of commodity, type of carrier, and land use and activity at trip ends can be used to understand trip-chain distribution patterns, and as inputs to develop activity-based truck travel demand models.

Trip Generation

A key application of travel diary surveys is in the development of trip generation estimates. Travel diaries provide data for the sampled trucks on total trip ends by land use, which after expanding to account for the universe of truck trips, can be used to develop trip generation rates or regression models for trip generation. Trip generation rates are derived by dividing the total trip ends for each land use category by the independent variable impacting truck travel demand (for example, economic/land use data such as employment/acreage). Similarly, trip ends for each land use category can be used to develop regression models. If there are sufficient data points spread across the region for trip ends, it can also be used to develop a statistically reliable model (for example, if most of the trips associated with a land use are concentrated at a couple of locations in the region, then there are only two data points for the regression model, which would impact the statistical validity of the model). Some important considerations affecting the accuracy of trip generation estimates derived from travel diary surveys are the source data used to develop the sample of trucking companies, as well as the trucking activity characteristics of the region. For example, if only those trucks registered in the region participate in the survey, while there are a large fraction of out-of-region registered trucks operating in the area, then the trip generation analysis will underpredict the total truck trips generated in the region.

Traffic Routing

Travel diaries record the routes taken by trucks for each truck trip between O-D pairs, which can be used to understand truck traffic routing patterns in the region for the validation of traffic assignment procedures. GPS-based travel diaries provide accurate and real-time truck routing information, which serve as critical inputs for the analysis of routing pattern variations by time of day. For example, how congestion during peak hours might impact truck routing patterns during the day, compared to the nighttime.

Implementation Issues

Sampling Frames

Selection of appropriate sampling frames is an important element in the design of travel diary surveys. Vehicle registration databases are commonly used data sources for developing sampling frames that contain the listing of all the trucks registered in a region. These databases are typically maintained by each state's Department of Motor Vehicles (DMV). The approach used to sample the population plays a critical role in determining the utility of the data gathered for planning and modeling applications. For example, in order for the survey to provide data to better understand truck trip-chaining activity in the region, the sampling approach should consider selecting a larger fraction of trucks primarily performing short-haul local distribution activity, compared to long-haul shipments. Thus, random or systematic sampling techniques are generally not optimal for selecting sampling frames for travel diary surveys because the sample tends to have the same distribution of trucks as in the population. Stratified sampling is the best approach, which involves stratifying trucks in the population and selecting samples from each stratum to develop the sampling frame. Vehicle registration databases may provide average trip length information for each individual truck record, which can be used as a parameter to stratify trucks based on short- and long-haul trucking activity. The sampling frame is developed by selecting a larger fraction of trucks performing short-haul trucking activity. The sampling fractions, depending on the desired sample size for the survey Annual VMT information for each truck record might be another potential parameter used for stratified sampling. However, annual VMT is not a very good indicator of short- versus long-haul trucking activity.

Costs

Cost is a major implementation issue only in the case of GPS-based travel diaries, owing to the high equipment costs associated with GPS receivers, and the costs of installation on trucks. However, limited data are available on the costs of conducting GPS-based travel diary surveys because of the relatively fewer applications of this survey methodology.

Data Limitations

Some key limitations associated with data collected from travel diary surveys include the following:

- Sampling process can be difficult, especially in cases where there is lack of good information on points of contact and their addresses and telephone numbers for trucks operating in the region.
- The use of vehicle registration databases for the surveys can produce biased results in cases where there is a significant fraction of trucking activity associated with trucks not registered within the region. In this case, the travel diary surveys also will potentially underpredict the total trucking activity in the region.
- One of the biggest problems associated with travel diary surveys is low response rates. Truck owners, in many cases, are not willing to participate in the survey due to confidentiality issues pertaining to sharing travel and customer information, as well as interruptions caused by the survey to drivers' normal work schedule.
- Travel diary surveys using GPS receivers are relatively more expensive to implement. There also is the potential for equipment failure in these surveys.

11.0 Applications Issues

11.1 Introduction

The purpose of this section is to give additional guidance on the application of the methods presented in this Manual. Many of theses applications issues are not unique to freight forecasting but are common to all forecasting, transportation or otherwise, but because they do affect freight forecasting, they are discussed here. Other application issues are unique to freight forecasting. Even though some of these issues have been discussed during the sections on the methods, for the sake of clarity they are discussed again in this section.

The earlier sections in this Manual discuss methods and data collection, but not all of the methods and data may be appropriate for a given area. When applying the methods of this manual, it is important to understand:

- What is the nature of the freight system in the area?
- What are the desired uses of the forecast?
- What is the availability and quality of data?
- What level of accuracy is needed, taking into consideration how the freight forecast relates to passenger forecasts?

Often, forecasts of freight are only a small part of a larger forecast encompassing both passenger and other types of truck travel. In these instances, the goals of the whole forecast need to be considered. Determining the level of effort should be based on an understanding of its importance in the whole forecast and to its potential contribution to the accuracy of the whole forecast. For example, if trucks comprise only 10 percent of the traffic in the area, then it would seem unreasonable to spend 50 percent of the forecasting effort on the freight portion. The challenge is to produce quality results by being resourceful, while still being efficient.

The issues of the nature and importance of the freight system, the uses of the forecasts and data availability have been discussed previously and will be discussed later in this section. The following discussion of level of accuracy is meant to reassure those who will be preparing forecasts of freight that the level of accuracy for freight forecasts need not always be held to the same standards as those of passenger forecasts. Error theory states that the most unreliable inputs have the greatest impact on the quality of the outputs. For example, on a major arterial in a city that has 20,000 vehicles per day, with 10 percent trucks and 90 percent passenger cars, the root mean square error (RMSE) of assigned passenger car volumes might be 15 percent, or 2,700 cars (15 percent = 2,700/[0.9*20,000]). If the error in the assigned volumes for trucks were to be 30 percent, then it would result in only a small increase in the totals error, making the typical assumption that the errors are independently distributed random variables.

$$\text{Total Error with a 15 Percent Truck Error} = (2{,}700^2 + 270^2)^{1/2} = 2{,}713$$

$$\text{Total Error with a 30 Percent Truck Error} = (2{,}700^2 + 540^2)^{1/2} = 2{,}753$$

The total RMSE error of all of the forecast volumes increases only 2 percent with the increase in truck error from 15 to 30 percent. Therefore, the truck forecast in this example can tolerate a much greater error than the passenger car forecast without adversely affecting the total vehicle forecast. Of course, this conclusion does not apply to instances where the freight forecast is of primary importance.

With the understanding that the level of accuracy in freight forecasting need not be as strict as those required for passenger forecasting, the remainder of this section will discuss model application issues from the previous sections.

■ 11.2 Controlling Factors

Understanding the controlling factors for freight forecasting and how a particular study or project can influence and be influenced by these factors is crucial in freight forecasting. The forecasting process must be able to address those factors that are significant, address the major characteristics of the alternatives that are under consideration, and consider factors that are within the jurisdiction of the agencies for which the forecasts are prepared.

Shipment sizes and frequency may be an important factor in the choice of mode by shippers. These business process decisions may vary markedly between industries, are subject to continuous and unpredictable change, may not be within the jurisdiction of public agencies, and would be unlikely to be addressed by public agency projects or programs. Therefore, it may not be necessary or appropriate when considering mode split in the forecasting of freight to include variables like shipment size in the forecasting methods.

Different modes may only be appropriate when the shipping distances exceed several hundreds of miles. If the planning jurisdiction is a metropolitan area that cover a radius of less than 100 miles, either those modes may need to be handled separately or be excluded from the agency forecasting methods; or if the actions of the agency are likely to impact mode choice for freight, the forecasting process for freight may need to cover a broader area than that of passenger forecasting. Covering a broader area has implications on the development of a network and obtaining data and forecast for this larger area.

Management systems may require forecasts for a time period that is much shorter than typical 20-year horizon considered by planning agencies. Pavement management systems may require forecasts of freight volumes that cover a period of only several years and may need to be sensitive to seasonal variations that are not typically considered in that agencies forecasting process. In those cases, simple growth factoring methods may be better able to provide short-term forecasts that are sensitive to seasonal demand.

These are only a few examples of some of the ways that an understanding of the controlling factors can influence the selection of a freight forecasting method. If the effort to consider these factors is not made, an agency runs the risk of expending scarce resources in developing a method that cannot consider certain policy and project attributes or developing a method that considers attributes that will never be changed or for which forecast of those attributes will not be available.

■ 11.3 Growth Factoring

Whether growth factoring methods rely on trends in historical flows or economic indicators, the use of growth factors assumes that the trend that existed in the past will continue into the future. More sophisticated forecasting methods should be considered when it is known that this assumption is not correct. One of the basic tenets in growth factoring is that if there is no activity in the past, then applying a growth factor to that lack of activity also will show no activity. In other words, zero times a factor will still be zero. In situations where new freight activity is expected, not just an extension of existing trends, growth factoring is probably not appropriate. Similarly, if an underlying change in the freight activity is expected that was not present during the period from which the growth factors were developed, then growth factoring may not be appropriate. An example of this may be growth factors that could be developed for a period that reflected the economic regulation of carriers, followed by a period without economic regulation. The use of factors based on these past trends into the future may not yield accurate forecasts.

In addition to the application issues associated with extending past trends, the use of economic indicator variables has additional issues. Developing the relationship between the freight flow and the economic indicator variables may be difficult. Truck counts may be available only in the aggregate and provide no information about underlying purposes or commodities that could be associated with economic indicators. Total truck volumes might be known, but flows by commodity might be unknown or difficult to obtain and average usage assumptions may not be appropriate. Average statewide truck usage assumptions by commodity, for example from VIUS, may not be appropriate for a specific corridor where the economic activity is different than the average of the whole state. For example, a corridor that has a higher average concentration of high-tech or service industries than the state average would not be expected to match average state freight flow patterns.

The establishment of a suitable geographic area for the economic indicator variables that can be associated with a facility may be difficult. If a facility carriers a great deal of through freight, then local employment might be a poor indicator of future growth. Even the establishment of a suitable influence area for a specific facility is difficult. This raises several questions, such as: Should it be surrounding census tracts? The county in which it is located? Surrounding counties? Substate areas? Even if the area can be determined, obtaining base and forecast economic indicators may not be possible. It is not possible to develop factors that are based on the growth in employment in a particular industrial sector when no forecasts of employment in that sector are available.

11.4 Network and Zone Structure

The ability to use four-step methods to forecast freight will be dictated by the network and zone structure that is available to support that analysis. The geographic area covered by the model may be too small to address the distances or cover the markets that need to be considered in freight forecasting. This is true whether the freight trip table is one that is created through a trip generation/trip distribution/mode split process or is one based on a commodity table obtained from other sources. The area covered by the model needs to cover the area which is expected to influence freight decisions.

Once the area to be covered by the model has been identified, the application issue will be to obtain base- and forecast-year data for that zone structure. In many cases, the zone structure at which that data are available for the geography outside of the model area will dictate the zone structure. For example, for a freight model for New York, if data is available only for the State of Florida, unless the forecasting process is going to estimate data at smaller levels of geography within Florida, then a single zone covering the State of Florida would be appropriate for this forecasting application.

The difficulty of obtaining networks outside of the area covered by the passenger travel model, i.e., state or urban area, and providing linkages between that model and the larger network is simpler than it has been in the past. FHWA developed a highway network in TransCAD format as part of its FAF1 project[1] and will soon be providing an update of that network as part of its FAF2 project. These networks have all of the attributes needed for travel demand model network (e.g., connected links and nodes, centroid connectors to county zones, link distances, functional classifications/facility types, capacities, free flow speed, congested speeds, etc.). The node and link locations are coded in a decimal degree projection and with sufficient detail (e.g., county FIPS code) to allow this highway network to be integrated with existing travel demand models covering areas of smaller geography. For other modes (i.e., rail and inland water), the BTS web site provides networks that can be downloaded[2] and modified for use in travel demand models.

---

[1] FAF1 TransCAD network available for download from http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf_highwaycap.htm.

[2] The National Transportation Atlas Databases 2006 (NTAD2006) is a set of nationwide geographic databases of transportation facilities, transportation networks, and associated infrastructure. These datasets include spatial information for transportation modal networks and intermodal

(Footnote continued on next page...)

11.5 Trip Generation

Trip generation application issues will vary depending on whether the model is a commercial truck model, like those used in most urban areas or densely populated states such as Connecticut or New Jersey, or is a multimodal commodity model like those used in states such as Florida, Wisconsin, or Indiana. In the case of truck models, the trip generation will forecast trips by truck type (e.g., medium and heavy, single unit and combinations, etc.). For multimodal commodity models, trip generation will be for groups of similar commodities. In both types of models, the trip generation equations may be created by regression of the independent variable (most often employment by industry) to a survey of the dependent variable, observed base year flows (most likely a commercial vehicle survey) for truck type models, and a CFS for multimodal commodity models. If the rates are borrowed, then they still would have been created in this fashion in the area from which it is borrowed. In the event that the rates are borrowed, it should be recognized that the assumption is that the conditions giving rise to those trip generation equations also are similar enough to make borrowing appropriate.

Whether the equations are borrowed or created from a survey, the equations should have no constant terms. No economic activity means there should be no freight activity. For models where the trip purposes are truck trips, the production equations will be the same as the attraction equations, i.e., the number of trucks entering a zone should equal the number of trucks leaving that zone. For models where the purpose is a commodity, there should be different equations for productions and attractions, i.e., there is no reason for the flow of a commodity from a zone to equal the flow of the commodity to that zone. Additionally, the independent variable in the commodity production equation will likely be related to the industry producing that commodity, while the attraction industry will be related to the industries consuming that commodity.

For commodity models that are based on surveys of unlinked trips, that is where the survey includes a separate record for each modal portion of multimodal trip, the change of mode will not be able to be explicitly calculated in the forecast. In those instances, the traffic originating or destined for zones that contain intermodal terminals will be unrelated to economic activity in that zone for the producing or consuming industries. In the case of those commodity surveys that include only the domestic portion of an international shipment of freight, such as the CFS, the freight shipments to or from those zones containing international marine ports also will be unrelated to economic activity in those zones. These zones will need to be handled as special generator zones in the trip generation process. Forecasts for these special generators should ideally be obtained from other sources, such as the facility operators.

---

terminals, as well as the related attribute information for these features. Available on CD or for download at http://www.bts.gov/publications/national_transportation_atlas_database/2006/.

11.6 Trip Distribution

The exchange of freight between zones is limited by the total production and attraction of freight trips from the trip generation step and is governed by the impedance or friction to travel between zones, in a manner similar to that used in passenger forecasting. Almost all freight trip distribution methods use a form of the gravity model. In both urban and long-distance freight modeling, an exponential form of the impedance function is most often used. The use of the exponential form of the impedance function provides a useful check on the coefficients that are used in freight trip distribution. When the impedance or friction factor between zones i and j is of the form:

$$F_{ij} = e^{-k * t_{ij}}$$

where the k-coefficient in that exponential distribution is by definition the inverse of the average trip length expressed in the travel units, usually time or distance, measured by t_{ij}. Thus, in an urban truck model, when the travel unit is minutes and the k-coefficient for a practical truck purpose is 0.08, the implied average travel time is 12.5 minutes (12.5 =1/.08). For long-distance freight models, the average trip length is typically given; for example, a 526 miles mean shipping distance for metallic ores will have a the coefficient of -0.0019 (1/526). An average distance of 562 miles, typically a longer distance than can be traveled in most statewide models, shows why these models need to include national networks, well beyond the study area focus, simply to forecast the behavior of freight in the study area.

In passenger forecasting, the result of the trip distribution process is a production attraction table which must be later transposed into an origin destination table. In passenger modeling, this is due to the need to make sure that the trips between the origin and destination are balanced for trips based at the home, i.e., trips made from a home zone to a work zone must return to the same home zone at the end of the day. There is no need to account for this process in freight modeling. The result of a freight trip distribution already is in an origin destination format. A shipment of metal products from a factory will not return to the factory but will be consumed by producing other goods, and those goods will be forecasted separately.

11.7 Mode Choice

Unlike passenger forecasting, mode choice is not often addressed by an equation in freight forecasting methods. In truck-based models, there is no need to calculate the mode because, by definition, it is truck. In commodity-based models, additional research is needed to better define the utility variables that give rise to modal choice, as well as to develop credible estimates of these utility variables for modes other than by highway. In the absence of these methods, most commodity-based models rely on the underlying distribution of freight in the base commodity survey and assume that this mode choice, by commodity, will remain constant in the future. Since the approach relies on the base CFS, the approach is transferable, but the mode shares will be specific to the region's CFS and are not transferable.

11.8 Conversion to Vehicles

For truck-based freight forecasting, there is obviously no need to convert to vehicles, since the flow unit already is expressed in vehicles. This step only is necessary for commodity-based multimodal freight forecasts. Generally, those forecasts will be calculated in a non-mode-specific flow unit, such as tons, ton-miles, or value. In order to be useful in many transportation forecasting applications, it is necessary to convert those flow units from annual tons to daily vehicles: most often trucks or less often rail cars.

A common source of information used to convert from tons to trucks is the U.S. Census Bureau's VIUS. This survey includes records of truck usage, in terms of percentage of miles traveled carrying certain categories of cargo. The state records in this database can be used to develop average payloads from the weight of the vehicle surveys and the percentage of miles that it carries specific commodities. Prior to 2002, VIUS used its own unique commodity classification system, and used coding roughly equivalent to the SCTG commodity classification.

The vehicle payloads by commodity shown in this Manual can be transferred for use elsewhere, but it should be understood that the estimates are based on trucks based in that state. VIUS cannot be used to determine information for trucks traveling to a state nor for trucks traveling through a state. The payload mix for a state is based on the survey mix of commodities for trucks based in that state. Although truck characteristics can be expected to be similar everywhere, transferred rates should be used with caution. The VIUS includes information on the percentage of miles a truck is driven empty. Therefore, the VIUS-derived payloads can include allowances for empty miles. The Florida and Wisconsin values shown in Section 5.0 of this Manual include allowances for empty miles.

VIUS has not been funded as part of the 2007 Economic Survey. To the extent that the commodity carrying characteristics of freight are not expected to change over time, it may be appropriate to use the 2002 VIUS, which may be the last such survey undertaken.

The conversion from annual tons to daily tons also is a consideration that must be considered in converting to vehicle trips. This conversion will be based on local considerations on how an average day is included in other transportation forecasting. Typically, this number is based on the number of working days per year during which freight is expected to move. Values commonly used are 312 days per year (6 days per week), 306 days per year (6 days per week less 6 major holidays), or 250 days per year (5 days per week). This consideration also is where adjustments to reflect seasonal variations could be made.

■ 11.9 Assignment

The results of the truck freight assignments in highway models can take one of two forms: 1) truck trips that will be pre-assigned to links before the passenger auto trips are assigned; or 2) a truck origin-destination trip table that will be assigned to the network at the same time as passenger auto trips. Depending upon the chosen assignment method and features of the software, each form has its advantages and disadvantages.

There may be valid conceptual considerations for pre-assigning assigning truck trips. The drivers of large trucks passing through an area may be unfamiliar with the possible alternate paths available in the event of congestion and may choose only the preferred paths. Large trucks may not be able to maneuver on the arterial and collector roads that comprise the alternate paths. Large truck companies/drivers may value reliability more than travel time and chose the certain travel time on congested routes over the less reliable time on faster alternate routes. There also are computational advantages of pre-assigning truck trips: 1) PCE factors can be adjusted for grade and other road conditions specific to individual links; and 2) certain links and turn movements can be prohibited. When trucks are pre-assigned, their volumes contribute to the congestion calculations for auto travel.

Assigning truck trip tables together with passenger auto trip tables in a multiclass assignment is appropriate when it is expected that trucks will respond to congestion in a manner similar to autos. This may be because the majority of truck drivers are familiar with alternate paths or congestion introduces unreliable conditions rendering all paths suitable for trucks. It is still possible in these multiclass assignments to restrict trucks or autos from certain links. It is just that both trucks and autos will modify their paths on all links in response to congestion. The computational advantages of assigning a truck trip table at the same time as a passenger car trip table are: 1) faster software execution; 2) less data manipulation; and 3) the ability to reroute trucks to avoid congested links and turns.

Assigning vehicles for modes other than trucks is not typically undertaken. When it is done, the assignment may use a predetermined set of paths between an origin and a destination that will not vary due to congestion. This approach is often the approach taken in forecasting rail flows on a network. The advantages of using a predetermined set of paths is that it can consider the private business decisions of the modal operators, where paths may be chosen to balance loads, maximize system revenue, provide incentives to favored shippers, or other reasons that may not optimize the paths for a specific shipment (user). However, these paths are usually obtained qualitatively through examination rather than quantitatively based on characteristics of the links on the path. Since the paths are not based on link characteristics, they cannot easily be changed in response to establishing new characteristics along the links, e.g., improved track speeds.

11.10 Integration with Passenger Forecasts

There are several application issues to consider when integrating freight forecasts with passengers models. Most of those issues occur in integrating truck forecasts into the highway model while the trip generation/trip distribution/mode split steps will remain separate from passenger forecast because they are being treated as different purposes. There is one purpose in particular in truck models that needs special consideration in integrating with the freight forecasting methods described in this manual. Four-tire trucks, FHWA vehicle Class 4, the category of vehicles that includes pickups, light vans, and SUVs, includes vehicles that can be used for both passenger and commercial purposes. The behavior of these light trucks in commercial purposes is very similar to that of all passenger vehicles used for Non-Home-Based (NHB) passenger trips. Those preparing forecasts will need to decide if these commercial trips should be considered separately or with NHB trips. Even if they are considered separately, the validation data available for the assignment of light trucks, observed truck counts on links, will not distinguish between passenger and commercial purposes of these trips and other means may be needed to validate these commercial light truck trips.

A similar application issue exists for commodity freight truck models in terms of how to integrate commodity trucks with passenger auto forecasts. In these models, the definition of freight may exclude local deliveries of freight, and those local delivery truck trips would not be included in the forecasts. The validation data that will be available, observed three-axle or higher truck trips on links, will not distinguish between trucks used in freight and trucks used in other purposes, such as for service, construction, or utility purposes, much less between the local delivery and commodity purposes of trucks. Validation of the truck portion of commodity models may need to be based on flows on links where these flows predominate over the local or non freight purposes; for example, on rural interstates and principal arterials. In this event, before the commodity truck forecasts can be integrated with passenger auto forecasts, some estimate of the remaining portion of commercial truck trips must be made. In developing noncommodity truck trip forecasts, for example, using the methods outlined in Section 4.1, it should be noted that these methods include commodity trucks and some means to exclude this portion of truck trips must be developed.

12.0 Case Studies

■ 12.1 Los Angeles Freight Forecasting Model

12.1.1 Purpose and Objective

The Los Angeles freight forecasting model (LAMTA model) was developed as part of the efforts by the Los Angeles County Metropolitan Transportation Authority (Metro) to address the impacts of the growing volume of goods movement in and around the Los Angeles metropolitan area on the overall transportation system in the region. The development of the LAMTA model was prompted by Metro's decision to upgrade its transportation demand model, with the objective of gaining the ability to assess the potential benefits that could be realized from the implementation of various freight transportation policies and infrastructure projects in the future. Also, it was crucial for the freight model to produce results at the same TAZ system as the passenger model to facilitate an integrated modeling framework for the analysis of goods and passenger movements on the transportation network.

The LAMTA model was developed using a more robust and innovative approach compared to previous modeling undertakings, in order to meet the above technical challenges and model application requirements. Some innovative modeling approaches incorporated in the LAMTA model are outlined below:

- Freight movements are modeled at different levels of detail for long- and short-haul movements. Long-haul freight is derived from commodity flows at a national level with full modal options (truck, rail, and air), and are chained with trips through intermodal terminals. Short-haul freight is derived from socioeconomic data in the region and chained with trips through warehouse and distribution centers.
- Service trucks that do not carry freight are modeled separately and included as part of overall truck movements.
- The model has a separate module for data inputs and modeling of transport logistics nodes/centers (warehouses, distribution centers, and intermodal terminals), which incorporates trip chaining concepts.
- The modeling framework provides forecasts that reflect trends in labor productivity, imports, and exports. Trend forecasts are derived from FAF national data.
- Freight movements coming in through the ports are simulated as special generators based on forecasts from the ports and data collected at the intermodal terminals.

12.1.2 Model Study Area

The study area for the LAMTA model is divided into internal and external zones. Internal zones include detailed representation of the six-county Southern California region, which comprises of Los Angeles, Orange, Imperial, San Bernardino, Ventura, and Riverside counties. The external zones include the rest of California, remainder of the United States (other than California), Canada, and Mexico. The LAMTA model comprises of two levels of zoning systems, namely a fine zoning system and a coarse zoning system. The fine zoning system is based on the LA metro passenger travel demand model zoning system, comprising of 3,000 zones, while the coarse zone system is based on zip code boundaries in the Southern California region. For external zones, both the fine and the coarse zone systems are based on county boundaries for the rest of California region, and state boundaries for the rest of the United States. The entire LAMTA model study area has 3,800 fine zones and 650 coarse zones.

12.1.3 Modeling Framework

The LAMTA model comprises of the following modeling components:

- Trip generation model;
- Trip distribution model;
- Mode split model;
- Transport logistics node (TLN) model; and
- Vehicle model.

The trip generation and distribution models use a combination of the hybrid modeling approach for freight forecasting, while the Transport Logistics Node (TLN) and the Vehicle models incorporate logistics chain/supply chain modeling and tour-based modeling approaches, respectively. The following sections provide a brief description of hybrid, logistics/supply chain, and tour-based models, before proceeding to the specifics of each modeling component of the LAMTA model.

Hybrid freight forecasting models for urban areas are based on a combination of commodity-based freight modeling (which use base year and forecast commodity flow data as inputs, and estimate multimodal freight trips on the transportation network) and three-step truck modeling approaches (which use trip generation, trip distribution, and traffic assignment steps specifically for the trucking mode, to estimate truck trips on the network). Typically, interregional or long-haul freight flows are modeled using commodity-based freight models, while three-step models find applications in modeling local truck trips in an urban area (since most of the intra-urban freight flows are carried by trucks).

Supply chain/logistics chain models simulate logistics choices throughout whole supply chains for specific industries, and those models use that information to model mode choices and the spatial distribution of freight flows through various stages in the supply chain. A typical example of a logistics model is one that combines an economic I-O model, which calculates supply and demand for each economic sector, with a logistics choice model, which assigns goods to logistics families, in order to determine the spatial patterns of supply and demand. A series of logistics models are developed that define the distribution systems that are used by each logistics family and the spatial organization of warehousing and distribution systems for product delivery and supply chain management.

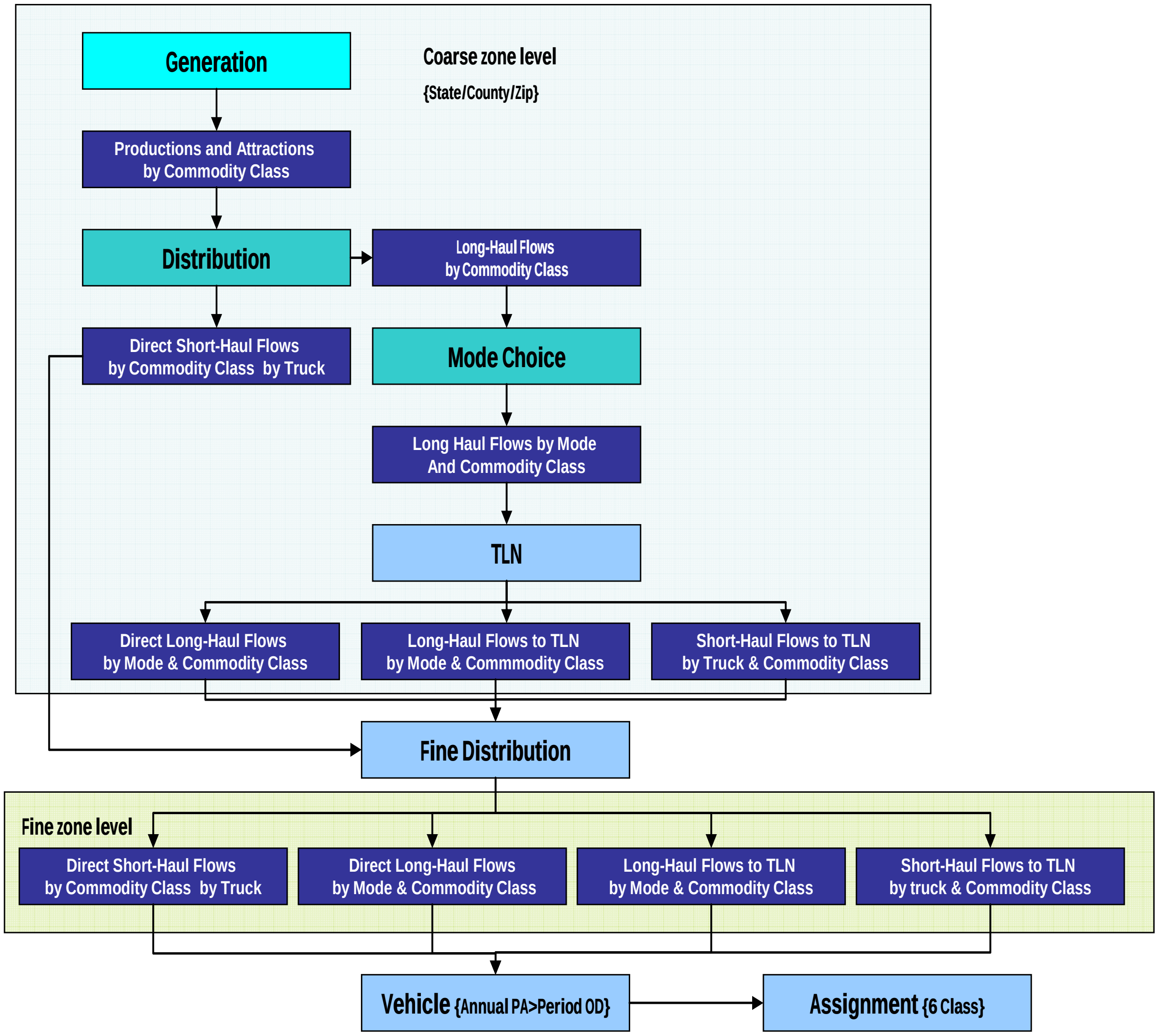
Tour-based models for truck trips derive methods from the relatively new world of activity-based passenger travel demand models. They focus on the tour characteristics of truck trips and are less concerned about what is being carried in the vehicle. These models are particularly applicable for the modeling of local truck trips in urban areas, where significant tour making activity of truck trips is prevalent (for example, truck trips that originate at retail distribution centers, and make multiple stops to deliver goods at many retail outlets in the urban area).

In the LAMTA model, the supply-chain and tour-based modeling concepts are applied selectively in the TLN and vehicle models, respectively, to ensure that these methods apply specifically to those freight or truck movements that will benefit from the additional modeling complexities. Figure 12.1 depicts the steps involved in the freight-forecasting process in the LAMTA model. Each of the modeling components in the LAMTA model are described more comprehensively in the following sections.

12.1.4 Trip Generation Model

The trip generation model is the first modeling component of the LAMTA model that forecasts total tons of each commodity group produced and consumed in all internal coarse zones. Commodity productions are divided into internal productions, which are destined to internal zones and exports that move to external zones in the model. Similarly, commodity attractions/consumptions are classified as internal attractions that originate from internal zones and imports, which come from external zones. The trip generation component of the LAMTA model has five elements, which are described below.

Figure 12.1 LAMTA Model Freight Forecasting Process



Source: Los Angeles Cargo Forecast Model Development, Outwater et al., 11th World Conference on Transportation Research, Berkeley, California.

Trip Generation for Internal Zones

Trip generation for internal zones is estimated by applying linear regression models, which use socioeconomic attributes of zones (population and employment) as inputs to estimate zonal commodity production and attraction tonnages. The parameters and constants of these models (regression coefficients) are estimated using the 2003 commodity flow data from the Caltrans Intermodal Transportation Management System (ITMS) database, and detailed zonal socioeconomic data from the Southern California Association of Governments (SCAG). Different linear regressions are developed for commodity production and attraction models for the 14 commodity categories in the LAMTA model. For production models, regressions are developed separately for each commodity group by modeling outbound commodity tonnages as a linear function of the corresponding industry employment. For attractions, an I-O matrix was used to identify the industries that consume each commodity group for secondary manufacturing and to use the zonal employment for those industries as regression model inputs to estimate the total zonal commodity attraction/consumption tonnages.

Special Generators

Sea and airports are included as special generators in the model, in order to identify and model goods movement flows by each commodity group that travel through these locations. Truck trips related to sea port activity are estimated from the port truck trip tables provided by the Port of Long Beach and Los Angeles model, while the SCAG airport model was used to derive truck trips associated with air cargo. These trip tables were converted into zone system of the LAMTA model and added to the final truck trip table before performing the truck traffic assignment.

Trends in Commodity Production Efficiencies and Other Factors

Trends in labor productivity are estimated by comparing commodity production tonnages with industry employment data at specific points in time. The CFS, conducted in 1997 and 2002, was the main data source used to calculate industrial labor productivity trends, and apply them to the future year LAMTA model.

External Commodity Flows

The external flows (flows between the internal model study area and external regions) are developed from the ITMS data. These are input as user-defined values by commodity class for the base (2003) and future years (2030). These commodity flows represent the amount of production exported to external zones, and the amount of consumption/attraction that is imported from external zones. These were compared to truck counts at external stations and updated.

Trends in Import and Export Levels

Trend rates in import and export levels have a significant impact on the growth in commodities and associated truck trips and are represented separately in the model to reflect this. These import and export trend rates, which are only applied to the future year model, are developed from the base and future years of FAF commodity flow data for California.

The generation model was calibrated by comparing model volumes to total truck counts and making appropriate adjustments to the generation models for productions and attractions to improve this comparison.

12.1.5 Trip Distribution Model

The trip distribution models in the LAMTA freight modeling framework produce trip tables of goods flows by commodity class, which are derived using gravity model techniques. Key assumptions of freight flow distribution in these models are developed using available freight data sources such as the ITMS and FAF.

The trip distribution model assumes percentage splits between short- and long-haul travel by commodity class which are derived from the ITMS data. Since these percentage splits may change over time, based on trends that may be outside the capabilities of the model to predict, these trends are incorporated in the model as external inputs, based on ITMS forecasts. The model assumes all short-haul flows to be carried by the trucking mode, while long-haul movements pass through a mode split modeling component, to determine the mode shares by trucking and rail modes.

A gravity model with a negative exponential deterrence function is used for the distribution of short-haul trips. The function is applied to the square of the distance as shown below:

$$F_C(d) = e^{(\frac{-d^2}{2p_c^2})}$$

where, c is a commodity group;

e is the base of the natural logarithm function (approximately 2.718282);

d is the distance;

Fc(d) is the deterrence function of distance (impedance) used in the gravity model; and

p_c is the calibration parameter for commodity c.

Similar to the short-haul trip distribution, a gravity model with a negative exponential deterrence function is applied for the long-haul trip distribution. However, the difference is in the impedance variable due to the multimodal aspect of the trip distribution, which in this case is the generalized cost calculated in the mode choice model. Generalized cost is a linear combination of time, distance, and cost by mode, weighted by the mode choice coefficients.

The mathematical equation for the long-haul trip distribution model is as follows:

$$\Phi_C(G_C) = e^{-P_C\left(1+\frac{\Gamma_c}{100}\right)^y G_C}$$

where, c is a commodity group;

e is the base of the natural logarithm function (approximately 2.718282);

G_c is the composite cost derived from the logit model used for modal split;

$F_c(G_c)$ is the deterrence function of generalized cost used in the gravity model;

P_c is the calibration parameter for commodity c;

Γ_c is the growth factor for the calibration parameter for commodity c; and

y is the time, in years, from the base year to the future year for which the model is being run.

Gravity model parameters are calibrated by commodity class for short- and long-haul goods movements using average trip length data from a variety of sources. Trip tables at the coarse-zone level are distributed to the fine-zone system based on an allocation of goods by commodity class using zonal socioeconomic data. The distribution models produce O-D tables (for short- and long-haul) of annual tons of goods movements by commodity class.

12.1.6 Mode Choice Model

Mode choice models are applicable only to the long-haul goods movements, since all short-haul moves occur by the trucking mode. The mode choice model is a multinomial logit (MNL) model stratified by commodity and distance classes. A generalized cost function is defined for each combination of commodity class and mode. There are three independent variables associated with each mode, which include time, distance, and highway generalized cost. The functions each involve four coefficients, one for each of the independent variables and one for the constant term, as follows:

$$\Gamma_c(d,\tau,\chi) = \sum_m \zeta_{cm}(d,\tau,\chi)\Gamma_{cm}(d,\tau,\chi)$$

where, c is a commodity group;

m is the mode;

d is the distance;

τ is the time;

χ is the highway generalized cost;

$\Gamma_c(d,\tau,\chi)$ is the composite cost function for commodity group c and mode m;

$\Gamma_{cm}(d,\tau,\chi)$ is the generalized cost function for commodity group c and mode m; and

$\zeta_{cm}(d,\tau,\chi)$: The proportion of tons of commodity group c that will travel by mode m.

Since distance classes were observed to have unique mode choice sensitivities based on calibration data, these models were further segmented based on distance classes. Coefficients for the model were borrowed from the Florida Statewide Freight Model. These were then calibrated from data in the ITMS. The output of the mode choice models include O-D tables (for long-haul shipments) of annual tons of goods moved by commodity class and mode.

Transport Logistics Node (TLN) Model

An innovative and important component of the LAMTA freight demand forecasting process is the representation and modeling of the long-haul freight logistics system through the Transport Logistics Node (TLN) model. The TLN model is only applied to long-haul freight flows, which are defined as flows between internal zones (within the six-county Southern California region), and external regions (remainder of the United States as well as entry points to/from Mexico and Canada). An example of a typical long-haul shipment treated in the TLN model would be automobiles manufactured in Michigan traveling to southern California. Freight flows that move entirely within the internal study area of the model are not modeled in the TLN model.

TLNs are defined as locations such as major intermodal yards, trucking terminals, transload facilities, and warehouse/distribution centers where trip chaining of long-distance flows occurs. The TLNs considered by the TLN model are only those located within the internal study area, information on which was collected through a shipper survey conducted for 131 locations in Southern California combined with rail operator data obtained at six intermodal yards.

The TLN model is based on two primary elements: the commodity flow matrices from the mode/distribution model and a description of the TLNs. The commodity flow matrices are inputs directly from the mode/distribution model – one table or matrix per combination of major mode of transport and commodity class. The following three parameters are applied where the internal zone has a TLN located within it:

1. Long-distance truck flow splits by direction (inbound and outbound). The following parameters serve as inputs to the model for each commodity class and direction:
   - Amount of goods moved by trucking mode that are shipped in full truckload, partial truckload, and consolidated load (less-than-truckload) shipments; and
   - For each of the above load types, the percentage of shipments that will pass through TLNs.
2. Long-distance rail flow splits by direction:
   - For each commodity class, by direction, the percentage of shipments that will pass through TLNs.
3. Long-distance inland-waterway flow splits by direction:
   - For each commodity class, by direction, the percentage of shipments that will pass through TLNs.

The commodity flows are split into two segments:

1. Long-haul portion of the movement (travels via the input mode: truck, rail, or ship); and
2. Short-haul portion of the movement (travels via truck).

The short-haul portion of the movements is distributed between the TLNs in the internal areas using another set of parameters. These are defined by direction for each commodity class, specifying the percentage of goods that will go to or come from each of the TLNs. At the end of this process, the TLN model produces four matrices per mode per commodity group. These are short-haul direct (do not go via a TLN), long-haul direct (do not go via a TLN), long-haul to or from TLN, and short-haul to or from a TLN. All short-haul flows to or from a TLN are truck only.

Vehicle Model

The vehicle model is used to convert the matrices that contain annual commodity flow tonnages by truck (direct-short-haul flows, short-haul trips to and from TLNs, and long-haul truck flows) into daily vehicle truck matrices. The truck matrices are divided into heavy and light trucks. All long-haul truck flows are assumed to be in heavy trucks.

The main parameters in the vehicle model include the fraction of shipments for each commodity flow category (direct-short-haul flows, short-haul trips to and from TLNs, and long-haul truck flows) that are carried by each truck class, and the payload factors by commodity group and truck classes. The following sections describe the applications of these parameters in the model, in greater detail:

- For the direct short-haul flows, percentage of the goods that move by light trucks by commodity class and average tons loaded in each truck. An additional scaling parameter is used to account for empty short-haul trucks.
- For the short-haul truck flows to and from the TLNs, percentage of the goods that move by light trucks by commodity class and average tons loaded in each truck. An additional scaling parameter is used to account for empty truck short-haul truck flows to and from TLNs.
- For long-haul truck movements, a parameter with the average tons loaded in each truck by commodity class, as well as a parameter to account for empty long-haul trucks.

These parameters are used within two models contained within the vehicle model:

- The standard vehicle model that is used for flows directly from origin to destination and back. This model allows return loads to come from the destination back to the origin and also allows the truck to find return loads within a user specified criteria.
- The touring vehicle model that simulates multi-point pickup and drop-off.
- The standard vehicle model is applied on all origin-destination flows, except those coming to or from TLNs and those specified by the user. Once the models have been run, all matrices for a given mode and commodity group are combined to give a single vehicle matrix, relative to the fine zoning system (i.e., trips to or from a TLN are now assumed to run to or from the fine zone containing the TLN), in vehicles per annum. The matrix is then divided by the value of control data parameter to give units of vehicles per day.

12.1.7 Data Requirements for the LAMTA Model

The following sections describe the model application data (base and future year data inputs) required for inputs to the LAMTA model for the freight forecasting process.

Roadway Network

The source data for the roadway network for the model is the FHWA's FAF. The roadway network is used to estimate truck travel times and distances, which also consider user assumptions related to average truck pickup and drop-off times, and driver rules related to break and overnight stop times. The roadway network costs are estimated using costs per ton-mile values for each commodity type, in conjunction with roadway distances.

Rail Network

FHWA's FAF also is the source data for the LAMTA model rail network. The network was used to estimate rail travel times, distances, and costs. User assumptions also are applied to add pickup and drop-off times, transfer times, and average rail speeds. Rail network costs are estimated based on assumptions on costs per ton-mile by commodity type, which are applied to distance. The railway network in the model consists of Class I railroads with other railroad classes retained in order to provide network connectivity.

Socioeconomic Data

Socioeconomic data is a major input for the LAMTA model since it is used to estimate forecast tons produced and consumed in each zone in the model. Socioeconomic data also are used in other parts of the modeling system, including the vehicle and routing model components. As described earlier, the LAMTA model uses a two-tiered zone system, namely the "coarse" and "fine" zone systems. Much of the calculation is done at the coarse zone system since observed matrices of commodity flows (for example, ITMS) are unavailable at a more detailed zonal level. The coarse zone data are then translated to the fine zone level for network assignment. For each zone system, the following socioeconomic data are used in the model:

- Population;
- Households;
- Agriculture, mining, and construction employment;
- Retail employment;
- Government employment;
- Manufacturing employment;
- Transportation employment;
- Wholesale employment; and
- Service employment.

Commodity Flow Matrices

Commodity flow matrices in the model are derived from the Caltrans ITMS database, which has three main regional segregations of commodity flows, including Internal (inter-county flows within California), Inbound (flows from other states in the United States, Canada, and Mexico to California counties), and Outbound (flows from California counties to other states in the United States, Canada, and Mexico). The data from the ITMS were analyzed and aggregated to 16 commodity categories for the LAMTA model, based on the objective of achieving homogenous distance and mode choice characteristics within each category. The commodity classes used in the model are presented below:

- Mining;
- Metal ores and petroleum;
- Raw materials manufacturing;
- Cement and concrete manufacturing;
- Metals manufacturing;
- Processed metals manufacturing;
- Transportation/HH equipment manufacturing;
- Other transportation equipment manufacturing;
- Chemical manufacturing;
- Wood;
- Paper/wood products manufacturing;
- Ranching;
- Farming;
- Grain and specialized;
- Food manufacturing; and
- Other manufacturing.

Transport Logistics Nodes

The TLN model routes a portion of the long-haul commodity flows through transport logistics nodes in order to better model the long-haul freight logistics system, as well as accurately represent and model trip chaining characteristics associated with freight flows through these critical nodes in the freight logistics system. The list of intermodal yards that form a critical nodal component of the freight logistics system in Southern California that are used in the model are presented below:

- Union Pacific Intermodal Container Transfer Facility (UP ICTF);
- Union Pacific East Los Angeles Yard (UP East LA);

- Burlington Northern Santa Fe Hobart Yard (BNSF Hobart);
- Union Pacific Los Angeles Transportation Center (UP LATC);
- Union Pacific City of Industry Yard (UP Industry); and
- Burlington Northern Santa Fe San Bernardino Yard (BNSF SB).

12.2 Portland Metro Truck Model

12.2.1 Introduction

The Portland Metro truck model also is referred to as the Tactical Model System. The Tactical Model System, together with the Strategic Model Database (SMD), form the core elements of the truck freight forecasting model for the Portland metropolitan area. The SMD, which provides commodity flow data inputs to the tactical model, contains aggregate present and future freight flows for different commodity and mode combinations. This database serves as a useful tool providing freight flow inputs required for strategic decision-making concerning the development and operation of Portland's seagoing and river marine terminal infrastructure, major air, rail, and trucking terminals, as well as its modal transportation networks of freight corridors and access routes, to ensure transportation efficiency, reliability, cost-effectiveness, and economic competitiveness in the region, in the future.

Portland's SMD, which has been regularly updated, was originally developed by ICF Kaiser (now Kaiser Engineers), and others from a number of data sources, which include the following:

- The Reebie Associates' (now Global Insight) TRANSEARCH database;
- For air freight, forecasts by commodity and route, based on FAA air freight traffic data and related freight data provided by the Portland airport;
- For seaborne trade, forecasts by commodity and route, based on international trade data showing shipments by customs district;
- Regional macroeconomic forecasts developed by the WEFA Group (now Global Insight);
- PIERS data from the Journal of Commerce showing sea trade movements; and
- Miscellaneous forecasts prepared by the Port of Portland.

The various dimensional characteristics of the SMD are summarized below:

- **Year of Data –** Every fifth year ranging from 1995 to 2030;
- **Commodity Classification –** Seventeen commodity groups, including waste by-products and courier services;
- **Origin-Destination –** Five origin and destination areas defined relative to the Portland region: within the region, northern United States, southern United States, eastern United States, and non-United States (further divided, in some cases, into five major regions; Canada, Asia, Latin America, Europe, and the rest of the world);
- **Modes –** Eight modes of travel, including private trucking, less than truckload (LTL), truckload, intermodal (truck/rail), rail, barge, sea, and air; and for all international flows by air and sea, the domestic mode also is provided: truck, intermodal, rail, or barge; and
- **Volume of Flow –** Each cell defined by the full set of dimensions listed above contains four measures of the estimated annual freight flows, which include containerized tons, noncontainerized tons, 40-foot equivalent units (FEU), and total tons.

The Tactical Model takes inputs from the SMD, and other external sources to predict future truck freight flows on the highway network using a set of freight modeling steps involving commodity flow analyses, regional allocations, conversion of commodity flows to truck trips, and the ultimate assignment of truck trips on the highway network. An important objective during development of the Tactical Model was to replicate heavy duty truck trips on the highway network in a way that would be responsive to dynamic changes in the freight market and industry logistics in the region in the future. Such changes typical to the freight transportation supply and demand environment might include, for example, increases or decreases in the volume of goods moving through the Port of Portland facilities, and shifts in market shares of truck and rail. Although the ability to predict these changes are not incorporated within the framework of the Tactical Model System, these changes are reflected in the data that enter the Model at the top level, as external inputs. The Tactical Model also is consistent with Metro's passenger travel demand modeling system, as it uses the same geographic structure (TAZs), districts, and model study area, and takes into account Metro's procedures for steps such as time-of-day modeling.

The Tactical Model, as it currently stands, is largely empirical and less behavioral, implying that it has many fixed percentages for data inputs at various stages of the modeling process. However, with better understanding of the regional freight system dynamics and industry shipper behavior, the model is expected to incorporate more behavioral components in various steps of the modeling process. Particularly notable in this regard is the current work being undertaken by Metro to improve the Tactical Model using the data collected from a recently concluded freight data collection project in the Portland metropolitan region, led by Cambridge Systematics, Inc. Apart from these improvement efforts, the Tactical Model has many notable advantages including the following:

- It provides for the sensitivity of heavy truck flows in the region to the level of economic activity and to the shares of this activity by commodity group.
- It provides a direct and consistent linkage to a TRANSEARCH-type commodity flow database that includes not only local flows, but also external domestic and international flows.
- It explicitly deals with reloading and terminal usage for truck trips.
- It retains information on flows by commodity in the sequential modeling steps.
- It provides a general framework within which improved submodels can be added in the future as more knowledge is gained concerning the behavior of commodity producers, carriers, and consumers in the Portland region, as well as those that use the region as a gateway for domestic and international trade.

12.2.2 Model Study Area

The study area of the Tactical Model is comprised of Columbia, Clackamas, part of Marion, Multnomah, Washington, and Yamhill counties in Oregon, and Clark County in Washington. The model comprises of 2,029 internal TAZs and 17 external TAZs.

12.2.3 Modeling Framework

The following steps are involved in the modeling framework of the Tactical Model for the estimation of forecast heavy duty truck trips on the highway network.

- Regional commodity flow inputs by commodity type, market segment, and mode;
- Allocation of commodity flows to origins and destinations;
- Linkage of commodity flows to reload facilities or terminals;
- Conversion of commodity flows to vehicle trips;
- Accounting for additional vehicle trip segments;
- Addition of through truck trips;
- Assignment of vehicle trips to the highway network; and
- Each of these modeling steps are discussed in detail in the following sections.

Regional Commodity Flow Inputs by Commodity Type, Market Segment, and Mode

This step involves the preparation of outputs from the SMD which serve as inputs to the Tactical Model system. The outputs from the SMD include a set of summary commodity flow tables at an aggregate geographic level that are used as control totals for the generation of commodity flows between TAZs in the subsequent modeling steps. The primary data inputs from the SMD can be categorized into commodity flows into, out of, and within the Portland region. The SMD also provides *through* commodity movements in the region, as long as there is a change of mode involved, for example, goods coming into the Port, and moving inland by truck. Since all goods movements that move through the region by the same mode (primarily truck and some rail) are not captured in the SMD, the Tactical Model needs to account for through truck movements using sources other than the SMD. As discussed earlier, the SMD includes 17 commodity classifications, which also are used in the model.

To provide the input data for internal-internal and internal-external freight modeling, the commodity flows from the SMD are categorized into distinct market segments, in order to provide a framework for the allocation and distribution of commodity flows to appropriate zones. The market segmentation approach developed for the optimal translation of data in the SMD to the data input needs of the Tactical Model is presented below:

- **Market Segmentation Based on Mode –** In this system, the major classification is the mode or a combination of major modes used for the commodity movement into, out of, or through the region. Some examples of these modal classifications include sea and rail, barge and truck, and private truck only shipments.
- **Market Segmentation Based on Terminal Facility Usage and Flow Directionality –** The classifications included in this scheme include flows from an origin location (within or outside the Portland metropolitan region) to a terminal facility in the region (Inbound), flows from a terminal facility in the region to a destination location (within or outside the Portland metropolitan region) (Outbound), and flows between origins and destinations without the use of a terminal facility (Direct).

Truck flows with specific origin and destination locations are associated with each market segment defined by the two levels of classification defined above. These origin and destination locations are categorized broadly in the SMD as within the Portland region (p), and external to the Portland region (e). To reflect the origin and destination locations of specific market segments in addition to the modes and terminal usage/directionality, the market segments in the SMD are designated with capitalized labels such as STI (sea/truck inbound) along with the location-related information in lower case extensions of the labels, for example, STIpe (sea/truck inbound that is destined to an external region) and STIpp (sea/truck inbound within the Portland region). The MSD also include broad geographic areas for the identification of external regions used by surface modes, which include North (designated by n, and comprising of all external locations reached with I-5 north, including Canada), South (designated by s, and comprising of all external locations accessible by I-5 south, including Mexico), and Other (mainly all external locations to the east of Portland).

Within each market segment and origin/destination pair, there are two additional variables required for data inputs to the tactical model that include the commodity category (cc), and the weight unit of the shipment (w). The commodity categories include the 16 commodity classes in the SMD, while the weight units comprise of noncontainerized tonnage (n), and containerized 40-foot equivalent units (f), which, as described earlier, are separately identified in the SMD. Thus, a complete specification of the origin/destination, commodity classification, and weight units in lower case characters that would accompany the upper case notations for the mode and directionality information, will be *odccw*.

Based on the comprehensive set of market segmentation considerations discussed above, the following sets of market segments form the commodity flow inputs for the Tactical Model:

- **Truck Flows –** This segment includes all external domestic, intraregional, and Canada and Mexico surface flows, with associated trucking submodes of truckload, LTL, and private trucking. This segment does not designate Inbound, Outbound, and Direct classifications to the trucking shipments since the usage of trucking terminals by trucking shipments are handled separately by the model in a later step. The notations for these truck flow market segments in the SMD include TP (private), TT (truckload), and TL (LTL).

- **Rail Flows –** This segment includes all external domestic, intraregional, and international rail flows to/from Canada and Mexico, with rail carload or intermodal as the major modes. All these rail flows involve an associated truck move to/from the rail terminal facility in the Portland region, which is indicated by labeling these flows Rail/Truck. However, the trucking submode information for these rail flows is not available from the SMD. The notations for rail flow market segments in the SMD include RSI and RSO, where S denotes the surface trucking mode, and I and O stand for inbound and outbound respectively, with respect to the truck movement to or from the rail terminal facility.

- **Sea Flows –** This segment includes all international nonair flows, excepting a limited number of surface flows to and from Canada and Mexico. For inputs to the Tactical Model, sea flows are further disaggregated into the following categories, based on the surface mode used to/from the port facility:

  – **Sea/Truck –** Truck moves associated with oceangoing shipments are an important component of total truck trips in the Portland region. These shipments are designated in the SMD based on the direction and trucking submode into SPI, SPO, STI, STO, SLI, and SLO.

  – **Sea/Rail and Sea/Intermodal (SR) –** These involve shipments that move by rail carload or intermodal to/from the port facility. Intermodal flows involve containers and trailers on flat cars, while rail flows involve all other rail movements. Some of the SR flows may involve associated truck moves related to drayage activity to/from rail terminals, which are accounted for by applying factors specific to the designated port facility. SR flows also are classified as SRI and SRO, depending on the directionality of truck drayage moves into or out of port facilities.

  – **Sea/Barge (SB) –** These involve oceangoing shipments that move by barge to or from the port facility. These shipments typically are not expected to generate significant trucking activity in the region. However, for consistency, they are designated by SBI and SBO, to identify directionality.

- **Air Flows –** This segment involves all air cargo flows in the SMD, both international and domestic that are delivered to or picked up from the Portland International Airport (PDX) by truck. Some portions of the air cargo flows in the SMD have trucking submode information for the surface portion of the flow, which are designated by AP, AT, and AL, to denote associated private, truckload, and LTL truck shipments. As with other market segments, these shipments are disaggregated further based on directionality into Inbound (I) and Outbound (O), depending on the direction of the truck move to or from the air cargo facility. For other portions of the SMD with no information on the trucking submode, the flows are designated by ASI and ASO.

- **Barge Flows –** This segment includes all intraregional and external domestic flows with barge as the major mode of transport (this does not include flows to and from Canada or Mexico, as no international barge flows to/from these regions are expected to be prevalent or significant). Each of the barge flows is associated with a truck movement to or from the barge terminal facility in the Portland region, which is indicated by denoting each barge flow in the database as Barge/Truck. The SMD does not contain the trucking submode information for barge flows, and consequently, shipments in this market segment are denoted by BSI and BSO.

The commodity flows provided by each of the market segment defined above serve as input to estimate annual flows in the SMD associated with each trucking submode (truckload, LTL, and private trucking). The SMD provides annual commodity flow tonnages while the goal of the Tactical Model is to generate average weekday trucking activity. Consequently, an average conversion factor from annual to average weekday of 1/264 is used for the estimation of weekday truck trips, based on information published in the report *Vehicle Volume Distributions by Classification*.[1]

12.2.4 Allocation of Commodity Flows to Origins and Destinations

The next step in the Tactical Model is the allocation of commodity flows derived from the first step described above to origins and destinations in the Portland metropolitan region. Origin locations in the model to which commodity flows need to be allocated include internal zones (with origins of internal-internal and internal-external flows), highway gateway locations or external zones (with origins of external-internal and through commodity movements), and terminal locations like port facilities, air cargo, or rail terminals, where international or external domestic shipments are offloaded and generate associated truck trip origins). Similarly, destination locations in the model include internal zones (for destinations of external-internal and internal-internal flows), highway gateway or external zones (for destinations of internal-external and through movements), and terminal locations where international exports or external domestic shipments leaving the region are loaded, which generated associated truck trip destinations.

---

[1] Hallenbeck et al., Washington State Transportation Center, draft, June 1997.

The purpose of this step in the model is to allocate the commodity flows to the origins and destinations described above. At the conclusions of the allocation process, the weekday truck flows defined in Step 1 are converted from a set of variables specific to a few general origins and destination locations to more disaggregate locations comprising zones, highways, and terminal locations. The following sections describe the allocation process for zones, highways, and terminals, respectively:

- **Internal Zones –** As described earlier, origins or internal-internal and internal-external flows, and destinations of internal-internal and external-internal flows, are allocated to TAZs in the Tactical Model system. This is accomplished by disaggregating flows to zones based on zonal employment shares for specific industry groups associated with each commodity category. For this purpose, the Tactical Model uses base year employment at the two-digit SIC industry level provided by Metro. For future employment forecasts, however, employment data inputs to the model are available only for two employment categories, retail and nonretail. Base year distribution of industry employment across detailed industry groups are applied to the future year total employment by zone to arrive at employment forecasts by zone for detailed industry groups.

- **Highway Gateways/External Zones –** The Tactical Model allocates commodity flow origins entering the region and destinations leaving the region by truck to highway gateways/external zones. The internal-external and external-internal commodity flows from the SMD by external region (North, South, and Other) are allocated to highway gateways based on a fixed allocation to major roadway facilities as external stations in the Metro travel forecasting network, based on the distribution of current (from observed classification counts) or forecast (based on truck count trends or statewide model results) truck trips on each of the facilities. The same distributions occur for the allocation of all commodity groups, unless there are certain specific restrictions for the use of a gateway by a particular commodity group or if there is specific commodity flow information available at each highway gateway location (for example, from surveys).

- **Terminals –** Allocation to terminal locations is performed by the Tactical Model for all market segments having their primary mode other than trucking. However, the procedure for the allocation of truck shipments associated with these market segments to specific terminals will depend on the primary mode. For example, all truck shipments associated with the air cargo market segment are allocated to only one terminal location, which is the Portland International Airport (PDX). Where more than one point of entry or exit may exist, the model uses inputs from the Port of Portland or other sources to identify shipment patterns and the use of each terminal location by individual commodity types. This step also allocates drayage truck trips to terminals for sea and rail, and sea and barge market segments, where the associated terminal facilities are at separate locations (thereby leading to a truck drayage move).

12.2.5 Linkage of Commodity Flows to Reload Facilities and Terminals

This step of the Tactical Model links applicable commodity flows to reload and terminal facilities. The model's current procedure for the linkage of commodity flows to reload/terminal facilities is based on an initial assumption on the trucking activity characteristics of each of the trucking submodes – truckload, LTL, and private. The model assumes that commodity flows moving by truckload carriers are not typically associated with a reload or terminal facility (in other words, these flows occur directly from the origin (pickup) to a destination (drop-off) location without having any intermediate reload activity). On the other hand, all LTL shipments are assumed by the model to be associated with reload activity (the reload activity for LTL trips being defined as the activity at LTL terminals, which involves the transfer of cargo between line-haul and pick-and-delivery trucks). For the purpose of determining reload activity associated with private trucks, the model assumes part of the private trucking shipments to behave like truckload shipments, while the rest behave as LTL shipments. Consequently, the fractions behaving like LTL shipments are used in this step to associate the flows to reload/trucking terminals.

The allocation of flows into and out of zones with reload facilities is accomplished by the model by developing a trip-rate factor for reload sites based on employment. The factor is determined using actual counts for some small number of reload sites, and a standard factor of 1.75 trips per employee was used for all other sites. By applying the trip rate to total reload employment in each zone (obtained from the freight facility database), the model estimates the reload truck trips into and out of each zone. Reload flows were allocated to zones in proportion to the amount of reload trips into/out of the zones, calculated as previously described. The model assumes that all flows that use reload facilities or terminals do so only once within the Portland region – that is, there are no reload-to-reload flows. Further, pickup and delivery tours are not represented as tours in the model.

12.2.6 Conversion of Commodity Flows to Vehicle Trips

This step of the Tactical Model converts the commodity flows derived from the previous step to equivalent heavy-duty truck trips. The model defines any truck with three or more axles as a heavy-duty truck (while two-axle six-tire trucks are treated as nonheavy trucks). The conversion factors required to translate commodity flows to equivalent truck trips need to be sensitive to the weight and volume characteristics of the commodity being carried, the type of truck, as well as the need for any specialized transportation equipment. The conversion process from commodity flows to vehicle trips essentially involves two steps, which include the following:

- **Heavy-Duty Truck Fractions –** This step involves the estimation of the fraction of total commodity flows moving by heavy versus nonheavy trucks. These fractions are derived using vehicle classification counts collected at a number of sites around the Portland region, getting the distribution of heavy versus nonheavy truck trips based on the classification counts, and using these distributions (after converting them to equivalent tonnages) to estimate the tonnage distributions to be allocated to heavy versus nonheavy trucks.

- **Flow-to-Truck Factors –** This step involves the application of flow-to-truck trip conversion factors by each truck type to estimate heavy duty (and nonheavy duty) truck trips for trip tables. ODOT roadside surveys provide the data for the development of conversion factors for use in this step of the Tactical Model. These factors currently are in the process of being revised using the data collected from the recently conducted roadside intercept surveys in the Portland region as part of the Portland Freight Data Collection project, led by Cambridge Systematics, Inc.

For containerized cargo, the commodity flow data from the SMD includes both TEUs and tonnage by commodity so that an average tonnage per TEU could be estimated for each commodity and multiplied by 2 (2 TEUs per truck) to get an average weight per truck. All containerized cargo are assumed to move on heavy trucks.

12.2.7 Accounting for Additional Vehicle Trip Segments

This step in the model accounts for additional vehicle trips related to empty returns associated with repositioning of tractor-trailers, as well as bob-tail trips associated with tractor-only repositioning. This step is required in the model since the previous modeling steps estimated loaded truck trips based on commodity flows, and did not account for empty truck trips, which are expected to be fairly significant in the region. In the current model, the only adjustments made for empty returns and repositioning are those made for LTL flows through terminal and reload facilities so that the model calculated trips match those from the truck counts around these facilities. In addition, the model also accounts for additional vehicle trips related to imbalanced origin and destination loaded truck trip totals. The predicted loaded flows from the model will be unbalanced in most cases, by commodity, market segment, weight type, as well as trucking submode. This step accounts for the net imbalance in the origins and destinations of these trips, and the additional trip segments associated with this imbalance.

12.2.8 Addition of Through Truck Trips

As discussed earlier, the SMD does not include commodity flows transported entirely by truck that move through the Portland metropolitan region. Originally, during the development of the Tactical Model, it was anticipated that the Statewide Model could be used to estimate through trips in the Portland region. However, in the absence of this, Metro currently accounts for through trips in the model based on a comparison of the assigned trips on the network (excluding through trips) with the truck counts at the external stations. The differences between counts and model assignment volumes are used as targets for an external-external trip table, which is estimated using a function in the truck modeling software. Since these through trip adjustments are made after the conversion of commodity flows to equivalent truck trips, no commodity distinction is available from the model specifically for through truck trips. Also, since the adjustment to account for additional vehicle trips (including empty trips) was done in a previous step, this step inherently also accounts for some empty through trips that might be present in the region although this effect is not expected to be significant.

12.2.9 Assignment of Truck Trips to the Highway Network

This step assigns the truck trip tables derived from previous steps of the modeling process to the highway network, to estimate the average weekday truck trips on each link of the network. Procedures for assigning these truck trip tables are integrated with the Metro passenger trip assignment modeling process. In order to achieve this integration, several issues were first addressed related to consistency with the Metro passenger modeling procedures, development of multi-class or multi-trip table procedures, as well as the development of freight transportation networks. The following trip tables feed into the truck trip assignment process:

- Loaded heavy truck trips developed at the conclusion of the modeling step *Conversion of Commodity Flows to Vehicle Trips;*
- Additional vehicle trips, obtained at the conclusion of the modeling step *Accounting for Additional Vehicle Trip Segments;*
- Through trips, developed at the end of the modeling step *Addition of Through Truck Trips*; and
- All nonheavy truck trips, developed at the conclusion of the modeling step *Conversion of Commodity Flows to Vehicle Trips.*

Truck trip tables are assigned to the network using a standard multi-class assignment. Truck trip tables are combined into two vehicle classes (heavy and light trucks) and are not assigned by commodity. Trip tables are estimated for average weekday conditions, and no time-of-day or peaking information is provided for the assignment.

12.2.10 Model Calibration and Validation

There were limited data for calibration and validation of the Tactical Model, until the recently concluded Portland Freight Data Collection project, as part of which, vehicle classification counts were specifically collected at 10 primary model screenline locations (screenline locations that account for majority of the truck flows on the regional highway network), to be used for the purpose of model validation. Metro is currently in the process of using the classification count data collected from the study to perform model validation. Owing to the geographic comprehensiveness of the locations included in the vehicle classification count program of the study, Metro also is considering using the data to perform an Origin-Destination Matrix Estimation (ODME) for model calibration. The ODME approach involves the use of the trip tables estimated from the initial model as a seed matrix and to adjust the input trip tables in order to minimize the differences between the model outputs (after assignment) and the vehicle classification counts on the highway network. A sum of square-differences (SSD) minimization approach could be used, or the minimization could be based on a linear-programming approach.

■ 12.3 Florida State Freight Model

12.3.1 Objective and Purpose of the Model

The Florida Intermodal Statewide Highway Freight Model (FISHFM) was designed to support the project-related work of FDOT and Florida's metropolitan planning organizations. 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 also is 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 should 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.

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.

12.3.2 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.

12.3.3 Modes

Although the primary purpose of the FISHFM was to analyze freight truck traffic, the model development recognized that over 80 percent 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 prepared to implement the Statewide Intermodal Systems Plan and respond to its Transportation Land Use Study Committee's recommendation that the Florida Intermodal Highway System (FIHS) be expanded to a Florida Intermodal Transportation System (FITS) covering all modes.

12.3.4 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 that was more geographically aggregated than that for Florida alone, as can be seen in Figure 12.2 later in this section.

12.3.5 Framework

Florida's Model Task Force decided that the structure of the FISHFM should follow the basic framework of the four-step Florida Statewide 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 are then 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.

12.3.6 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 percent of the total truck trips in Florida, but 45 percent of the total truck vehicle miles traveled within the State. These freight movements are surveyed as part of Global Insight's 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.

12.3.7 Base and Forecast Data

Florida Data – The forecasting data include population and employment that are 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.

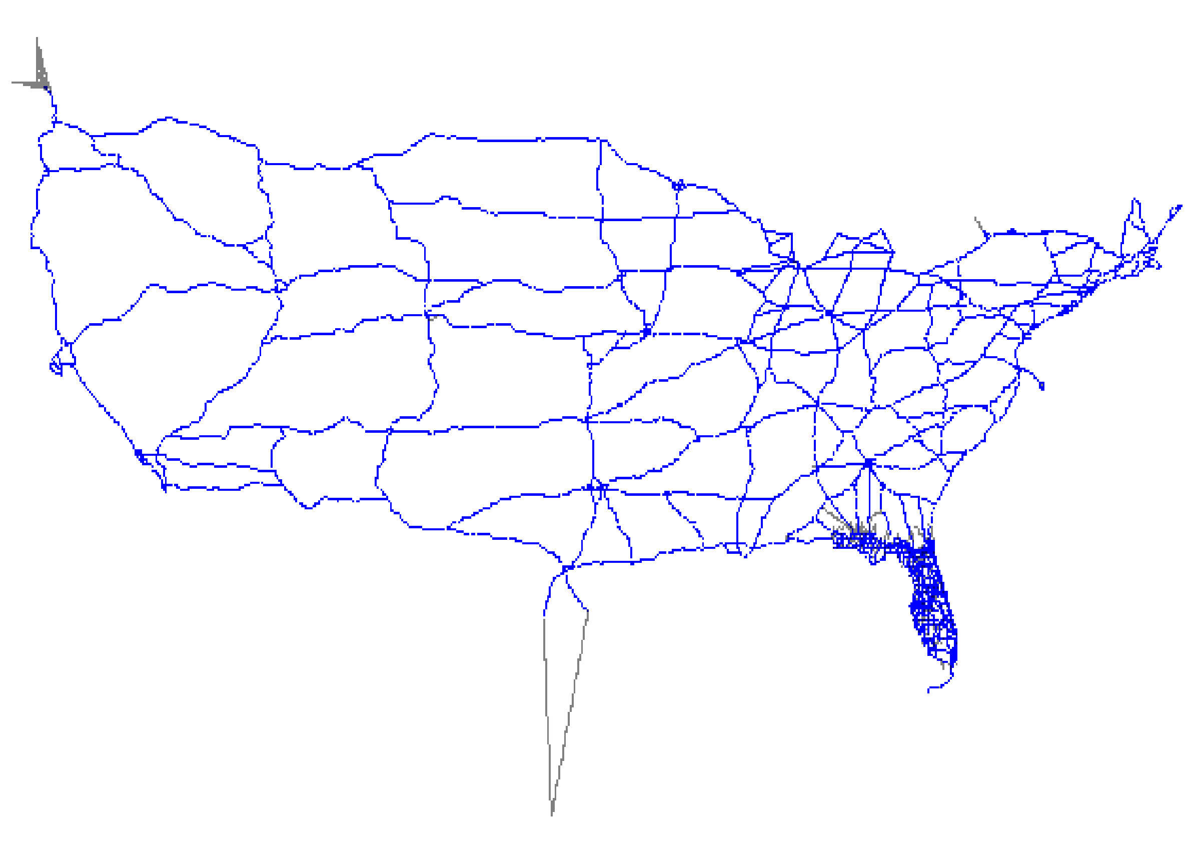
Employment by commodity sector serves as an independent variable in trip generation (production and attraction) equations for freight tonnage produced and attracted by commodity group. Employment data by industry code are the principal explanatory variables in the trip generation equations. Base year 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.

12.3.8 Modal Networks

Freight Modal Networks – Although 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, were 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 National Highway Planning Network, as shown in Figure 12.2.

Figure 12.2 Highway Network for Florida Intermodal Statewide Highway Freight Model



Intermodal Terminal Data (seaports, rail yards, airports) – The location of the intermodal terminals (x and 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 United States and Florida, the Strategic Investment Plan to Implement the Intermodal Access Needs of Florida's Seaports (Part II, United States and Florida seaports), FAA Aviation Forecasts for the fiscal years 2000-2011, the North America Airport Traffic Report, the Port Facilities Inventory (United States and Florida water ports), the U.S. Maritime Administration's Office of Intermodal Development, and published reports from port operators.

12.3.9 Model Development Data

The TRANSEARCH commodity flow database as purchased for Florida was chosen to represent the survey of existing freight flows. The STCC 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.

12.3.10 Conversion Data

Values per Ton – The TRANSEARCH data used for the model is in the STCC commodity classification code. The dollar value per ton by commodity can be obtained from the CFS records for Florida. However, the 1997 CFS uses the SCTG commodity classification system. 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.

12.3.11 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 Annual Average Daily Traffic Report for Florida and Truck Weight Study Data for the United States. These truck counts include all trucks, not just freight trucks. The FAF's loaded highway network was used to estimate the percentage of freight trucks observed in truck counts.

12.3.12 Software

The Florida Intermodal Statewide Highway Freight Model was designed to run using TRANPLAN software and Florida Standard Urban Transportation Model Structure (FSUTMS) scripts.

Two FORTRAN programs were written specifically to run FISHFM components. The commodity 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.

12.3.13 Model Application

The FISHFM 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 origin-destination 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 origin-destination table;
- The existing and forecast table of daily truck trips derived from the origin-destination 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.

12.4 Texas State Analysis Model (SAM)

12.4.1 Introduction

The Texas Statewide Analysis Model (SAM) is a traditional four-step model covering passenger and freight flows in Texas. The program is TransCAD-based and mainly utilizes geographic files as its input data. It was developed for TxDOT by Alliance Texas and Wilbur Smith Associates. SAM is a multimodal and intermodal travel demand modeling system with two major components, passenger and freight. The passenger component models highway and rail systems while the freight component models highway, rail, air, and water systems. Passenger and freight models by mode are integrated through common demographic and transportation systems databases within the TransCAD software environment.

The various sources of data provide information for analysis of highway networks, intermodal facilities and traffic, intercity traffic, demographics, and for the purposes of this study, freight. The SAM model is comprised of 4,600 zones within Texas, as well as another 142 external zones, thereby creating a one-county buffer around the State.

TxDOT primarily developed SAM to expand and enhance its travel demand modeling capabilities and process to be state of the practice, to analyze the increase in commercial traffic on Texas highways due to the North American Free Trade Agreement (NAFTA); and to consider passenger and freight modes and quantify the interaction between modes as part of long-distance passenger and freight improvement projects. The model was not designed to replace urban models, but to assist in the development of forecasting activities in nonurban areas. Therefore, the zone structure in urban areas is not as extensive as those of urban models. SAM Traffic Analysis Zones (TAZ) follow census block geography in rural areas, while in urban areas, MPO TAZs are aggregated.

12.4.2 Data

The freight component of the SAM utilizes Global Insight's TRANSEARCH commodity flow data for the primary commodity movements in the State. Global Insight is a private vendor of commodity flow data. The commodity flow data purchased by TxDOT for the model include origin-destination (O-D) data by two-digit STCC for each county in the State. The commodity flow data were acquired for truck, rail, air, and water. The SAM model supplements the TRANSEARCH data with additional data to cover Mexican freight flows, including data from Wharton Economic Forecasting Associates (WEFA) and the Latin America Trade Transportation Study (LATTS).

TRANSEARCH data are best suited for long-distance commodity movements. It is common for freight models that utilize Global Insight data to supplement the freight flow data with short-distance truck trips based on local socioeconomic data. In the SAM, a second set of commercial vehicle trips are generated as part of the passenger model component utilizing a category called "OTH" with production and attraction rates based on the 1996 *Quick Response Freight Manual*. The commercial vehicles accounted for in the passenger model include both four-tire commercial vehicles that are purely passenger cars and single-unit trucks with six or more tires. The trucks generated in this component of the model are used to account for the short-distance truck trips not captured in the Global Insight's data.

While 30 or so commodity types are represented in the base year flow data, the large majority of all tonnage flows is made up of a smaller number (perhaps 10 or so) of commodity types. The commodity types (and tonnages) present within each major flow generation category were reviewed to identify the most significant commodities within each movement group (intrastate, internal-external, and external). The procedure used was to identify the commodities (starting with the largest) making up about 90 percent of the total tonnage in the movement group. Using this definition, 11 commodity groups were established, these are shown in Table 12.1.

Table 12.1 SAM Commodity Groups

1 – Agriculture	6 – Chemicals/Petroleum
2 – Raw Material	7 – Building Materials
3 – Food	8 – Machinery
4 – Textiles	9 – Miscellaneous Mixed
5 – Wood	10 – Secondary
	11 – Hazardous

12.4.3 Network

The SAM network covers roadways in Texas only and relies on Global Insight's data for out-of-state trips. The SAM 1998 roadway network currently contains approximately 54,800 links that have a total length of 87,200 miles. Three hundred sixty-seven links representing future roadway projects were added to the master network for 2025. This adds 730 miles of network and 3,100 lanes miles. In addition, 2,846 links either added lanes or moved up in SAM road class. These links total 4,374 miles in length and equal 9,587 lane miles. The full SAM multimodal network contains approximately 60,500 links.

Texas Network

The biggest piece of the SAM Texas network, state system roadways, was provided by the TxDOT in several ArcView geographic files. These files were converted to TransCAD format and all of the relevant attributes were compiled into one geographic file. The attributes compiled from the TxDOT files include: number of lanes, road name, functional class, and posted speed. The road name and functional class attributes were generally acceptable. However, the number of lanes and speed attributes were inconsistent and required considerable editing before use.

County roads and urban arterials were added to the state system network for connectivity and completeness. County roads (6,604 miles) were added. An additional comprising 1,554 links were used to represent the county roads. Urban arterials (1,555 miles) comprising of 1,330 links also were added.

The 1999 Unified Transportation Program (UTP) and the Metropolitan Transportation Plans (MTP) for each of the 25 MPOs in the State of Texas served as the sources for future roadway projects. The UTP is an annual publication of TxDOT that serves as TxDOT's 10-year plan for transportation project development. It is the only plan for future roadway improvements that includes the entire State of Texas. The 1999 UTP was chosen over the 2000 or 2001 UTPs so there would be no gap between the SAM 1998 base year and scheduled projects. MTPs are planning documents designed to identify existing and future transportation deficiencies and guide transportation improvements in MPO areas. Typically, MTPs cover a period of 25 years and are updated every 3 to 5 years. Rural projects were identified for a 10-year period form the UTP.

The network contains projects to be built in the next 25 years in urban areas, whereas the rural areas contain projects to be built in the next 10. There is no source for projects past that timeframe in rural areas. However, projects defined by an urban TIP that ended at an MPO's boundary were extended into the "rural" area to a logical point of termination. These projects were typically extended to the next town or major intersection.

Not all projects in the UTP or MTPs are relevant or represented in the SAM network. Only projects that change the capacity of a roadway are included in the SAM forecast network. A project must add or remove lanes from a roadway already in the SAM network, or add or remove a roadway of statewide significance entirely to be included in the SAM network. Intersection improvements, the addition of turn lanes, and bridge replacements are examples of projects that are not included in the SAM forecast network.

12.4.4 Trip Generation

The freight trip generation models in the SAM are developed at the county level as TRANSEARCH data are organized with origins and destinations by county. As described previously, only primary commodity movements are accounted for in the freight model. The model, therefore, assumes that all of these trucks are combination vehicles.

The model structure used for trip generation was regression equations relating independent variables (employment types and dummy variables representing special freight handling facilities) to the tonnages produced or attracted to individual counties. All trip generation models (and other freight model components) were developed at the county level of geography. Global Insight data flows defined freight origins and destinations as counties. Therefore, no finer level of disaggregation was possible for model development.

Equations were developed for the following freight movement types:

- Internal-Internal Productions;
- Internal-Internal Attractions;
- Internal-External Productions; and
- External-Internal Attractions.

12.4.5 Trip Distribution

Trip distribution is the process of matching trip productions with trip attractions. Trip distribution at the zone level in the SAM is performed by a gravity model that assumes the probability of trips between two locations is inversely related to the trip distance and directly related to the magnitude of activity at the destination. The SAM uses mathematical equations to replicate observed trip length distributions. Adjustment factors also are applied on a district-to-district basis to acceptably reproduce movements between subareas of the State. The SAM uses a standard software plug-in for trip distribution calculations. Friction factors were developed using standard factors extracted from TransCAD, a commonly used transportation software. Additional information on trip distribution can be found in the SAM Theory Report[2] and the FHWA primer on trip distribution.[3]

12.4.6 Mode Choice

The trip table generated from the TRANSEARCH data in the SAM can be assigned either to road or rail (and in some instances water). A logit model formulation is used to

---

[2] TxDOT, Statewide Analysis Model Theory Documentation, 1999.

[3] Federal Highway Administration, Trip Distribution Modeling, 2002.

estimate the share of freight that would be assigned for each mode. Coefficients are developed for each commodity group. Those movements that had a rail access distance greater than 25 miles are assigned to the truck mode.

For the truck portion of the SAM model that was developed from TRANSEARCH data, the conversion from tons to number of vehicles was performed using vehicle load factors. These vehicle load factors are adjusted from a single value per commodity group to a set of values related to trip length. Load factors also were increased 15 to 20 percent to provide a better match with traffic count data. Empty truck movements also were reduced to 40 percent of their original values to calibrate the truck volumes with observed truck counts.

12.4.7 Assignment

The truck trips developed by the TRANSEARCH data in the SAM are preloaded as the initial step in traffic assignment. Freight truck assignment volumes are converted to Passenger Car Equivalents (PCE) using a conversion factor of 2.5 minimum travel-time paths are used when assigning truck movements to the road network. An all or nothing procedure is used as there are no other vehicles being assigned at this point. Roadway capacities are then adjusted to account for trucks, and these adjusted values are used to calculate congestion impacts on road speeds and route selection.

The commercial vehicle trips were added to the passenger model. Passenger trips were disaggregated into time periods and assigned to the network using a shortest time algorithm that accounted for potential congestion in the assignment.

Rail Assignment (Passenger and Freight)

Rail trips (passengers and freight tons) produced by the passenger and freight mode choice models are assigned using networks and paths produced specifically for this purpose (they include the appropriate rail and access links of the passenger and freight rail system). Impedance factors are used to increase road travel times so that a rail path is produced (and assigned traffic) if it is a reasonable travel alternative.

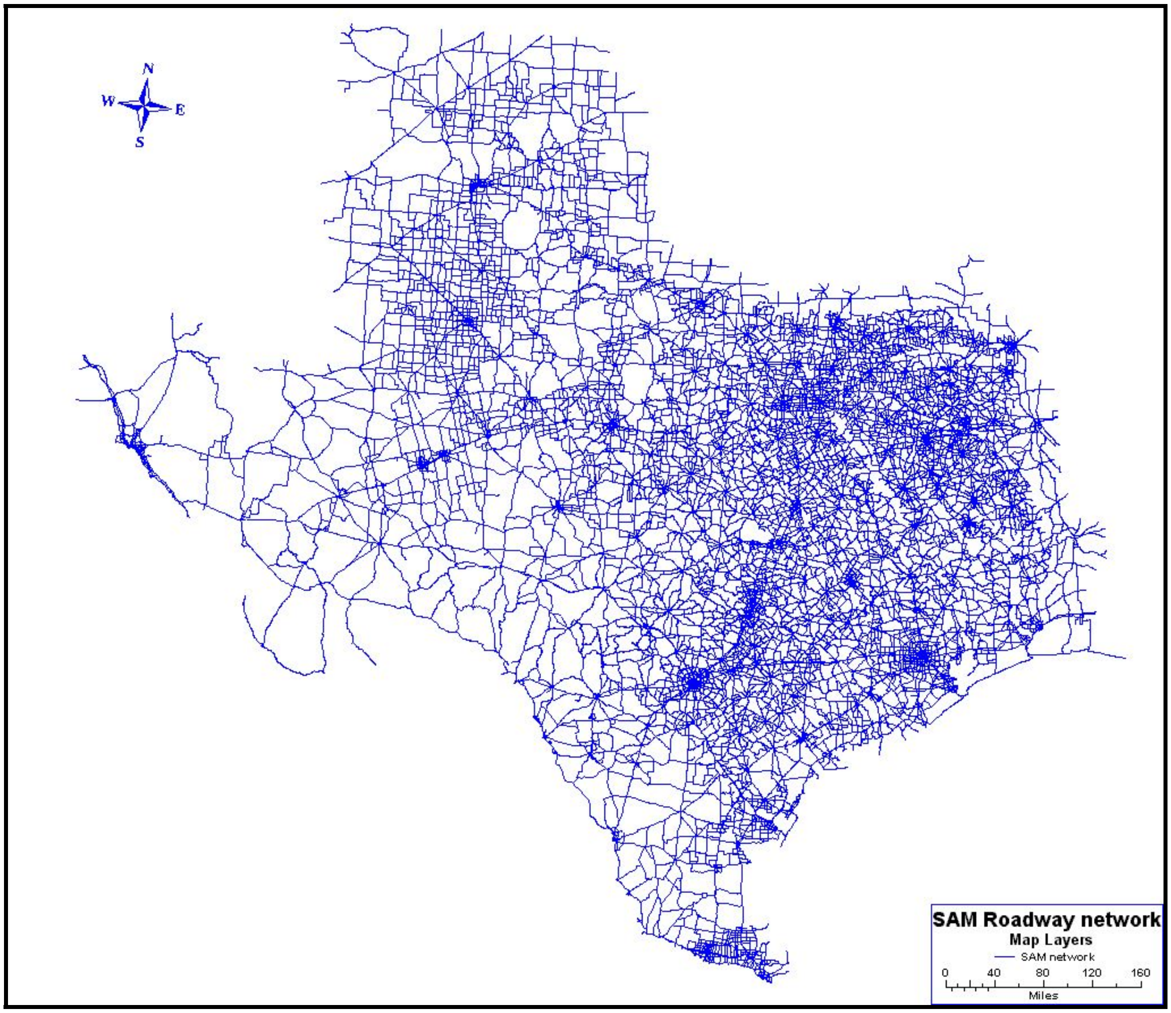
Rail passenger trips are assigned at the zone level. Rail freight tonnages are assigned at the county level. Both assignments are made using the all or nothing assignment procedure (no basis exists for defining alternate paths).

Validation

Model validation work consisted of applying the trip generation, distribution, and mode choice models to obtain estimates of freight tonnage and vehicle flows. These were then compared to two sources of actual freight flows; the TRANSEARCH data bases from Global Insight and traffic counts of "heavy" commercial vehicles. As the process proceeded, and comparisons between the estimated and observed data found significant differences, revisions were made to the original forecasting models to improve their performance.

Many of the comparisons made were organized on a geographic basis. Figure 12.3 shows the areas employed (six internal districts and four external districts). The internal districts were structured to include contiguous areas (so that major origin-destination trip patterns could be examined). The three largest urban areas, Houston, Dallas/Fort Worth, and the San Antonio-Austin Corridor, were defined as separate districts. The eastern, northern (panhandle), and southwestern parts of the State comprised the three remaining internal districts. The four major directions of approach to Texas, east from Louisiana/Arkansas, north from Oklahoma, west from New Mexico, and south from Mexico, were used to define the external districts.

Figure 12.3 Texas SAM Network



13.0 Intermodal Considerations in Freight Modeling and Forecasting

13.1 Introduction

To foster a better appreciation of the need for modeling and forecasting of intermodal freight, it is imperative to first gain an understanding of the concept of intermodalism. Intermodalism generally has been defined in somewhat narrower terms by different segments of the freight transportation industry. For example, for the international seaborne shipping industry, intermodalism implies cargo transport in standard shipping containers. However, for the domestic surface-borne trade, intermodalism would pertain to the transport of highway trailers on railroad flat cars. These differences in characterization of intermodal freight transportation call for a broader and comprehensive definition of the concept of intermodalism, in order to capture different aspects of the intermodal freight transportation system in the context of freight modeling and forecasting, and to assist with better freight planning and policy analysis.

The section begins with a brief overview of the types and characteristics of intermodal freight transportation. This is followed by the pertinent discussion on the importance of considering intermodal freight in the freight planning process for the analysis of current and future transportation issues, policies, programs, and initiatives. From the perspective of incorporating intermodal freight into the freight modeling and planning process, a discussion on the extent to which various elements of intermodal freight transportation are captured in existing freight data sources is then presented, which is followed by discussions of the implications of data constraints/limitations on the development of intermodal freight models, as well as innovative approaches to model intermodal freight demand, within the constraints of existing data sources. The section is categorized into the following sections for the discussion of intermodal freight considerations, including drayage, in freight modeling:

- Types of intermodal freight transportation;
- Characteristics of intermodal freight transportation; and
- Intermodal freight data sources.

13.2 Types of Intermodal Freight Transportation

Intermodal freight transportation involves the use of two or more modes of transportation in a closely linked network for the seamless movement of goods. Intermodalism has gained a particularly strong focus in goods movement in recent decades, both from a policy perspective from the public sector, as well as from a business perspective from shippers and carriers, due to the advantages compared to traditional truck or rail freight transportation related to increased operational efficiency, and economies-of-scale.

Intermodal freight transport typically is associated with containerization or in more general terms, the transport of goods involving direct transfer of equipment between modes without any handling of transported goods. For example, containers transferred directly from a containership onto rail cars, or a highway trailer transferred from a truck onto rail cars. This concept of containerization is more of a technical innovation that has transformed intermodalism, but is not entirely synonymous with intermodalism. Intermodalism, in a more broader sense, can be defined as the movement of goods on two or more modes, involving either direct transfer (as in the case of containerized transport), or intermediate storage (for example, shipments involving truck-rail transloading or cross-docking at LTL terminals, wherein there is intermediate storage and handling of goods before modal exchange).

The following sections describe the different types of direct transfer intermodal freight movements, based on the modes involved in the shipment (for international shipments, the modes involved relate to that part of the shipment occurring in the United States):

- **Sea-Truck –** Sea-truck intermodal involves the shipment of goods in containers which are transported on trucks to/from seaports from/to their points of O-D for international exports/imports. The containers are directly transferred between oceangoing vessels (containerships) and trucks at marine container terminals.

- **Sea-Rail –** Sea-rail intermodal involves the shipment of goods in containers on oceangoing vessels (containerships), which are transported by rail on the surface leg line-haul movement. The modal transfer process for the exchange of containers between containerships and railroad flat cars depends on the location of intermodal rail yards. In the case of on-dock intermodal yards (rail yards located on or adjacent to marine container terminals), there is a direct transfer of goods between containerships and railroad flat cars (without the use of any other mode), while in the case of off-dock intermodal yards, there is an additional leg of the container movement on trucks, which provides the link between the sea and rail modes.

- **Truck-Rail –** Truck-rail intermodal involves the shipment of trailers on railroad flat cars, the trailers being transported by trucks between points of O-D and intermodal ramps. This type of intermodal freight transportation also is referred to as Trailer on Flat Car (TOFC) or piggyback.

- **Air-Truck –** Air-truck intermodal involves the movement of goods in air freight containers (typically referred to as Unit Load Devices), which are carried on trucks to/from air cargo terminals from/to their points of O-D.

- **Barge-Truck –** Barge-truck intermodal involves the movement of goods in containers or trailers on barges that are transported on trucks for the surface leg of the shipment. Roll-on/roll-off barge transport is an example of barge-truck intermodal movement, in which wheeled containers or trailers are transported on barges, which are loaded and unloaded by the means of ramps, without the use of cranes.

In addition to the common forms of direct transfer intermodal movements described above, there are forms of freight movements involving modal exchanges of goods in the supply chain that are associated with cargo handling and/or storage at intermediate facilities. Examples of these intermediate facilities include bulk transfer facilities, LTL cross-docking terminals, and transloading docks at warehouses and distribution centers. Marine terminals also can play the role of bulk transfer facilities in the case of modal transfer of bulk commodities between oceangoing vessels, and unit trains (for example, for coal).

The modes used in the U.S. intermodal freight transportation system typically depend on the market area, which can be broadly categorized into domestic, international (Canada and Mexico), and international (sea-based) trade market areas. The modes involved with these intermodal trade market areas are briefly described below:

- **U.S. Domestic (Intermodal) Trade –** This primarily involves truck-rail intermodal (TOFC or piggyback), while a small fraction also occurs on truck-barge intermodal (involving cabotage activity, and/or shipments between mainland U.S. and Hawaii or Puerto Rico).

- **U.S. International (Canada and Mexico) Intermodal Trade –** This primarily involves truck-rail intermodal shipments. However, a few instances of cross-border truck-barge intermodal moves have been observed.

- **U.S. International (Sea-Based Intermodal) Trade –** This involves the containerized transportation of goods on surface (truck and/or rail) and marine (oceangoing vessels) modes (sea-truck, sea-rail). International sea-based intermodal trade typically involves sea-truck or sea-rail intermodal movements.

■ 13.3 Characteristics of Intermodal Freight Transportation

Some useful characteristics of intermodal freight transport that are useful to understand from a freight modeling perspective are discussed below.

13.3.1 Drayage

Drayage is an essential component of intermodal freight transportation, which is defined as the movement of a container or trailer on a truck between an intermodal terminal (marine or railroad) and a customer's facility. Drayage movements in intermodal transportation are particularly relevant from a freight modeling perspective, since they are additional truck trips, which need to be accounted for in order to accurately estimate total truck trips on the highway network. It also is important to understand and model time-of-day distributions of drayage trips and how they interact with auto traffic, based on the operations of intermodal terminals. Drayage truck trips also are a major source of emissions around intermodal terminals, which are modeled as a function of the Gross Vehicle Weight (GVW)-based truck classification. These requirements affect the truck classification schemes used in truck models that use the three truck classes based on GVW ratings (heavy heavy-duty trucks, medium heavy-duty trucks, and light heavy-duty trucks). Typically, heavy heavy-duty trucks (HHDT) are used for intermodal drayage, which have different engine emission characteristics compared to light and medium heavy-duty trucks. In addition to the above considerations, market area is an important parameter affecting intermodal drayage truck trips, which is defined as the maximum radial coverage area around the intermodal terminal for which intermodal transportation retains its cost-effectiveness compared to conventional movement of goods. The costs associated with a truck-rail intermodal move, for example, can be divided into two drayage cost components (costs of drayage from point of origin to the intermodal terminal, and from the intermodal terminal to the point of destination), line-haul cost, and terminal handling costs at the two intermodal terminals. For distances exceeding the intermodal market area, the drayage costs relative to the total intermodal transportation cost become too prohibitive for the entire truck-rail intermodal move to be cost-effective.

13.3.2 Equipment

The types of equipment used in intermodal transportation, as well as equipment ownership and lease issues, can have a significant effect on the magnitude and distribution of modal intermodal freight flows in a region. Following is a list of equipment that plays a critical role in the movement of goods in the direct transfer intermodal supply chain:

- **Containers** (international oceangoing intermodal trade) and trailers (domestic and international surface intermodal trade).
- **Intermodal Chassis –** They are wheeled frames with container locking devices which can be attached to truck tractors for the highway transport of containers.
- **Intermodal Terminal/Yard Equipment** – These are equipments used at marine and rail intermodal terminals for the terminal movement, stacking, loading, and unloading of containers/trailers, which include packers (for lifting containers from the bottom), top lifts (for lifting containers from the top), yard/reach stackers (for stacking containers), hostlers (tractors used for moving containers/trailers), and intermodal lifts and cranes for the loading and unloading of containers/trailers.

- **Transportation Equipment –** These are the main modal transportation equipments used for the line-haul transport of intermodal freight. These include truck-tractors, railroad flat cars, container and ro/ro barges, and ocean-going containerships.

The ownership and lease issues related to intermodal equipment can impact the distribution of freight flows, as well as empty truck trips in a region, which is important to understand from a modeling perspective. In the case of international intermodal trade, containers typically are owned by ocean carriers, which entails the need for the truck to pickup/return of empty containers from/to marine terminals. For example, in the case of an export move, the trucking company will pick up the empty container from the port, go to the customer's location for loading, and take the loaded container to the port (in the case of an import move, the trucking company will have to return the empty container, after unloading at the customer's location, back to the port). The ownership of intermodal chassis determines the location of chassis yards, which in turn impact the distribution of truck trips. Chassis can be owned by the railroads, terminal operators, intermodal chassis providers (independent companies), or intermodal trucking carriers.

13.3.3 Logistics and Operations of Intermodal Terminals

Operational and logistics issues associated with intermodal terminals also have a major effect on intermodal freight traffic in a region. A major operational issue related to intermodal terminals from a modeling perspective is the time-of-day operations of terminals, which have a direct impact on time-of-day activity of drayage truck trips. In the case of large marine terminals, for example, peak-hour drayage trucking activity can coincide with peak-hour auto traffic on major freight corridors and access routes, thereby leading to congestion, as well as adverse safety and environmental impacts (associated with idling and slow moving vehicles). If there are any particular programs initiated by sea ports to encourage shifting of time-of-day activity of drayage trucking, then the associated changes in time-of-day trucking activity as a result of these programs need to be reflected and incorporated into truck models, to accurately predict time-of-day trucking activity in the region. The PierPass off-peak program at the ports of Los Angeles and Long Beach is an example of an initiative to shift time-of-day trucking activity to avoid peak-hour congestion at the ports, as part of which, a Traffic Mitigation Fee (TMF) is assessed for cargo movements through the ports during the peak hours, to encourage off-peak cargo trucking at the ports.

From an intermodal terminal logistics standpoint, an important consideration for modeling, especially pertinent to international intermodal trade, is the amount of intermodal cargo moving through on-dock yards relative to near-dock intermodal rail facilities. This typically is affected by the capacity of on- and near-dock intermodal yards, as well as the logistics of the inherent intermodal supply chain. This has a major impact on intermodal trucking activity associated with the ports, since cargo moving between seaports and near-dock yards are carried by trucks, and these truck trips need to be accounted for in the modeling process. Another intermodal terminal logistics issue that might be relevant in some scenarios is the transloading of cargo between international containers and domestic trailers. For example, an international intermodal import cargo that arrives at the Port of

Oakland to be transloaded to a domestic trailer at a transload facility, and then is carried to an off-dock intermodal yard for loading onto railroad flat cars. These logistical issues have an impact on the distribution of truck trips in the region, which are important for consideration in regional truck modeling. Finally, the sheer increase in size of container ships, the largest of which are approaching 15,000 TEUs in capacity, is affecting the logistics of total rail and truck drayage demand at marine ports.

13.3.4 Cargo Handling at Intermediate Facilities

For intermodal freight movements that involve intermediate cargo handling and storage between modal exchanges, the locations and operations of these intermediate cargo handling and storage facilities impact the magnitude and distribution of freight flows in the region. The operations of different kinds of intermediate facilities, and their impacts on modeling issues associated with freight flows moving through these facilities, is discussed in the following sections:

- **Bulk Transfer Facilities –** These are intermediate facilities for transloading of liquid or solid bulk commodities, such as petroleum or gravel, between transport modes, typically between truck and rail. Such facilities generally are operated by railroads close to major industrial bulk commodity production facilities for the large scale and cost-effective transport of these goods by rail. From a modeling perspective, the truck trips between the shipper/receiver's facility and the bulk transfer facility need to be considered in the modeling process.

- **LTL Cross-docking Terminals –** In the case of long-haul LTL trucking activity, the LTL cargo may move through LTL cross-docking terminals in a hub and spoke system where intermediate handling of cargo takes place before cross-docking between long- and short-haul distribution trucks. The term cross-docking in LTL trucking activity typically refers to the immediate truck-to-truck transfer of cargo without (or minimal) warehousing/storage. For each long-haul LTL shipment, there are typically many short-haul distribution truck trips for pickup and delivery between the LTL cross-docking terminal and LTL shippers/receivers whose cargo has been consolidated in a single LTL shipment. An LTL shipment typically is represented in terms of the cargo movement between the two LTL terminals. However, from a modeling perspective, the additional short-haul trips associated with LTL pickup and delivery need to be captured in the model. Also, the differences in truck types used for long- and short-haul pickup and delivery operations in LTL trucking need to be accurately reflected in the model.

- **Transloading Docks at Warehouses and Distribution Centers –** Warehouses and distribution centers are important freight facilities with significant intermediate cargo handling and storage between modal exchanges. For a typical warehouse, the transloading activity could be associated with truck-truck or truck-rail transfer of cargo. An example of a truck-rail transloading activity at a warehouse is rail carload shipments arriving at a warehouse, which are eventually transloaded to trucks for outbound shipments, after intermediate cargo handling and storage. Truck-truck transloading activity is more common in the case of distribution centers where cargo is delivered to the facility by trucks, which undergoes intermediate handling/storage, and is then transloaded to trucks for outbound distribution. In developing regional truck models, it is important to consider the linkages of commodity flows between modes as they move through warehouses and distribution centers. In many cases, information on only one leg of the shipment might be available (for example, goods moving into or out of a warehouse), but if considered as part of an intermodal (multi-modal) movement with intermediate handling/storage, there are additional modal flows associated with that shipment that need to be considered in the modeling process.

13.4 Intermodal Freight Data Sources

The availability of data sources for intermodal freight shipments in the United States, and the extent to which these sources capture the various ramifications and elements of intermodal transportation, has a major impact on the ability to develop robust models to accurately predict intermodal freight flows in the future. Intermodal freight flows are captured in many standard freight data sources. However, none of the data sources provide all the commodity flow linkages associated with intermodal freight movements. Following are some key areas of limitations of standard data sources in capturing intermodal freight movements:

- The biggest limitation of standard data sources with respect to intermodal freight flows is that they do not capture all the commodity flow linkages associated with intermodal freight movements. For example, some data sources like CFS represent intermodal freight in terms of commodity flows by intermodal from the point of origin (shipper's location) to the point of destination (receiver's location). This freight flow representation precludes the ability to determine the intermodal transfer terminal location, which is a critical input from a modeling perspective to determine truck trip distributions. Another limitation with regard to commodity flow linkages is the representation of import container flows moving to off-dock intermodal yards as sea-rail intermodal, without any indication of the intermediate truck move linking the sea and rail modes. Some data sources also provide freight flows associated with each leg of the intermodal move, in terms of the individual mode associated with each leg (for example, truck move from A to B, rail move from B to C, and a truck move from C to D). However, this type of representation can lead to potential errors in the modeling process. For example, the truck move from A to B, which is a short-haul intermodal drayage move, could be treated by the model as a local distribution truck trip, which can lead to errors in truck classification for the shipment, as well as the number of truck trips associated with that shipment (for example, by using inappropriate payload factors).

- In many cases, data sources might provide commodity flows in terms of tonnages, without any representation of flows in terms of TEU. This creates problems associated with the need to determine which commodities potentially move in containers, estimating the fraction of the tonnages of each commodity that move in containers, as well as estimating the number of container movements based on tonnages (without any representative information on average tons per TEU by commodity group).

- In the case of intermodal (multimodal) movements involving intermediate cargo handling/storage, especially at LTL cross-docking facilities, data sources typically only provide the long-haul LTL component of the shipment without any information on local LTL pick up and delivery movements by O-D. This lack of information can impact the accuracy of modeling local LTL short-haul pickup and delivery trips, which are critical components of trucking activity, particularly in an urban area. Similarly, data sources also do not capture the linkages of commodity flows moving through the warehouse and distribution center transload supply chain, information on which is important from a modeling perspective to account for secondary trucking activity associated with these facilities.

Given the above limitations, however, the data provided by standard data sources, coupled with data from other secondary sources (such as seaports, rail yards, etc.), and primary freight data collection efforts, can greatly enhance the capabilities for the robust modeling of intermodal freight flows in a region. The following sections present the potential applications of data available from standard data sources, other secondary sources, and primary data collection programs for intermodal freight modeling and forecasting.

13.4.1 Standard Freight Data Sources

The discussion in this section focuses on data available from standard national freight data sources, which include the FAF database developed by the FHWA and the TRANSEARCH database developed by Global Insight. While there may be other local and regional freight data sources (for example, ITMS database for California), which might provide data on intermodal freight flows, that discussion on which is out of scope of this section.

FHWA Freight Analysis Framework (FAF)

A detailed description of the commodity flow data available from the FHWA FAF is available from another section of the QRFM, on freight data sources. This section is, however, limited to the discussion on intermodal freight data elements in FAF. The 2002 O-D database from FAF provides commodity flows for three distinct market areas, which include U.S. domestic (FAFOD_DOM_2002), border crossing with Canada and Mexico (FAFOD_BRD_2002), and international sea and air borne trade (FAFOD_SEA_2002). The modal information in each of these databases pertains to the modes used in the domestic leg of the shipment, within the United States. The following intermodal freight flow components are captured in the FAF O-D databases:

- **Truck-Rail –** Includes truck-rail intermodal shipments.
- **Truck-Air –** Includes truck-air intermodal shipments. However, these are included as part of total Air shipments.
- **Other Intermodal –** Includes sea-truck, sea-rail, and other intermodal combinations (such as truck-barge). However, this group also includes all less than 100 pound shipments by Parcel, U.S. Postal Service, or Courier.

The O-D level of detail in FAF is limited to Metropolitan Statistical Areas (MSA), Consolidated Statistical Areas (CSA), and balances of states, which are regions encompassing groups of counties. This aggregate O-D detail is a potential limitation when analyzing intermodal freight flows using FAF. However, innovative O-D freight flow disaggregation techniques combined with the modal information from FAF for intermodal flows can find useful applications in intermodal freight flow modeling.

The domestic and border crossing commodity O-D databases from FAF can be used to analyze primarily truck-rail intermodal flows. The origins and destinations in the domestic and border crossing database correspond to final production and attraction locations but not the intermediate intermodal terminal transfer location for truck-rail intermodal flows. From a regional truck modeling perspective, the primary objective of the commodity flow analysis would be to determine the magnitude and distribution of intermodal freight flows between points of O-D and intermodal terminal locations. Since FAF also provides commodity information for truck-rail intermodal flows in terms of tonnages, these flows can be allocated to further disaggregate zones of origin and destination based on corresponding zonal industry employment data, and input-output modeling approaches. The next step would be to determine what fraction of these intermodal freight flow origins and destinations are associated with the various intermodal yards in the region, which can be estimated using an approximate procedure, based on the relative amount of intermodal traffic using various yards. If more detailed information is available from intermodal yards on major origins and destinations of drayage truck trips, this information can be a critical input for the drayage truck trip distribution estimation process.

In the case of the seaborne O-D database from FAF, there are two primary components of international intermodal freight flows that are critical from a modeling perspective. These include drayage truck trips between seaports and customer facilities (mainly warehouse and distribution centers), and drayage truck trips between seaports and near and off-dock intermodal terminal locations. Information on drayage truck trips at seaports can be derived from the "Other Intermodal" modal specification in the FAF database (flows through specific seaports are provided in FAF in the "Port" data field). However, since this mode also includes shipments less than 100 pounds by Parcel, U.S. Postal Service and to Courier, the first step would be to look at the commodity classification for these flows, and exclude all the flows associated with postal, parcel, and courier shipments. The remainder of the intermodal flows will primarily be associated with either sea-truck or sea-rail intermodal flows. The flow fractions associated with each of these intermodal combinations can be estimated based on the analysis of the O-D of shipments.

Most of the long-haul intermodal shipments (greater than 250 miles) can be assumed to occur by sea-rail intermodal, while the short-haul intermodal shipments will primarily be sea-truck intermodal shipments, with trucks providing intermodal drayage between the seaports and customer facilities. The disaggregation of these drayage flows to more detailed O-D locations than MSA/CSA level in FAF might not be a straightforward process since a large fraction of these truck trips might potentially originate/terminate at warehouse/distribution center locations (zonal industrial employment or input-output data cannot be used for the disaggregation process). For sea-rail intermodal shipments, an additional analysis step will be required to determine the fraction of flows through on- and off-dock intermodal yards. The truck trips associated with the flows through off-dock yards will then need to be allocated to zones containing off-dock rail terminal facilities. The analysis steps associated with both the sea-truck and the sea-rail intermodal flows from FAF will need to be potentially supplemented with data from the Ports as well as primary data collection around Port facilities. For example, ports can provide data on the fraction of rail intermodal flows through on- and off-dock yards, while roadside intercept surveys of trucks conducted at marine container terminal gate locations can be used to estimate O-D distribution of drayage truck trips, as well as O-D facility types used by drayage trucks.

Since FAF provides forecast O-D commodity flows (the 2002 O-D commodity flow database includes forecasts every five years from 2010 to 2035, while the 2007 benchmark O-D database will include forecasts through 2040), the intermodal commodity flow data from FAF offer the capabilities to develop intermodal freight flow forecasts when used as inputs to intermodal freight models.

13.4.2 TRANSEARCH

Detailed discussion on the freight data elements in TRANSEARCH are provided in the freight data sources section of the QRFM. This section is limited to the discussion on intermodal freight flows in TRANSEARCH. TRANSEARCH is a proprietary database developed by Global Insight, and is one of the most comprehensive data sources of domestic and international freight flows in the United States. One of the primary strong points of the TRANSEARCH database is the provision of commodity flows at the county level of detail, which increases its utility for applications in the analysis of freight flows at detailed regional levels.

TRANSEARCH is unique compared to other freight data sources in the treatment and representation of intermodal freight flows. TRANSEARCH represents intermodal freight flows in terms of separate O-D flows for each leg of the intermodal movement. For a truck-rail intermodal move, for example, there are three components of O-D flows, which include the truck drayage portion of the flow from the point of origin to the intermodal terminal, the rail shipment from one intermodal terminal to the other, and the truck drayage flow from the intermodal terminal to the point of destination. TRANSEARCH estimates the rail portion of rail/truck intermodal activity primarily from the STB Waybill sample, which is supplemented with data collected directly from the railroads. In addition, information directly obtained from leading intermodal marketing companies and drayage carriers is used to estimate the truck drayage portion of truck-rail intermodal flows. In order to separate the truck drayage trips from other short-haul truck trips, the drayage portion of the intermodal movement is indicated by the STCC commodity code 5020, which stands for intermodal truck drayage. However, due to the use of this classification, the type of commodity moving in the drayage truck trip remains unknown.

The separation of truck and rail portions of truck-rail intermodal flows in TRANSEARCH, and the denotation of truck drayage flows with unique codes, makes TRANSEARCH particularly robust for applications in intermodal freight flow modeling. However, there might be some issues that might need to be addressed when using TRANSEARCH for addressing intermodalism in regional freight models. Although TRANSEARCH accounts for truck and rail modes of truck-rail intermodal separately in the database, there is no way to determine the commodity flow linkages for these intermodal flows, from the point of origin to the point of final destination of the shipment. This is because the rail portion of the intermodal shipment is incorporated into the total rail flows in tons for O-D pairs (the origin and destination for rail intermodal being the locations of the intermodal terminals for the origin and destination of the rail shipment), which precludes the ability to extract the fraction of the total rail tonnages from a particular origin to destination by rail intermodal, compared to rail carload. The consequences of this from a modeling perspective is that for a truck drayage move in TRANSEARCH, particularly intracounty drayage moves, it might be difficult to determine whether it is a drayage move from a shipper's location to an intermodal terminal (as part of the first leg of the intermodal move), or from an intermodal terminal to the receiver's location (as part of the last leg of the intermodal move). In these cases, an approximate procedure can be used to determine the fractions that are first leg versus last leg drayage moves, by looking at the inbound and outbound rail tonnages for that county.

13.4.3 Additional Sources of Intermodal Freight Data for Modeling Applications

The following are some additional sources of intermodal freight flow data that can find potential applications in the development of models incorporating intermodal freight flows:

- **Seaport Data –** Seaports typically collect and maintain data on many different elements related to international intermodal trade (particularly because of its rapid growth rate) for infrastructure planning, and economic and environmental impact analyses. Some of these data elements that can serve as potential inputs to intermodal freight models include the following:
  - Fraction of international container traffic moving through on- and off-dock intermodal yards, which is a critical input to determine truck trips performing drayage to/from off-dock intermodal yards.
  - Port forecasts of intermodal container traffic in TEUs, which can be used to estimate future port truck trip generations (productions and attractions).

- Truck drayage activity around marine container terminals by time of day. This can be used to develop time-of-day models, as well as for overall validation of port truck models.
- Bulk transloading activity in and around Port facilities, by type of commodity. This information can be useful to account for the flows through ports that move by multiple modes, but are associated with intermediate handling and storage.

- **Primary Data Collection Programs –** A separate section of the QRFM discusses in detail the applications of primary freight data collection programs for freight modeling and forecasting. Some potential applications of primary freight data collection programs for direct transfer and intermediate handling/storage intermodal freight modeling are presented below:

  - Gate intercept surveys conducted at marine container terminal gate locations can provide useful information on the O-D distributions of drayage truck trips, as well as the types of freight facilities that drayage truck trips originate from or are destined to. Information on the origin or destination facility type of drayage trips is useful from a modeling perspective, because locations such as warehouses, distribution centers, and other facilities (i.e., container freight stations and LCL consolidation/deconsolidation terminals) generate secondary truck trips as part of the overall intermodal supply chain, which need to be accounted for in regional truck models. Roadside intercept surveys also can inform the locations of off-dock intermodal yards used by drayage truck trips for the distribution of drayage flows to off-dock yards.
  - Vehicle classification counts around marine container and rail intermodal terminals are critical inputs for developing trip generation models, as well as for model validation.
  - Trip diary surveys of intermodal drayage trucks can provide useful information to understand and model trip chaining activity. For example, an entire drayage truck trip chain starting from the trucking terminal location and ending back at the terminal location can be tracked in a trip diary survey. There could be different combinations of trip chains associated with such a drayage move, involving variations in where the empty container is picked up and dropped off, whether the truck has the chassis when originating from the terminal location or has to pick up the chassis from a separate location (like a chassis yard), etc., which are critical pieces of information that can significantly improve the modeling of intermodal truck trips in a region.
  - Establishment surveys of terminal locations, for example, LTL cross-docking facilities can provide information on the types of trucks used for long-haul versus local LTL pickup and delivery operations, time-of-day operations of LTL trips, and major origin and destination locations of LTL pickup/delivery trips, which can serve as useful inputs for the modeling of truck trips associated with LTL cross-docking terminals.

Appendix A

Freight Glossary

Freight Glossary

Average Annual Daily Truck Traffic (AADTT) – The total volume of truck traffic on a highway segment for one year, divided by the number of days in the year.

Backhaul – The process of a transportation vehicle (typically a truck) returning from the original destination point to the point of origin. A backhaul can be with a full or partially loaded trailer.

Barge – The cargo-carrying vehicle that inland water carriers primarily use. Basic barges have open tops, but there are covered barges for both dry and liquid cargoes.

Belly Cargo – Air freight carried in the belly of passenger aircraft.

Bill of Lading – A transportation document that is the contract of carriage containing the terms and condition between shipper and carrier.

Bottleneck – A section of a highway or rail network that experiences operational problems such as congestion. Bottlenecks may result from factors such as reduced roadway width or steep freeway grades that can slow trucks.

Boxcar – An enclosed railcar, typically 40 or more feet long, used for packaged freight and some bulk commodities.

Breakbulk Cargo – Cargo of non-uniform sizes, often transported on pallets, sacks, drums, or bags. These cargoes require labor-intensive loading and unloading processes. Examples of breakbulk cargo include coffee beans, logs, or pulp.

Broker – A person whose business it is to prepare shipping and customs documents for international shipments. Brokers often have offices at major freight gateways, including border crossings, seaports, and airports.

Bulk Cargo – Cargo that is unbound as loaded; it is without count in a loose unpackaged form. Examples of bulk cargo include coal, grain, and petroleum products.

Cabotage – A national law that requires costal and intercostal traffic to be carried in its own nationally registered, and sometimes built and crewed ships.

Capacity – The physical facilities, personnel, and process available to meet the product of service needs of the customers. Capacity generally refers to the maximum output or producing ability of a machine, person, process, factory, product, or service.

Cargo Ramp – A dedicated load/unload facility for cargo aircraft.

Carload – Quantity of freight (in tons) required to fill a railcar; amount normally required to qualify for a carload rate.

Carrier – A firm which transports goods or people via land, sea, or air.

Centralized Dispatching – The organization of the dispatching function into one central location. This structure often involves the use of data collection devices for communication between the centralized dispatching function, which usually reports to the production control department and the shop manufacturing departments.

Chassis – A trailer-type device with wheels constructed to accommodate containers, which are lifted on and off.

Claim – Charges made against a carrier for loss, damage, delay, or overcharge.

Class I Carrier – A classification of regulated carriers based upon annual operating revenues-motor carrier of property greater than or equal to $5.0 million; motor carriers of passengers; greater than or equal to $3.0 million.

Class II Carrier – A classification of regulated carriers based upon annual operating revenues-motor carrier of property $1.0 million to $5.0 million; motor carriers of passengers; less than or equal to $3.0 million.

Class III Carrier – A classification of regulated carriers based upon annual operating revenues-motor carrier of property less than or equal to $1.0 million.

Class I Railroad – Railroads which have annual gross operating revenues over $266.7 million.

Class II Railroad – See **Regional Railroad**.

Class III Railroad – See **Shortline Railroad.**

Classification Yard – A railroad terminal area where railcars are grouped together to form train units.

Coastal Shipping – Also known as short-sea or coastwise shipping, describes marine shipping operations between ports along a single coast or involving a short sea crossing.

Commercial Vehicle Information Systems and Networks (CVISN) – A national program administered by the Federal Motor Carrier Safety Administration designed to improve motor carrier safety and to enhance the efficiency of administrative processes for industry and government.

Commodity – An item that is traded in commerce. The term usually implies an undifferentiated product competing primarily on price and availability.

Commodity Classification – A coding scheme used to identify commodities. Some commonly used are the Standard Transportation Commodity Classification used by railroads, the Standard Classification of Transported Goods used by the Bureau of Transportation Statistics, and the Harmonized Series used by Customs.

Common Carrier – Any carrier engaged in the interstate transportation of persons/ property on a regular schedule at published rates, whose services are for hire to the general public.

Consignee – The receiver of a freight shipment, usually the buyer.

Consignor – The sender of a freight shipment, usually the seller.

Container on Flatcar (COFC) – Containers resting on railway flatcars without a chassis underneath.

Container – A "box"' typically ten to forty feet long, which is used primarily for ocean freight shipment. For travel to and from ports, containers are loaded onto truck chassis' or on railroad flatcars.

Containerization – A shipment method in which commodities are placed in containers and after initial loading, the commodities per se are not re-handled in shipment until they are unloaded at destination.

Containerized Cargo – Cargo that is transported in containers that can be transferred easily from one transportation mode to another.

Contract Carrier – A carrier that does not serve the general public but provides transportation for hire for one or a limited number of shippers under a specific contract.

Contract Carrier – Carrier engaged in interstate transportation of persons/property by motor vehicle on a for-hire basis but under continuing contract with one or a limited number of customers to meet specific needs.

Cubage – Cubic volume of space being used or available for shipping or storage.

Deadhead – The return of an empty transportation container back to a transportation facility. Commonly-used description of an empty backhaul.

Demurrage – The carrier charges and fees applied when rail freight cars and ships are retained beyond a specific loading or unloading time.

Detention Fee – The carrier charges and fees applied when rail freight cars, ship, and carriers are retained beyond a specified loading or unloading time.

Direct to Store – Process of shipping direct from a manufacturer's plant or distribution center to the customer's retail store, thus bypassing the customer's distribution center.

Dispatcher – An individual tasked to assign available transportation loads to available carriers.

Distribution Center (DC) – The warehouse facility which holds inventory from manufacturing pending distribution to the appropriate stores.

Dock – A space used or receiving merchandise at a freight terminal.

Double-Stack – Railcar movement of containers stacked two high.

Drayage – Transporting of rail or ocean freight by truck to an intermediate or final destination; typically a charge for pickup/delivery of goods moving short distances (e.g., from marine terminal to warehouse).

Drop – A situation in which an equipment operator deposits a trailer or boxcar at a facility at which it is to be loaded or unloaded.

Durable Goods – Generally, any goods whose continuous serviceability is likely to exceed three years.

Exempt Carrier – A for-hire carrier that is free from economic regulation. Trucks hauling certain commodities are exempt from Interstate Commerce Commission economic regulation. By far the largest portion of exempt carrier transports agricultural commodities or seafood.

Flatbed – A trailer without sides used for hauling machinery or other bulky items.

Foreign Trade Zone (FTZ) – A specially designated area, in or adjacent to a U.S. Customs Port of Entry, which is considered to be outside the Customs Territory of the United States.

For-Hire Carrier – Carrier that provides transportation service to the public on a fee basis.

Four P's – Set of marketing tools to direct the business offering to the customer. The four P's are product, price, place, and promotion.

Freight All Kinds (FAK) – Goods classified FAK are usually charged higher rates than those marked with a specific classification and are frequently in a container that includes various classes of cargo.

Freight Broker – A person whose business it is to prepare shipping and customs documents for international shipments. Brokers often have offices at major freight gateways, including border crossings, seaports, and airports.

Freight Forwarder – A person whose business is to act as an agent on behalf of a shipper. A freight forwarder frequently consolidates shipments from several shippers and coordinates booking reservations.

Fuel-Taxed Waterway System – Eleven thousand miles of the U.S. waterway system designated by the Water Resources Development Act of 1986. Commercial users of this system pay a per gallon fuel tax which is deposited in the Inland Waterways Trust Fund and used to fund inland navigation projects each year.

Gross Domestic Product (GDP) – The final market value of goods and services produced by labor and property located in the nation.

Gross State Product (GSP) – The final market value of goods and services produced by labor and property located in a state.

Gross Vehicle Weight (GVW) – The combined total weight of a vehicle and its freight.

Hazardous Material – A substance or material which the Department of Transportation has determined to be capable of posing a risk to health, safety, and property when stored or transported in commerce.

Hours of Service – Ruling that stipulates the amount of time a driver is allotted to work.

Hub – A common connection point for devices in a network. Referenced for a transportation network as in "hub and spoke" which is common in the airline and trucking industry.

In-Bond Shipment – A shipment status in which goods are permitted to enter a country and temporarily stored for transport to a final destination where the duty will be paid.

Inbound Logistics – The movement of materials from shippers and vendors into production processes or storage facilities.

Input-Output Models – An economic analysis method to systematically quantify the interrelationships among various sectors of an economic system.

Interline Freight – Freight moving from point of origin to destination over the lines of two or more transportation lines.

Intermodal Terminal – A location where links between different transportation modes and networks connect. Using more than one mode of transportation in moving persons and goods. For example, a shipment moved over 1,000 miles could travel by truck for one portion of the trip, and then transfer to rail at a designated terminal.

Inventory – The number of units and/or value of the stock of good a company holds.

Just-in-Time (JIT) – Cargo or components that must be at a destination at the exact time needed. The container or vehicle is the movable warehouse.

Laker – Large commercial ship operating on the Great Lakes carrying bulk cargo. The Lakers are up to 1,000 feet long and can carry up to 66,000 tons of cargo. The large bulk Lakers stay within the Great Lakes because they are too large to enter the Saint Lawrence Seaway portion.

Lead-Time – The total time that elapses between an order's placement and it receipt. It includes the time required for order transmittal, order processing, order preparation, and transit.

Less-Than-Containerload/Less-Than-Truckload (LCL/LTL) – A container or trailer loaded with cargo from more than one shipper; loads that do not by themselves meet the container load or truckload requirements.

Level of Service (LOS) – A qualitative assessment of a road's operating conditions. For local government comprehensive planning purposes, level of service means an indicator of the extent or degree of service provided by, or proposed to be provided by, a facility based on and related to the operational characteristics of the facility. Level of service indicates the capacity per unit of demand for each public facility.

Lift-on/Lift-off (lo/lo) Cargo – Containerized cargo that must be lifted on and off vessels and other vehicles using handling equipment.

Line Haul – The movement of freight over the road/rail from origin terminal to destination terminal, usually over long distances.

Liquid Bulk Cargo – A type of bulk cargo that consists of liquid items, such as petroleum, water, or liquid natural gas.

Live Load – As situation in which the equipment operation stays with the trailer or boxcar while being loaded or unloaded.

Lock – A channel where the water rises and falls to allow boats to travel a dammed river.

Logbook – A daily record of the hours an interstate driver spends driving, off duty, sleeping in the berth, or on duty not driving.

Logistics – All activities involved in the management of product movement; delivering the right product from the right origin to the right destination, with the right quality and quantity, at the right schedule and price.

Lumpers – Individuals that assist a motor carrier owner operator in the unloading of property; quite commonly used in the food industry.

Neo-Bulk Cargo – Shipments consisting entirely of units of a single commodity, such as cars, lumber, or scrap metal.

Nitrogen Oxide (NOx) Emissions – Nitrogen oxides (NOx), the term used to describe the sum of nitric oxide (NO), nitrogen dioxide (NO_2) and other oxides of nitrogen, play a major role in the formation of ozone. The major sources of man-made NOx emissions are high-temperature combustion processes, such as those occurring in automobiles and power plants.

Node – A fixed point in a firm's logistics system where goods come to rest; includes plants, warehouses, supply sources, and markets.

On-Dock Rail – Direct shipside rail service. Includes the ability to load and unload containers/breakbulk directly from rail car to vessel.

Operating Ratio – A measure of operation efficiency defined as: (Operating Expenses/ Operation Revenues) x 100.

Outbound Logistics – The process related to the movement and storage of products from the end of the production line to the end user.

Over, Short and Damaged (OS&D) – Report is issued at warehouse when goods are damaged; claim is usually filed with the carrier.

Owner-Operator – Trucking operation in which the owner of the truck is also the driver.

Particulate Matter (PM) Emissions – Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. They originate from many different stationary and mobile sources as well as from natural sources, including fuel combustion from motor vehicles, power generation, and industrial facilities, as well as from residential fireplaces and wood stoves. Fine particles are most closely associated with such health effects as increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function, and even premature death.

Piggyback – A rail/truck service. A shipper loads a highway trailer, and a carrier drives it to a rail terminal and loads it on a flatcar; the railroad moves the trailer-on-flatcar combination to the destination terminal, where the carrier offloads the trailer and delivers it to the consignee.

Placard – A label that identifies a hazardous material shipment and the hazards present.

Point of Sale (POS) – The time and place at which a sale occurs, such as a cash register in a retail operation, or the order confirmation screen in an on-line session. Supply chain partners are interested in capturing data at the POS because it is a true record of the sale rather than being derived from other information such as inventory movement.

Pool/Drop Trailers – Trailer that are staged at a facilities for preloading purposes.

Port Authority – State or local government that owns, operates, or otherwise provides wharf, dock, and other terminal investments at ports.

Prepaid – A freight term, which indicates that charges are to be paid by the shipper. Prepaid shipping charges may be added to the customer invoice, or the cost may be bundled into the pricing of the product.

Private Carrier – A carrier that provides transportation service to the firm that owns or leases the vehicles and does not charge a fee.

Private Warehouse – A company-owned warehouse.

Proof of Delivery – Information supplied by the carrier containing the name of the person who signed for the shipment, the time and date of delivery, and other shipment delivery related information.

Pull Logistics System – "Just in time" logistics system driven by customer demand and enabled by telecommunications and information systems rather than by manufacturing process and inventory stockpiling.

Purchase Order (PO) – The purchaser's authorization used to formalize a purchase transaction with a supplier. The physical form or electronic transaction a buyer uses when placing an order for merchandise.

Push Logistics System – Inventory-based logistics system characterized by regularly scheduled flows of products and high inventory levels.

Radio Frequency (RFID) – A form of wireless communication that lets users relay information via electronic energy waves from a terminal to a base station, which is linked in turn to a host computer. The terminals can be placed at a fixed station, mounted on a forklift truck, or carried in the worker's hand. The base station contains a transmitter and receiver for communication with the terminals. When combined with a bar-code system for identifying inventory items, a radio-frequency system can relay data instantly, thus updating inventory records in so-called "real time."

Rail Siding – A very short branch off a main railway line with only one point leading onto it. Sidings are used to allow faster trains to pass slower ones or to conduct maintenance.

Receiving – The function encompassing the physical receipt of material, the inspection of the shipment for conformance with the purchase order (quantity and damage), the identification and delivery to destination, and the preparation of receiving reports.

Reefer Trailer – A refrigerated trailer that is commonly used for perishable goods.

Regional Railroad – Railroad defined as line-haul railroad operating at least 350 miles of track and/or earns revenue between $40 million and $266.7 million.

Reliability – Refers to the degree of certainty and predictability in travel times on the transportation system. Reliable transportation systems offer some assurance of attaining a given destination within a reasonable range of an expected time. An unreliable transportation system is subject to unexpected delays, increasing costs for system users.

Return to Vendor (RTV) – Material that has been rejected by the customer or buyer's inspection department and is awaiting shipment back to supplier for repair or replacement.

Reverse Logistics – A specialized segment of logistics focusing on the movement and management of products and resources after the sale and after delivery to the customer. Includes product returns and repair for credit.

Roll-on/Roll-off (ro/ro) Cargo – Wheeled cargo, such as automobiles, or cargo carried on chassis that can be rolled on or off vehicles without using cargo handling equipment.

Seasonality – Repetitive pattern of demand from year to year (or other repeating time interval) with some periods considerably higher than others. Seasonality explains the fluctuation in demand for various recreational products, which are used during different seasons.

Secondary Traffic –Freight flows to and from distribution centers or through intermodal facilities.

Shipper – Party that tenders goods for transportation.

Shipping Manifest – A document that lists the pieces in a shipment.

Short Line Railroad – Freight railroads which are not Class I or Regional Railroads, that operate less than 350 miles of track and earn less than $40 million.

Short-Sea Shipping – Also known as coastal or coastwise shipping, describes marine shipping operations between ports along a single coast or involving a short sea crossing.

Sleeper Team – Two drivers who operated a truck equipped with a sleeper berth; while one driver sleeps in the berth to accumulate mandatory off-duty time, the other driver operates the vehicle.

Stock Keeping Unit (SKU) – A category of unit with unique combination of form, fit, and function.

Stock Outs – Merchandise that is requested by a customer but is temporarily unavailable. Also referred to as Out of Stock (OOS).

Stop Off Charge – Charge associated with a load that has more than one drop off point. Typically, the first stop of a multi-stop load is free, and then the charge applies to the subsequent stops.

Strategic Highway Network (STRAHNET) – A network of highways which are important to the United States' strategic defense policy and which provide defense access, continuity, and emergency capabilities for defense purposes.

Strategic Rail Corridor Network (STRACNET) – An interconnected and continuous rail line network consisting of over 38,000 miles of track serving over 170 defense installations.

Supply Chain – Starting with unprocessed raw materials and ending with final customer using the finished goods.

Switching and Terminal Railroad – Railroad that provides pick-up and delivery services to line-haul carriers.

Third-Party Logistics (3PL) Provider – A specialist in logistics who may provide a variety of transportation, warehousing, and logistics-related services to buyers or sellers. These tasks were previously performed in-house by the customer.

Throughput – Total amount of freight imported or exported through a seaport measured in tons or 20-foot Equivalent Units.

Ton-Mile – A measure of output for freight transportation. It reflects the weight of shipment and the distance it is hauled; a multiplication of tons hauled by the distance traveled.

Trailer on Flatcar (TOFC) – Transport of trailers with their loads on specially designed rail cars.

Transit Time – The total time that elapses between a shipment's delivery and pickup.

Transloading – Transferring bulk shipments from the vehicle/container of one mode to that of another at a terminal interchange point.

Truckload (TL) – Quantity of freight required to fill a truck, or at a minimum, the amount required to qualify for a truckload rate.

Twenty-Foot Equivalent Unit (TEU) – The eight-foot by eight-foot by 20-foot intermodal container is used as a basic measure in many statistics and is the standard measure used for containerized cargo.

Unit Train – A train of a specified number of railcars handling a single commodity type which remain as a unit for a designated destination or until a change in routing is made.

Vehicle Classification (VMT) – A system used to classify motor vehicles, primarily trucks. The most commonly used classification system is based on 13 different axle and body types used by Federal Highway Administration and state departments of transportation.

Vehicle Miles of Travel (VMT) – A unit to measure vehicle travel made by a private vehicle, such as an automobile, van, pickup truck, or motorcycle.

Warehouse – Storage place for products. Principal warehouse activities include receipt of product, storage, shipment and order picking.

Weigh-in-Motion – Defined by the American Society for Testing and Materials (ASTM as "the process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle." It allows truck weights to be determined without requiring the vehicle to stop.

Acronyms

AAPA – American Association of Port Authorities

AAR – American Association of Railroads

AASHTO – American Association of State Highway and Transportation Officials

ACE – Automated Commercial Environment

ATA – American Trucking Association

BTS – Bureau of Transportation Statistics

CBP – Customs Border Protection

CDL – Commercial Drivers License

CFS – Commodity Flow Survey

CMAQ – Congestion Mitigation and Air Quality

CMV – Commercial motor Vehicle

CTPAT – Customs Trade Partnership Against Terrorism

CVISN – Commercial Vehicle Information Systems and Networks

CVO – Commercial Vehicle Operations

DOD – Department of Defense

FAA – Federal Aviation Administration

FAF – Freight Analysis Framework

FAST – Free and Secure Trade

FHWA – Federal Highway Administration

FMCSA – Federal Motor Carrier Safety Administration

FPD – Freight Professional Development

FRA – Federal Railroad Administration

GIS – Geo Information Systems

GPS – Global Positioning System

HERS – Highway Economic Requirements Systems

HPMS – Highway Performance Monitoring System

HS – Harmonized Series

ITE – Institute of Transportation Engineers

ITS – Intelligent Transportation System

MPG – Miles Per Gallon

MPO – Metropolitan Planning Organization

MUTCD – Manual on Uniform Traffic Control Devices

NAFTA – North American Free Trade Agreement

NAICS – North American Industrial Classification System

NHS – Nation Highway System

NVOCC – Non-Vessel Operating Common Carriers

P&D – Pick up and delivery

POD – Proof of Delivery

POE – Port of Entry

SCAC – Standard Carrier Alpha Code

SCTG – Standard Classification of Transported Goods

SED – Shipper's Export Declaration

SIC – Standard Industrial Classification

SLSC/SLDC – Shipper Load, Shipper Count/Shipper Load, Driver Count

STB – Surface Transportation Board

STCC – Standard Transportation Commodity Classification

TRANSCAD – Transportation Computer Assisted Design

UFC – Uniform Freight Classification

Appendix B

Commodity Classifications

Commodity Classifications

STCC 2 and STCC4 Concordance[1]

STCC2	STCC2 Name	STCC4	STCC4 Name
01	Farm Products	0112	Cotton, Raw
01	Farm Products	0113	Grain
01	Farm Products	0114	Oil Kernels, Nuts, or Seeds
01	Farm Products	0119	Miscellaneous Field Crops
01	Farm Products	0121	Citrus Fruits
01	Farm Products	0122	Deciduous Fruits
01	Farm Products	0123	Tropical Fruits
01	Farm Products	0129	Miscellaneous Fresh Fruits or Tree Nuts
01	Farm Products	0131	Bulbs, Roots, or Tubers
01	Farm Products	0133	Leafy Fresh Vegetables
01	Farm Products	0139	Miscellaneous Fresh Vegetables
01	Farm Products	0141	Livestock
09	Fresh Fish or Other Marine Products	0912	Fresh Fish or Whale Products
09	Fresh Fish or Other Marine Products	0913	Marine Products
09	Fresh Fish or Other Marine Products	0989	Fish Hatcheries
10	Metallic Ores	1011	Iron Ores
10	Metallic Ores	1021	Copper Ores
10	Metallic Ores	1051	Bauxite or Other Alum Ores
10	Metallic Ores	1061	Manganese Ores
10	Metallic Ores	1092	Miscellaneous Metal Ores
11	Coal	1121	Bituminous Coal
14	Nonmetallic Minerals, except Fuels	1421	Broken Stone or Riprap
14	Nonmetallic Minerals, except Fuels	1441	Gravel or Sand
14	Nonmetallic Minerals, except Fuels	1451	Clay Ceramic or Refrac. Minerals
14	Nonmetallic Minerals, except Fuels	1471	Chemical or Fertilizer Mineral Crude
14	Nonmetallic Minerals, except Fuels	1491	Miscellaneous Nonmetallic Minerals, nec.
14	Nonmetallic Minerals, except Fuels	1492	Water
19	Ordnance	1911	Guns
19	Ordnance	1925	Missiles and Rockets

[1] Source: FAF2 Technical Documentation Report Number 8. Crosswalk for Commodities Classified under the STCC and SCTC.

STCC2	STCC2 Name	STCC4	STCC4 Name
19	Ordnance	1929	Ammunition
19	Ordnance	1931	Armored Tanks and Vehicles
19	Ordnance	1941	Aiming Circles
19	Ordnance	1951	Small Arms Ammunition
19	Ordnance	1961	Cartridges and Ammunition
19	Ordnance	1991	Other Ordnance
20	Food or Kindred Products	2011	Meat, Fresh or Chilled
20	Food or Kindred Products	2012	Meat, Fresh Frozen
20	Food or Kindred Products	2013	Meat Products
20	Food or Kindred Products	2014	Animal By-Products, Inedible
20	Food or Kindred Products	2015	Dressed Poultry, Fresh
20	Food or Kindred Products	2016	Dressed Poultry, Frozen
20	Food or Kindred Products	2017	Processed Poultry or Eggs
20	Food or Kindred Products	2021	Creamery Butter
20	Food or Kindred Products	2023	Condensed, Evaporated or Dry Milk
20	Food or Kindred Products	2024	Ice cream or related. Frozen Desserts
20	Food or Kindred Products	2025	Cheese or Special Dairy Products
20	Food or Kindred Products	2026	Processed Milk
20	Food or Kindred Products	2031	Canned or Cured Sea Foods
20	Food or Kindred Products	2032	Canned Specialties
20	Food or Kindred Products	2033	Canned Fruits, Vegetables, etc.
20	Food or Kindred Products	2034	Dehydrated or Dried Fruit or Vegetables
20	Food or Kindred Products	2035	Pickled Fruits or Vegetables
20	Food or Kindred Products	2036	Processed Fish Products
20	Food or Kindred Products	2037	Frozen Fruit, Vegetables or Juice
20	Food or Kindred Products	2038	Frozen Specialties
20	Food or Kindred Products	2039	Canned or Preserved Food, Mixed
20	Food or Kindred Products	2041	Flour or Other Grain Mill Products
20	Food or Kindred Products	2042	Prepared or Canned Feed
20	Food or Kindred Products	2043	Cereal Preparations
20	Food or Kindred Products	2044	Milled Rice, Flour or Meal
20	Food or Kindred Products	2045	Blended or Prepared Flour
20	Food or Kindred Products	2046	Wet Corn Milling or Milo.
20	Food or Kindred Products	2047	Dog, Cat or Other Pet Food, nec.
20	Food or Kindred Products	2051	Bread or Other Bakery Products
20	Food or Kindred Products	2052	Biscuits, Crackers or Pretzels
20	Food or Kindred Products	2061	Sugar Mill Products or By-Products
20	Food or Kindred Products	2062	Sugar, Refined, Cane or Beet
20	Food or Kindred Products	2071	Candy or Other Confectionery

STCC2	STCC2 Name	STCC4	STCC4 Name
20	Food or Kindred Products	2082	Malt Liquors
20	Food or Kindred Products	2083	Malt
20	Food or Kindred Products	2084	Wine, Brandy, or Brandy Spirit
20	Food or Kindred Products	2085	Distilled or Blended Liquors
20	Food or Kindred Products	2086	Soft Drinks or Mineral Water
20	Food or Kindred Products	2087	Miscellaneous Flavoring Extracts
20	Food or Kindred Products	2091	Cottonseed Oil or By-Products
20	Food or Kindred Products	2092	Soybean Oil or By-Products
20	Food or Kindred Products	2093	Nut or Vegetable Oils or By-Products
20	Food or Kindred Products	2094	Marine Fats or Oils
20	Food or Kindred Products	2095	Roasted or Instant Coffee
20	Food or Kindred Products	2096	Margarine, Shortening, etc.
20	Food or Kindred Products	2097	Ice, Natural or Manufactured
20	Food or Kindred Products	2098	Macaroni, Spaghetti, etc.
20	Food or Kindred Products	2099	Miscellaneous Food Preparations, nec.
21	Tobacco Products	2111	Cigarettes
21	Tobacco Products	2121	Cigars
21	Tobacco Products	2131	Chewing or Smoking Tobacco
21	Tobacco Products	2141	Stemmed or Re-Dried Tobacco
22	Textile Mill Products	2211	Cotton Broad-Woven Fabrics
22	Textile Mill Products	2221	Man-made or Glass Woven Fiber
22	Textile Mill Products	2222	Silk-Woven Fabrics
22	Textile Mill Products	2231	Wool Broad-Woven Fabrics
22	Textile Mill Products	2241	Narrow Fabrics
22	Textile Mill Products	2251	Knit Fabrics
22	Textile Mill Products	2271	Woven Carpets, Mats or Rugs
22	Textile Mill Products	2272	Tufted Carpets, Rugs or Mats
22	Textile Mill Products	2279	Carpets, Mats or Rugs, nec.
22	Textile Mill Products	2281	Yarn
22	Textile Mill Products	2284	Thread
22	Textile Mill Products	2291	Felt Goods
22	Textile Mill Products	2292	Lace Goods
22	Textile Mill Products	2293	Paddings, Upholstery Fill, etc.
22	Textile Mill Products	2294	Textile Waste, Processed
22	Textile Mill Products	2295	Coated or Imprinted Fabric
22	Textile Mill Products	2296	Cord or Fabrics, Industrial
22	Textile Mill Products	2297	Wool or Mohair
22	Textile Mill Products	2298	Cordage or Twine
22	Textile Mill Products	2299	Textile Goods, nec.

STCC2	STCC2 Name	STCC4	STCC4 Name
23	Apparel	2311	Men's or Boys' Clothing
23	Apparel	2331	Women's or Children's' Clothing
23	Apparel	2351	Millinery
23	Apparel	2352	Caps or Hats or Hat Bodies
23	Apparel	2371	Fur Goods
23	Apparel	2381	Gloves, Mittens or Linings
23	Apparel	2384	Robes or Dressing Gowns
23	Apparel	2385	Raincoats or Other Rain Wear
23	Apparel	2386	Leather Clothing
23	Apparel	2387	Apparel Belts
23	Apparel	2389	Apparel, nec.
23	Apparel	2391	Curtains or Draperies
23	Apparel	2392	Textile House furnishings
23	Apparel	2393	Textile Bags
23	Apparel	2394	Canvas Products
23	Apparel	2395	Textile Products, Pleated, etc.
23	Apparel	2396	Apparel Findings
23	Apparel	2399	Miscellaneous Fabricated Textile Products
24	Lumber or Wood Products	2411	Primary Forest Materials
24	Lumber or Wood Products	2421	Lumber or Dimension Stock
24	Lumber or Wood Products	2429	Miscellaneous Sawmill or Planing Mill
24	Lumber or Wood Products	2431	Millwork or Cabinetwork
24	Lumber or Wood Products	2432	Plywood or Veneer
24	Lumber or Wood Products	2433	Prefab Wood Buildings
24	Lumber or Wood Products	2434	Kitchen Cabinets, Wood
24	Lumber or Wood Products	2439	Structural Wood Products, nec.
24	Lumber or Wood Products	2441	Wood Container or Box Hooks
24	Lumber or Wood Products	2491	Treated Wood Products
24	Lumber or Wood Products	2492	Rattan or Bamboo Ware
24	Lumber or Wood Products	2493	Lasts or Related Products
24	Lumber or Wood Products	2494	Cork Products
24	Lumber or Wood Products	2495	Hand Tool Handles
24	Lumber or Wood Products	2496	Scaffolding Equipment or Ladders
24	Lumber or Wood Products	2497	Wooden Ware or Flatware
24	Lumber or Wood Products	2498	Wood Products, nec.
24	Lumber or Wood Products	2499	Miscellaneous Wood Products
25	Furniture or Fixtures	2511	Benches, Chairs, Stools
25	Furniture or Fixtures	2512	Tables or Desks
25	Furniture or Fixtures	2513	Sofas, Couches, etc.

STCC2	STCC2 Name	STCC4	STCC4 Name
25	Furniture or Fixtures	2514	Buffets, China Closets, etc.
25	Furniture or Fixtures	2515	Bedsprings or Mattresses
25	Furniture or Fixtures	2516	Beds, Dressers, Chests, etc.
25	Furniture or Fixtures	2517	Cabinets or Cases
25	Furniture or Fixtures	2518	Children's' Furniture
25	Furniture or Fixtures	2519	Household or Office Furniture, nec.
25	Furniture or Fixtures	2531	Public Building or Related Furniture
25	Furniture or Fixtures	2541	Wood Lockers, Partitions, etc.
25	Furniture or Fixtures	2542	Metal Lockers, Partitions, etc.
25	Furniture or Fixtures	2591	Venetian Blinds, Shades, etc.
25	Furniture or Fixtures	2599	Furniture or Fixtures, nec.
26	Pulp, Paper, or Allied Products	2611	Pulp or Pulp Mill Products
26	Pulp, Paper, or Allied Products	2621	Paper
26	Pulp, Paper, or Allied Products	2631	Fiber, Paper or Pulp Board
26	Pulp, Paper, or Allied Products	2642	Envelopes
26	Pulp, Paper, or Allied Products	2643	Paper Bags
26	Pulp, Paper, or Allied Products	2644	Wallpaper
26	Pulp, Paper, or Allied Products	2645	Die-Cut Paper or Pulp Board Products
26	Pulp, Paper, or Allied Products	2646	Pressed or Molded Pulp Goods
26	Pulp, Paper, or Allied Products	2647	Sanitary Paper Products
26	Pulp, Paper, or Allied Products	2649	Miscellaneous Converted Paper Products
26	Pulp, Paper, or Allied Products	2651	Containers or Boxes, Paper
26	Pulp, Paper, or Allied Products	2654	Sanitary Food Containers
26	Pulp, Paper, or Allied Products	2655	Fiber Cans, Drums or Tubes
26	Pulp, Paper, or Allied Products	2661	Paper or Building Board
27	Printed Matter	2711	Newspapers
27	Printed Matter	2721	Periodicals
27	Printed Matter	2731	Books
27	Printed Matter	2741	Miscellaneous Printed Matter
27	Printed Matter	2761	Manifold Business Forms
27	Printed Matter	2771	Greeting Cards, Seals, etc.
27	Printed Matter	2781	Blank Book, Loose Leaf Binder
27	Printed Matter	2791	Service Indus. for Print Trades
28	Chemicals	2810	Industrial Chemicals
28	Chemicals	2812	Potassium or Sodium Compound
28	Chemicals	2813	Industrial Gases
28	Chemicals	2814	Crude Products of Coal, Gas, Petroleum
28	Chemicals	2815	Cyclic Intermediates or Dyes
28	Chemicals	2816	Inorganic Pigments

STCC2	STCC2 Name	STCC4	STCC4 Name
28	Chemicals	2818	Miscellaneous Indus. Organic Chemicals
28	Chemicals	2819	Miscellaneous Indus. Inorganic Chemicals
28	Chemicals	2821	Plastic Matter or Synthetic Fibers
28	Chemicals	2831	Drugs
28	Chemicals	2841	Soap or Other Detergents
28	Chemicals	2842	Specialty Cleaning Preparations
28	Chemicals	2843	Surface Active Agents
28	Chemicals	2844	Cosmetics, Perfumes, etc.
28	Chemicals	2851	Paints, Lacquers, etc.
28	Chemicals	2861	Gum or Wood Chemicals
28	Chemicals	2871	Fertilizers
28	Chemicals	2879	Miscellaneous Agricultural Chemicals
28	Chemicals	2891	Adhesives
28	Chemicals	2892	Explosives
28	Chemicals	2893	Printing Ink
28	Chemicals	2899	Chemical Preparations, nec.
29	Petroleum or Coal Products	2911	Petroleum Refining Products
29	Petroleum or Coal Products	2912	Liquefied Gases, Coal or Petroleum
29	Petroleum or Coal Products	2951	Asphalt Paving Blocks or Mix
29	Petroleum or Coal Products	2952	Asphalt Coatings or Felt
29	Petroleum or Coal Products	2991	Miscellaneous Coal or Petroleum Products
30	Rubber or Miscellaneous Plastics Products	3011	Tires or Inner Tubes
30	Rubber or Miscellaneous Plastics Products	3021	Rubber or Plastic Footwear
30	Rubber or Miscellaneous Plastics Products	3031	Reclaimed Rubber
30	Rubber or Miscellaneous Plastics Products	3041	Rub or Plastic Hose or Belting
30	Rubber or Miscellaneous Plastics Products	3061	Miscellaneous Fabricated Products
30	Rubber or Miscellaneous Plastics Products	3071	Miscellaneous Plastic Products
30	Rubber or Miscellaneous Plastics Products	3072	Miscellaneous Plastic Products
31	Leather or Leather Products	3111	Leather, Finished or Tanned
31	Leather or Leather Products	3121	Industrial Leather Belting
31	Leather or Leather Products	3131	Boot or Shoe Cut Stock
31	Leather or Leather Products	3141	Leather Footwear
31	Leather or Leather Products	3142	Leather House Slippers
31	Leather or Leather Products	3151	Leather Gloves or Mittens
31	Leather or Leather Products	3161	Leather Luggage or Handbags
31	Leather or Leather Products	3199	Leather Goods, nec.
32	Clay, Concrete, Glass, or Stone Products	3211	Flat Glass
32	Clay, Concrete, Glass, or Stone Products	3221	Glass Containers
32	Clay, Concrete, Glass, or Stone Products	3229	Miscellaneous Glassware, Blown or Pressed

STCC2	STCC2 Name	STCC4	STCC4 Name
32	Clay, Concrete, Glass, or Stone Products	3241	Portland Cement
32	Clay, Concrete, Glass, or Stone Products	3251	Clay Brick or Tile
32	Clay, Concrete, Glass, or Stone Products	3253	Ceramic Floor or Wall Tile
32	Clay, Concrete, Glass, or Stone Products	3255	Refractories
32	Clay, Concrete, Glass, or Stone Products	3259	Miscellaneous Structural Clay Products
32	Clay, Concrete, Glass, or Stone Products	3261	Vitreous China Plumbing Fixtures
32	Clay, Concrete, Glass, or Stone Products	3262	Vitreous China Kitchen Articles
32	Clay, Concrete, Glass, or Stone Products	3264	Porcelain Electric Supplies
32	Clay, Concrete, Glass, or Stone Products	3269	Miscellaneous Pottery Products
32	Clay, Concrete, Glass, or Stone Products	3271	Concrete Products
32	Clay, Concrete, Glass, or Stone Products	3273	Ready-Mix Concrete, Wet
32	Clay, Concrete, Glass, or Stone Products	3274	Lime or Lime Plaster
32	Clay, Concrete, Glass, or Stone Products	3275	Gypsum Products
32	Clay, Concrete, Glass, or Stone Products	3281	Cut Stone or Stone Products
32	Clay, Concrete, Glass, or Stone Products	3291	Abrasive Products
32	Clay, Concrete, Glass, or Stone Products	3292	Asbestos Products
32	Clay, Concrete, Glass, or Stone Products	3293	Gaskets or Packing
32	Clay, Concrete, Glass, or Stone Products	3295	Nonmetal Minerals, Processed
32	Clay, Concrete, Glass, or Stone Products	3296	Mineral Wool
32	Clay, Concrete, Glass, or Stone Products	3299	Miscellaneous Nonmetallic Minerals
33	Primary Metal Products	3311	Blast Furnace or Coke
33	Primary Metal Products	3312	Primary Iron or Steel Products
33	Primary Metal Products	3313	Electrometallurgical Products
33	Primary Metal Products	3315	Steel Wire, Nails or Spikes
33	Primary Metal Products	3321	Iron or Steel Castings
33	Primary Metal Products	3331	Primary Copper Smelter Products
33	Primary Metal Products	3332	Primary Lead Smelter Products
33	Primary Metal Products	3333	Primary Zinc Smelter Products
33	Primary Metal Products	3334	Primary Aluminum Smelter Products
33	Primary Metal Products	3339	Miscellaneous Prim. Nonferrous Smelter Products
33	Primary Metal Products	3351	Copper or Alloy Basic Shapes
33	Primary Metal Products	3352	Aluminum or Alloy Basic Shapes
33	Primary Metal Products	3356	Miscellaneous Nonferrous Basic Shapes
33	Primary Metal Products	3357	Nonferrous Wire
33	Primary Metal Products	3361	Aluminum or Alloy Castings
33	Primary Metal Products	3362	Copper or Alloy Castings
33	Primary Metal Products	3369	Miscellaneous Nonferrous Castings
33	Primary Metal Products	3391	Iron or Steel Forgings
33	Primary Metal Products	3392	Nonferrous Metal Forgings

STCC2	STCC2 Name	STCC4	STCC4 Name
33	Primary Metal Products	3399	Primary Metal Products, nec.
34	Fabricated Metal Products	3411	Metal Cans
34	Fabricated Metal Products	3421	Cutlery, not Electrical
34	Fabricated Metal Products	3423	Edge or Hand Tools
34	Fabricated Metal Products	3425	Hand Saws or Saw Blades
34	Fabricated Metal Products	3428	Builders or Cabinet Hardware
34	Fabricated Metal Products	3429	Miscellaneous Hardware
34	Fabricated Metal Products	3431	Metal Sanitary Ware
34	Fabricated Metal Products	3432	Plumbing Fixtures
34	Fabricated Metal Products	3433	Heating Equipment, not Electrical
34	Fabricated Metal Products	3441	Fabricated Structural Metal Products
34	Fabricated Metal Products	3442	Metal Doors, Sash, etc.
34	Fabricated Metal Products	3443	Fabricated Plate Products
34	Fabricated Metal Products	3444	Sheet Metal Products
34	Fabricated Metal Products	3446	Architectural Metal Work
34	Fabricated Metal Products	3449	Miscellaneous Metal Work
34	Fabricated Metal Products	3452	Bolts, Nuts, Screws, etc.
34	Fabricated Metal Products	3461	Metal Stampings
34	Fabricated Metal Products	3481	Miscellaneous Fabricated Wire Products
34	Fabricated Metal Products	3491	Metal Shipping Containers
34	Fabricated Metal Products	3492	Metal Safes or Vaults
34	Fabricated Metal Products	3493	Steel Springs
34	Fabricated Metal Products	3494	Valves or Pipe Fittings
34	Fabricated Metal Products	3499	Fabricated Metal Products, nec.
35	Machinery – Other than Electrical	3511	Steam Engines, Turbines, etc.
35	Machinery – Other than Electrical	3519	Miscellaneous Internal Combustion Engines
35	Machinery – Other than Electrical	3522	Farm Machinery or Equipment
35	Machinery – Other than Electrical	3524	Lawn or Garden Equipment
35	Machinery – Other than Electrical	3531	Construction Machinery or Equipment
35	Machinery – Other than Electrical	3532	Mining Machinery or Parts
35	Machinery – Other than Electrical	3533	Oil Field Machinery or Equipment
35	Machinery – Other than Electrical	3534	Elevators or Escalators
35	Machinery – Other than Electrical	3535	Conveyors or Parts
35	Machinery – Other than Electrical	3536	Hoists, Industrial Cranes, etc.
35	Machinery – Other than Electrical	3537	Industrial Trucks, etc.
35	Machinery – Other than Electrical	3541	Machine Tools, Metal Cutting
35	Machinery – Other than Electrical	3542	Machine Tools, Metal Forming
35	Machinery – Other than Electrical	3544	Special Dies, Tools, Jigs, etc.
35	Machinery – Other than Electrical	3545	Machine Tool Accessories

STCC2	STCC2 Name	STCC4	STCC4 Name
35	Machinery – Other than Electrical	3548	Metalworking Machinery
35	Machinery – Other than Electrical	3551	Food Product Machinery
35	Machinery – Other than Electrical	3552	Textile Machinery or Parts
35	Machinery – Other than Electrical	3553	Woodworking Machinery
35	Machinery – Other than Electrical	3554	Paper Industries Machinery
35	Machinery – Other than Electrical	3555	Printing Trades Machinery
35	Machinery – Other than Electrical	3559	Miscellaneous Special Industry Machinery
35	Machinery – Other than Electrical	3561	Industrial Pumps
35	Machinery – Other than Electrical	3562	Ball or Roller Bearings
35	Machinery – Other than Electrical	3564	Ventilating Equipment
35	Machinery – Other than electrical	3566	Mechanical Power Transmission Equipment
35	Machinery – Other than Electrical	3567	Industrial Process Furnaces
35	Machinery – Other than Electrical	3569	Miscellaneous General Industrial
35	Machinery – Other than Electrical	3572	Typewriters or Parts
35	Machinery – Other than Electrical	3573	Electronic Data Processing Equipment
35	Machinery – Other than Electrical	3574	Accounting or Calculating Equipment
35	Machinery – Other than Electrical	3576	Scales or Balances
35	Machinery – Other than Electrical	3579	Miscellaneous Office Machines
35	Machinery – Other than Electrical	3581	Automatic Merchandising Machines
35	Machinery – Other than Electrical	3582	Commercial Laundry Equipment
35	Machinery – Other than Electrical	3585	Refrigeration Machinery
35	Machinery – Other than Electrical	3589	Miscellaneous Service Industry Machinery
35	Machinery – Other than Electrical	3592	Carburetors, Pistons, etc.
35	Machinery – Other than Electrical	3599	Miscellaneous Machinery or Parts
36	Electrical Machinery, Equipment, or Supplies	3611	Electric Measuring Instruments
36	Electrical Machinery, Equipment, or Supplies	3612	Electrical Transformers
36	Electrical Machinery, Equipment, or Supplies	3613	Switchgear or Switchboards
36	Electrical Machinery, Equipment, or Supplies	3621	Motors or Generators
36	Electrical Machinery, Equipment, or Supplies	3622	Industrial Controls or Parts
36	Electrical Machinery, Equipment, or Supplies	3623	Welding Apparatus
36	Electrical Machinery, Equipment, or Supplies	3624	Carbon Products for Electric Uses
36	Electrical Machinery, Equipment, or Supplies	3629	Miscellaneous Electrical Industrial Equipment
36	Electrical Machinery, Equipment, or supplies	3631	Household Cooking Equipment
36	Electrical Machinery, Equipment, or Supplies	3632	Household Refrigerators
36	Electrical Machinery, Equipment, or Supplies	3633	Household Laundry Equipment
36	Electrical Machinery, Equipment, or Supplies	3634	Electric House Wares or Fans
36	Electrical Machinery, Equipment, or Supplies	3635	Household Vacuum Cleaners
36	Electrical Machinery, Equipment, or Supplies	3636	Sewing Machines or Parts
36	Electrical Machinery, Equipment, or Supplies	3639	Miscellaneous Household Appliances

STCC2	STCC2 Name	STCC4	STCC4 Name
36	Electrical Machinery, Equipment, or Supplies	3641	Electric Lamps
36	Electrical Machinery, Equipment, or Supplies	3642	Lighting Fixtures
36	Electrical Machinery, Equipment, or Supplies	3643	Current Carrying Wiring Equipment
36	Electrical Machinery, Equipment, or Supplies	3644	Noncurrent Wiring Devices
36	Electrical Machinery, Equipment, or Supplies	3651	Radio or Television Receiving Sets
36	Electrical Machinery, Equipment, or Supplies	3652	Phonograph Records
36	Electrical Machinery, Equipment, or Supplies	3661	Telephone or Telegraph Equipment
36	Electrical Machinery, Equipment, or Supplies	3662	Radio or Television Transmitting Equipment
36	Electrical Machinery, Equipment, or Supplies	3671	Electronic Tubes
36	Electrical Machinery, Equipment, or Supplies	3674	Solid State Semiconductors
36	Electrical Machinery, Equipment, or Supplies	3679	Miscellaneous Electronic Components
36	Electrical Machinery, Equipment, or Supplies	3691	Storage Batteries or Plates
36	Electrical Machinery, Equipment, or Supplies	3692	Primary Batteries
36	Electrical Machinery, Equipment, or Supplies	3693	X-Ray Equipment
36	Electrical Machinery, Equipment, or Supplies	3694	Electronic Equipment for Intern Comb. Engine
36	Electrical Machinery, Equipment, or Supplies	3699	Electrical Equipment, nec.
37	Transportation Equipment	3711	Motor Vehicles
37	Transportation Equipment	3712	Passenger Motor Car Bodies
37	Transportation Equipment	3713	Motor Bus or Truck Bodies
37	Transportation Equipment	3714	Motor Vehicle Parts or Accessories
37	Transportation Equipment	3715	Truck Trailers
37	Transportation Equipment	3721	Aircraft
37	Transportation Equipment	3722	Aircraft or Missile Engines
37	Transportation Equipment	3729	Miscellaneous Aircraft Parts
37	Transportation Equipment	3732	Ships or Boats
37	Transportation Equipment	3741	Locomotives or Parts
37	Transportation Equipment	3742	Railroad Cars
37	Transportation Equipment	3751	Motorcycles, Bicycles, or Parts
37	Transportation Equipment	3769	Missile or Space Vehicle Parts
37	Transportation Equipment	3791	Trailer Coaches
37	Transportation Equipment	3799	Transportation Equipment, nec.
38	Instruments – Photographic or Optical Goods	3811	Engineering, Lab or Scientific Equipment
38	Instruments – Photographic or Optical Goods	3821	Mechanical Measuring or Control Equipment
38	Instruments – Photographic or Optical Goods	3822	Automatic Temperature Controls
38	Instruments – Photographic or Optical Goods	3831	Optical Instruments or Lenses
38	Instruments – Photographic or Optical Goods	3841	Surgical or Medical Instruments
38	Instruments – Photographic or Optical Goods	3842	Orthopedic or Prosthetic Supplies
38	Instruments – Photographic or Optical Goods	3843	Dental Equipment or Supplies
38	Instruments – Photographic or Optical Goods	3851	Ophthalmic or Opticians Goods

STCC2	STCC2 Name	STCC4	STCC4 Name
38	Instruments – Photographic or Optical Goods	3861	Photographic Equipment or Supplies
38	Instruments – Photographic or Optical Goods	3871	Watches, Clocks, etc.
39	Miscellaneous Manufacturing Products	3911	Jewelry, Precious Metal, etc.
39	Miscellaneous Manufacturing Products	3914	Silverware or Plated Ware
39	Miscellaneous Manufacturing Products	3931	Musical Instruments or Parts
39	Miscellaneous Manufacturing Products	3941	Games or Toys
39	Miscellaneous Manufacturing Products	3942	Dolls or Stuffed Toys
39	Miscellaneous Manufacturing Products	3943	Children's' Vehicles or Parts, nec.
39	Miscellaneous Manufacturing Products	3949	Sporting or Athletic Goods
39	Miscellaneous Manufacturing Products	3951	Pens or Parts
39	Miscellaneous Manufacturing Products	3952	Pencils, Crayons, or Artists Materials
39	Miscellaneous Manufacturing Products	3953	Marking Devices
39	Miscellaneous Manufacturing Products	3955	Carbon Paper or Inked Ribbons
39	Miscellaneous Manufacturing Products	3961	Costume Jewelry or Novelties
39	Miscellaneous Manufacturing Products	3962	Feathers, Plumes, etc.
39	Miscellaneous Manufacturing Products	3963	Buttons
39	Miscellaneous Manufacturing Products	3964	Apparel Fasteners
39	Miscellaneous Manufacturing Products	3991	Brooms, Brushes, etc.
39	Miscellaneous Manufacturing Products	3992	Linoleum or Other Coverings
39	Miscellaneous Manufacturing Products	3993	Signs or Advertising Displays
39	Miscellaneous Manufacturing Products	3994	Morticians Goods
39	Miscellaneous Manufacturing Products	3996	Matches
39	Miscellaneous Manufacturing Products	3997	Furs, Dressed or Dyed
39	Miscellaneous Manufacturing Products	3999	Manufactured Products, nec.
40	Waste or Scrap Materials	4021	Metal Scrap or Tailings
40	Waste or Scrap Materials	4024	Paper Waste or Scrap
40	Waste or Scrap Materials	4029	Miscellaneous Waste or Scrap
41	Miscellaneous Freight Shipments	4111	Miscellaneous Freight Shipments
43	Mail and Express Traffic	4311	Mail and Express Traffic
46	Miscellaneous Mixed Shipments	4611	FAK Shipments
50	Secondary Traffic	5010	Warehouse and Distribution Center
50	Secondary Traffic	5020	Rail Intermodal Drayage
50	Secondary Traffic	5030	Air Freight Drayage

SCTG2 to STCC2 Concordance

STCC2	STCC2 Name	SCTG2	SCTG2 Name
1	Farm Products	1	Live Animals and Live Fish
9	Fresh Fish or Other Marine Products	1	Live Animals and Live Fish
1	Farm Products	2	Cereal Grains
1	Farm Products	3	Other Agricultural Products
8	Forestry Products	3	Other Agricultural Products
20	Food or Kindred Products	3	Other Agricultural Products
20	Food or Kindred Products	4	Animal Feed and Products of Animal Origin, nec.
9	Fresh Fish or Other Marine Products	5	Meat, Fish, Seafood, and their Preparations
20	Food or Kindred Products	5	Meat, Fish, Seafood, and their Preparations
20	Food or Kindred Products	6	Milled Grain Products and Preparations, and Bakery Products
20	Food or Kindred Products	7	Other Prepared Foodstuffs and Fats and Oils
20	Food or Kindred Products	8	Alcoholic Beverages
21	Tobacco Products	9	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, nec.
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, nec.
29	Petroleum or Coal Products	19	Coal and Petroleum Products, nec.
28	Chemicals	20	Basic Chemicals
28	Chemicals	21	Pharmaceutical Products
28	Chemicals	22	Fertilizers
28	Chemicals	23	Chemical Products and Preparations, nec.
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

STCC2	STCC2 Name	SCTG2	SCTG2 Name
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
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, nec.
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

SCTG2 to STCC4 Concordance[2]

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
1	Live Animals/Fish	0141	Livestock
1	Live Animals/Fish	0151	Live Poultry
1	Live Animals/Fish	0192	Animal or Vegetable Fertilizer
1	Live Animals/Fish	0989	Fish Hatcheries
2	Cereal Grains	0113	Grain
2	Cereal Grains	0115	Other Seeds for Sowing
3	Other Agricultural Products	0115	Other Seeds for Sowing
3	Other Agricultural Products	0112	Cotton, Raw
3	Other Agricultural Products	0114	Oil Kernels, Nuts, or Seeds
3	Other Agricultural Products	0119	Miscellaneous Field Crops
3	Other Agricultural Products	0121	Citrus Fruits
3	Other Agricultural Products	0122	Deciduous Fruits
3	Other Agricultural Products	0123	Tropical Fruits
3	Other Agricultural Products	0129	Miscellaneous Fresh Fruits or Tree Nuts
3	Other Agricultural Products	0131	Bulbs, Roots, or Tubers
3	Other Agricultural Products	0133	Leafy Fresh Vegetables
3	Other Agricultural Products	0134	Leguminous Vegetables
3	Other Agricultural Products	0139	Miscellaneous Fresh Vegetables
3	Other Agricultural Products	0191	Flowers and Nursery Stock
3	Other Agricultural Products	0199	Cereal Straw or Husks and Forage
3	Other Agricultural Products	0842	Gums and Resins
3	Other Agricultural Products	0861	Nursery Products
3	Other Agricultural Products	2034	Dehydrated or Dried Fruit or Vegetable
3	Other Agricultural Products	2071	Candy or Other Confectionery
3	Other Agricultural Products	2091	Cottonseed Oil or By-Prod
3	Other Agricultural Products	2141	Stemmed or Redried Tobacco
3	Other Agricultural Products	4966	Other Regulated Wastes Group E
4	Animal Feed	0192	Animal or Vegetable Fertilizer
4	Animal Feed	0119	Miscellaneous Field Crops
4	Animal Feed	0199	Cereal Straw or Husks and Forage
4	Animal Feed	2091	Cottonseed Oil or By-Prod
4	Animal Feed	0143	Wool and Animal Hair
4	Animal Feed	0152	Eggs
4	Animal Feed	0913	Marine Products

[2] Source: FAF2 Technical Documentation Report Number 8. Crosswalk for Commodities Classified under the STCC and SCTC.

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
4	Animal Feed	2014	Animal By-Prod, Inedible
4	Animal Feed	2015	Dressed Poultry, Fresh
4	Animal Feed	2016	Dressed Poultry, Frozen
4	Animal Feed	2041	Flour or Other Grain Mill Products
4	Animal Feed	2042	Prepared or Canned Feed
4	Animal Feed	2046	Wet Corn Milling or Milo
4	Animal Feed	2047	Dog, Cat, or Other Pet Food, nec
4	Animal Feed	2061	Sugar Mill Prod or By-Prod
4	Animal Feed	2062	Sugar, Refined, Cane or Beet
4	Animal Feed	2082	Malt Liquors
4	Animal Feed	2083	Malt
4	Animal Feed	2085	Distilled or Blended Liquors
4	Animal Feed	2092	Soybean Oil or By-Products
4	Animal Feed	2093	Nut or Vegetable Oils or By-Products
4	Animal Feed	2094	Marine Fats or Oils
5	Meat/Seafood	2015	Dressed Poultry, Fresh
5	Meat/Seafood	2016	Dressed Poultry, Frozen
5	Meat/Seafood	0912	Fresh Fish or Whale Products
5	Meat/Seafood	2011	Meat, Fresh or Chilled
5	Meat/Seafood	2012	Meat, Fresh Frozen
5	Meat/Seafood	2013	Meat Products
5	Meat/Seafood	2017	Processed Poultry or Eggs
5	Meat/Seafood	2031	Canned or Cured Sea Foods
5	Meat/Seafood	2036	Processed Fish Products
5	Meat/Seafood	4945	Other Regulated Wastes Group A
6	Milled Grain Products	2041	Flour or Other Grain Mill Products
6	Milled Grain Products	2046	Wet Corn Milling or Milo
6	Milled Grain Products	2083	Malt
6	Milled Grain Products	2023	Condensed, Evaporated, or Dry Milk
6	Milled Grain Products	2043	Cereal Preparations
6	Milled Grain Products	2044	Milled Rice, Flour or Meal
6	Milled Grain Products	2045	Blended or Prepared Flour
6	Milled Grain Products	2051	Bread or Other Bakery Prod
6	Milled Grain Products	2052	Biscuits, Crackers, or Pretzels
6	Milled Grain Products	2098	Macaroni, Spaghetti, etc.
6	Milled Grain Products	2099	Miscellaneous Food Preparations, nec
7	Other Foodstuffs	0129	Miscellaneous Fresh Fruits or Tree Nuts
7	Other Foodstuffs	2034	Dehydrated or Dried Fruit or Vegetables
7	Other Foodstuffs	2071	Candy or Other Confectionery

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
7	Other Foodstuffs	2091	Cottonseed Oil or By-Prod
7	Other Foodstuffs	2014	Animal By-Prod, Inedible
7	Other Foodstuffs	2046	Wet Corn Milling or Milo
7	Other Foodstuffs	2061	Sugar Mill Prod or By-Prod
7	Other Foodstuffs	2062	Sugar, Refined, Cane or Beet
7	Other Foodstuffs	2092	Soybean Oil or By-Products
7	Other Foodstuffs	2093	Nut or Vegetable Oils or By-Products
7	Other Foodstuffs	2094	Marine Fats or Oils
7	Other Foodstuffs	0912	Fresh Fish or Whale Products
7	Other Foodstuffs	2013	Meat Products
7	Other Foodstuffs	2017	Processed Poultry or Eggs
7	Other Foodstuffs	2031	Canned or Cured Sea Foods
7	Other Foodstuffs	2036	Processed Fish Products
7	Other Foodstuffs	2023	Condensed, Evaporated, or Dry Milk
7	Other Foodstuffs	2052	Biscuits, Crackers or Pretzels
7	Other Foodstuffs	2099	Miscellaneous Food Preparations, nec
7	Other Foodstuffs	0142	Dairy Products
7	Other Foodstuffs	1492	Water
7	Other Foodstuffs	2021	Creamery Butter
7	Other Foodstuffs	2024	Ice Cream or Related Frozen Desserts
7	Other Foodstuffs	2025	Cheese or Special Dairy Products
7	Other Foodstuffs	2026	Processed Milk
7	Other Foodstuffs	2032	Canned Specialties
7	Other Foodstuffs	2033	Canned Fruits, Vegetables, etc.
7	Other Foodstuffs	2035	Pickled Fruits or Vegetables
7	Other Foodstuffs	2037	Frozen Fruit, Vegetables, or Juice
7	Other Foodstuffs	2038	Frozen Specialties
7	Other Foodstuffs	2086	Soft Drinks or Mineral Water
7	Other Foodstuffs	2087	Miscellaneous Flavoring Extracts
7	Other Foodstuffs	2095	Roasted or Instant Coffee
7	Other Foodstuffs	2096	Margarine, Shortening, etc.
7	Other Foodstuffs	2097	Ice, Natural or Manufactured
7	Other Foodstuffs	2297	Wool or Mohair
7	Other Foodstuffs	2841	Soap or Other Detergents
8	Alcoholic Beverages	2082	Malt Liquors
8	Alcoholic Beverages	2085	Distilled or Blended Liquors
8	Alcoholic Beverages	2084	Wine, Brandy, or Brandy Spirit
9	Tobacco Products	2141	Stemmed or Redried Tobacco
9	Tobacco Products	2111	Cigarettes

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
9	Tobacco Products	2121	Cigars
9	Tobacco Products	2131	Chewing or Smoking Tobacco
10	Building Stone	1411	Quarry Stone
11	Natural sands	1441	Gravel or Sand
12	Gravel	1441	Gravel or Sand
12	Gravel	1421	Broken Stone or Riprap
13	Nonmetallic Minerals	1421	Broken Stone or Riprap
13	Nonmetallic Minerals	1451	Clay Ceramic or Refrac Minerals
13	Nonmetallic Minerals	1471	Chemical or Fertilizer Mineri Crude
13	Nonmetallic Minerals	1491	Miscellaneous Nonmetallic Minerals, nec
13	Nonmetallic Minerals	2899	Chemical Preparations, nec
13	Nonmetallic Minerals	3295	Nonmetal Minerals, Processed
13	Nonmetallic Minerals	4945	Other Regulated Wastes Group A
14	Metallic Ores	1011	Iron Ores
14	Metallic Ores	1021	Copper Ores
14	Metallic Ores	1031	Lead Ores
14	Metallic Ores	1032	Zinc Ores
14	Metallic Ores	1033	Lead Zinc Ores
14	Metallic Ores	1041	Gold Ores
14	Metallic Ores	1042	Silver Ores
14	Metallic Ores	1051	Bauxite or Other Alum Ores
14	Metallic Ores	1061	Manganese Ores
14	Metallic Ores	1071	Tungsten Ores
14	Metallic Ores	1081	Chrome Ores
14	Metallic Ores	1092	Miscellaneous Metal Ores
15	Coal	1111	Anthracite coal
15	Coal	1121	Bituminous coal
15	Coal	1122	Lignite
17	Gasoline	2911	Petroleum Refining Products
18	Fuel oils	2911	Petroleum Refining Products
18	Fuel oils	1311	Crude Petroleum
18	Fuel oils	4906	Flammable Liquids
19	Coal-n.e.c.	1491	Miscellaneous Nonmetallic Minerals, nec
19	Coal-n.e.c.	2911	Petroleum Refining Products
19	Coal-n.e.c.	1312	Natural Gas
19	Coal-n.e.c.	1321	Natural Gas
19	Coal-n.e.c.	2814	Crude Prod of Coal, Gas, Petroleum
19	Coal-n.e.c.	2912	Liquefied Gases, Coal, or Petroleum
19	Coal-n.e.c.	2951	Asphalt Paving Blocks or Mix

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
19	Coal-n.e.c.	2952	Asphalt Coatings or Felt
19	Coal-n.e.c.	2991	Miscellaneous Coal or Petroleum Products
19	Coal-n.e.c.	3311	Blast Furnace or Coke
19	Coal-n.e.c.	4905	Hazardous LPG
19	Coal-n.e.c.	4914	Combustible Gases
19	Coal-n.e.c.	4915	Combustible Gases
19	Coal-n.e.c.	4920	Metallic oxides Waste
19	Coal-n.e.c.	4961	Other Regulated Wastes Group E
19	Coal-n.e.c.	4962	Other Regulated Wastes Group E
20	Basic Chemicals	2899	Chemical Preparations, nec
20	Basic Chemicals	2812	Potassium or Sodium Compound
20	Basic Chemicals	2813	Industrial Gases
20	Basic Chemicals	2815	Cyclic Intermediates or Dyes
20	Basic Chemicals	2816	Inorganic Pigments
20	Basic Chemicals	2818	Miscellaneous Industrial Organic Chemicals
20	Basic Chemicals	2819	Miscellaneous Industrial Inorganic Chemicals
20	Basic Chemicals	2831	Drugs
20	Basic Chemicals	2892	Explosives
20	Basic Chemicals	3291	Abrasive Products
20	Basic Chemicals	4904	Non-flammable Compressed Gases
20	Basic Chemicals	4907	Flammable Liquids
20	Basic Chemicals	4908	Flammable Liquids
20	Basic Chemicals	4909	Alcohols and Organic
20	Basic Chemicals	4910	Natural Gas
20	Basic Chemicals	4912	Combustible Gases
20	Basic Chemicals	4913	Combustible Gases
20	Basic Chemicals	4916	Combustible Gases
20	Basic Chemicals	4917	Combustible Gases
20	Basic Chemicals	4918	Combustible Gases
20	Basic Chemicals	4921	Organic Poisons
20	Basic Chemicals	4923	Inorganic Poisons
20	Basic Chemicals	4925	Irritating Materials
20	Basic Chemicals	4927	Radioactive Materials, Fissile
20	Basic Chemicals	4929	Radioactive Materials, Non Fissile
20	Basic Chemicals	4930	Acid Wastes
20	Basic Chemicals	4931	Corrosive Materials
20	Basic Chemicals	4932	Corrosive Materials
20	Basic Chemicals	4934	Corrosive Materials
20	Basic Chemicals	4935	Corrosive Materials

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
20	Basic Chemicals	4936	Corrosive Materials
20	Basic Chemicals	4940	Other Regulated Wastes Group A
20	Basic Chemicals	4941	Other Regulated Wastes Group A
20	Basic Chemicals	4945	Other Regulated Wastes Group A
20	Basic Chemicals	4960	Other Regulated Wastes Group E
20	Basic Chemicals	4961	Other Regulated Wastes Group E
20	Basic Chemicals	4962	Other Regulated Wastes Group E
20	Basic Chemicals	4963	Other Regulated Wastes Group E
21	Pharmaceuticals	2831	Drugs
22	Fertilizers	0192	Animal or Vegetable Fertilizer
22	Fertilizers	1471	Chemical or Fertilizer mineri crude
22	Fertilizers	1051	Bauxite or Other Alum Ores
22	Fertilizers	3311	Blast Furnace or Coke
22	Fertilizers	2812	Potassium or Sodium Compound
22	Fertilizers	2819	Miscellaneous Industrial Inorganic Chemicals
22	Fertilizers	2861	Gum or Wood Chemicals
22	Fertilizers	2871	Fertilizers
22	Fertilizers	4966	Other Regulated Wastes Group E
23	Chemical Products	2087	Miscellaneous Flavoring Extracts
23	Chemical Products	2841	Soap or Other Detergents
23	Chemical Products	2899	Chemical Preparations, nec
23	Chemical Products	2815	Cyclic Intermediates or Dyes
23	Chemical Products	2818	Miscellaneous Industrial Organic Chemicals
23	Chemical Products	2611	Pulp or Pulp Mill Products
23	Chemical Products	2842	Specialty Cleaning Preparations
23	Chemical Products	2843	Surface Active Agents
23	Chemical Products	2844	Cosmetics, Perfumes, etc.
23	Chemical Products	2851	Paints, Lacquers, etc.
23	Chemical Products	2879	Miscellaneous Agricultural Chemicals
23	Chemical Products	2891	Adhesives
23	Chemical Products	2893	Printing Ink
23	Chemical Products	3861	Photographic Equipment or Supplies
23	Chemical Products	3952	Pencils, Crayons, or Artists Materials
23	Chemical Products	3996	Matches
23	Chemical Products	3999	Manufactured Prod, nec
23	Chemical Products	4901	Hazardous Materials
23	Chemical Products	4902	Hazardous Materials
23	Chemical Products	4910	Natural Gas
23	Chemical Products	4925	Irritating Materials

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
24	Plastics/Rubber	0842	Gums and Resins
24	Plastics/Rubber	2621	Paper
24	Plastics/Rubber	2821	Plastic Mater or Synthetic Fibers
24	Plastics/Rubber	3011	Tires or inner Tubes
24	Plastics/Rubber	3031	Reclaimed Rubber
24	Plastics/Rubber	3041	Rub or Plastic Hose or Belting
24	Plastics/Rubber	3061	Miscellaneous Fabricated Products
24	Plastics/Rubber	3071	Miscellaneous Plastic Products
24	Plastics/Rubber	3072	Miscellaneous Plastic Products
25	Logs	2411	Primary Forest Materials
25	Logs	2491	Treated Wood Products
26	Wood Products	2411	Primary Forest Materials
26	Wood Products	2491	Treated Wood Products
26	Wood Products	2421	Lumber or dimension Stock
26	Wood Products	2429	Miscellaneous Sawmill or Planing Mill
26	Wood Products	2431	Millwork or Cabinetwork
26	Wood Products	2432	Plywood or Veneer
26	Wood Products	2433	Prefab Wood Buildings
26	Wood Products	2439	Structural Wood Prod, nec
26	Wood Products	2441	Wood Cont. or Box Shooks
26	Wood Products	2492	Rattan or Bamboo Ware
26	Wood Products	2493	Lasts or Related Products
26	Wood Products	2494	Cork Products
26	Wood Products	2495	Hand Tool Handles
26	Wood Products	2496	Scaffolding Equipment or Ladders
26	Wood Products	2497	Wooden Ware or Flatware
26	Wood Products	2498	Wood Prod, nec
26	Wood Products	2499	Miscellaneous Wood Products
26	Wood Products	2661	Paper or Building Board
27	Newsprint/Paper	2611	Pulp or Pulp Mill Products
27	Newsprint/Paper	2621	Paper
27	Newsprint/Paper	2661	Paper or Building Board
27	Newsprint/Paper	2631	Fiber, Paper, or Pulpboard
27	Newsprint/Paper	2645	Die-cut Paper or ppbd Products
28	Paper Articles	2661	Paper or Building Board
28	Paper Articles	2645	Die-cut Paper or ppbd Products
28	Paper Articles	2642	Envelopes
28	Paper Articles	2643	Paper Bags
28	Paper Articles	2644	Wallpaper

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
28	Paper Articles	2646	Pressed or Molded Pulp Goods
28	Paper Articles	2647	Sanitary Paper Products
28	Paper Articles	2649	Miscellaneous Converted Paper Products
28	Paper Articles	2651	Containers or Boxes, Paper
28	Paper Articles	2654	Sanitary Food Containers
28	Paper Articles	2655	Fiber cans, Drums or Tubes
28	Paper Articles	2741	Miscellaneous Printed Matter
28	Paper Articles	3955	Carbon Paper or Inked Ribbons
29	Printed Products	2741	Miscellaneous Printed Matter
29	Printed Products	2711	Newspapers
29	Printed Products	2721	Periodicals
29	Printed Products	2731	Books
29	Printed Products	2761	Manifold Business Forms
29	Printed Products	2771	Greeting Cards, Seals, etc.
29	Printed Products	2781	Blankbook, Loose Leaf Binder
30	Textiles/Leather	2297	Wool or Mohair
30	Textiles/Leather	3061	Miscellaneous Fabricated Products
30	Textiles/Leather	2211	Cotton Broad-Woven Fabrics
30	Textiles/Leather	2221	Man-Made or Glass Woven Fibre
30	Textiles/Leather	2222	Silk-Woven Fabrics
30	Textiles/Leather	2231	Wool Broad-Woven Fabrics
30	Textiles/Leather	2241	Narrow Fabrics
30	Textiles/Leather	2251	Knit Fabrics
30	Textiles/Leather	2271	Woven Carpets, Mats, or Rugs
30	Textiles/Leather	2272	Tufted Carpets, Rugs, or Mats
30	Textiles/Leather	2279	Carpets, Mats, or Rugs, nec
30	Textiles/Leather	2281	Yarn
30	Textiles/Leather	2284	Thread
30	Textiles/Leather	2291	Felt Goods
30	Textiles/Leather	2292	Lace Goods
30	Textiles/Leather	2293	Paddings, Upholstery Fill, etc
30	Textiles/Leather	2295	Coated or Imprinted Fabric
30	Textiles/Leather	2296	Cord or Fabrics, Industrial
30	Textiles/Leather	2298	Cordage or Twine
30	Textiles/Leather	2299	Textile Goods, nec
30	Textiles/Leather	2311	Men’s or Boys’ Clothing
30	Textiles/Leather	2331	Women’s or Children’s’ Clothing
30	Textiles/Leather	2351	Millinery
30	Textiles/Leather	2352	Caps, Hats, or Hat Bodies

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
30	Textiles/Leather	2371	Fur Goods
30	Textiles/Leather	2381	Gloves, Mittens, or Linings
30	Textiles/Leather	2384	Robes or Dressing Gowns
30	Textiles/Leather	2385	Raincoats or Other Rain Wear
30	Textiles/Leather	2386	Leather Clothing
30	Textiles/Leather	2387	Apparel Belts
30	Textiles/Leather	2389	Apparel, nec
30	Textiles/Leather	2391	Curtains or Draperies
30	Textiles/Leather	2392	Textile House furnishings
30	Textiles/Leather	2393	Textile Bags
30	Textiles/Leather	2394	Canvas Products
30	Textiles/Leather	2395	Textile Prod, Pleated, etc.
30	Textiles/Leather	2396	Apparel Findings
30	Textiles/Leather	2399	Miscellaneous Fabricated Textile Products
30	Textiles/Leather	3021	Rubber or Plastic Footwear
30	Textiles/Leather	3111	Leather, Finished or Tanned
30	Textiles/Leather	3121	Industrial Leather Belting
30	Textiles/Leather	3131	Boot or Shoe Cut Stock
30	Textiles/Leather	3141	Leather Footwear
30	Textiles/Leather	3142	Leather House Slippers
30	Textiles/Leather	3151	Leather Gloves or Mittens
30	Textiles/Leather	3161	Leather Luggage or Handbags
30	Textiles/Leather	3199	Leather Goods, nec
30	Textiles/Leather	3949	Sporting or Athletic Goods
30	Textiles/Leather	3997	Furs, Dressed or Dyed
31	Nonmetal Mineral Products	3295	Nonmetal Minerals, Processed
31	Nonmetal Mineral Products	2952	Asphalt Coatings or Felt
31	Nonmetal Mineral Products	3291	Abrasive Products
31	Nonmetal Mineral Products	3211	Flat Glass
31	Nonmetal Mineral Products	3221	Glass Containers
31	Nonmetal Mineral Products	3229	Miscellaneous Glassware, Blown or Pressed
31	Nonmetal Mineral Products	3241	Portland Cement
31	Nonmetal Mineral Products	3251	Clay Brick or Tile
31	Nonmetal Mineral Products	3253	Ceramic Floor or Wall Tile
31	Nonmetal Mineral Products	3255	Refractories
31	Nonmetal Mineral Products	3259	Miscellaneous Structural Clay Products
31	Nonmetal Mineral Products	3261	Vitreous China Plumbing Fixtures
31	Nonmetal Mineral Products	3262	Vitreous China Kitchen Articles
31	Nonmetal Mineral Products	3264	Porcelain Electric Supplies

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
31	Nonmetal Mineral Products	3269	Miscellaneous Pottery Products
31	Nonmetal Mineral Products	3271	Concrete Products
31	Nonmetal Mineral Products	3273	Ready-Mix Concrete, Wet
31	Nonmetal Mineral Products	3274	Lime or Lime Plaster
31	Nonmetal Mineral Products	3275	Gypsum Products
31	Nonmetal Mineral Products	3281	Cut Stone or Stone Products
31	Nonmetal Mineral Products	3292	Asbestos Products
31	Nonmetal Mineral Products	3296	Mineral Wool
31	Nonmetal Mineral Products	3299	Miscellaneous Nonmetallic Minerals
31	Nonmetal min. Products	3842	Orthopedic or Prosthetic Supplies
31	Nonmetal Mineral Products	3961	Costume Jewelry or Novelties
31	Nonmetal Mineral Products	4918	Combustible Gases
32	Base Metals	3311	Blast Furnace or Coke
32	Base Metals	2621	Paper
32	Base Metals	3312	Primary Iron or Steel Products
32	Base Metals	3313	Electrometallurgical Products
32	Base Metals	3315	Steel Wire, Nails or Spikes
32	Base Metals	3331	Primary Copper Smelter Products
32	Base Metals	3332	Primary Lead Smelter Products
32	Base Metals	3333	Primary Zinc Smelter Products
32	Base Metals	3334	Primary Aluminum Smelter Products
32	Base Metals	3339	Miscellaneous Prim Nonferr Smelter Products
32	Base Metals	3351	Copper or Alloy Basic Shapes
32	Base Metals	3352	Aluminum or alloy Basic Shapes
32	Base Metals	3356	Miscellaneous Nonferrous Basic Shapes
32	Base Metals	3357	Nonferrous Wire
32	Base Metals	3399	Primary Metal Products, nec
32	Base Metals	3499	Fabricated Metal Products, nec
33	Articles-Base Metal	3291	Abrasive Products
33	Articles-Base Metal	3312	Primary Iron or Steel Products
33	Articles-Base Metal	3315	Steel Wire, Nails or Spikes
33	Articles-Base Metal	3351	Copper or Alloy Basic Shapes
33	Articles-Base Metal	3352	Aluminum or Alloy Basic Shapes
33	Articles-Base Metal	3356	Miscellaneous Nonferrous Basic Shapes
33	Articles-Base Metal	3357	Nonferrous Wire
33	Articles-Base Metal	3399	Primary Metal Products, nec
33	Articles-Base Metal	3499	Fabricated Metal Products, nec
33	Articles-Base Metal	2542	Metal Lockers, Partitions, etc.
33	Articles-Base Metal	2591	Venetian Blinds, Shades, etc.

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
33	Articles-Base Metal	3321	Iron or Steel Castings
33	Articles-Base Metal	3361	Aluminum or Alloy Castings
33	Articles-Base Metal	3362	Copper or Alloy Castings
33	Articles-Base Metal	3369	Miscellaneous Nonferrous Castings
33	Articles-Base Metal	3391	Iron or Steel Forgings
33	Articles-Base Metal	3392	Nonferrous Metal Forgings
33	Articles-Base Metal	3411	Metal Cans
33	Articles-Base Metal	3421	Cutlery, Not Electrical
33	Articles-Base Metal	3423	Edge or Hand Tools
33	Articles-Base Metal	3425	Hand Saws or Saw Blades
33	Articles-Base Metal	3428	Builders or Cabinet Hardware
33	Articles-Base Metal	3429	Miscellaneous Hardware
33	Articles-Base Metal	3431	Metal Sanitary Ware
33	Articles-Base Metal	3433	Heating Equipment, Not Electrical
33	Articles-Base Metal	3441	Fabricated Structural Metal Products
33	Articles-Base Metal	3442	Metal Doors, Sash, etc.
33	Articles-Base Metal	3443	Fabricated Plate Products
33	Articles-Base Metal	3444	Sheet Metal Products
33	Articles-Base Metal	3446	Architectural Metal Work
33	Articles-Base Metal	3449	Miscellaneous Metal Work
33	Articles-Base Metal	3452	Bolts, Nuts, Screws, etc.
33	Articles-Base Metal	3461	Metal Stampings
33	Articles-Base Metal	3481	Miscellaneous Fabricated Wire Products
33	Articles-Base Metal	3491	Metal Shipping Containers
33	Articles-Base Metal	3492	Metal Safes or Vaults
33	Articles-Base Metal	3493	Steel Springs
33	Articles-Base Metal	3494	Valves or Pipe Fittings
33	Articles-Base Metal	3533	Oil Field Machinery or Equipment
33	Articles-Base Metal	3537	Industrial Trucks, etc.
33	Articles-Base Metal	3599	Miscellaneous Machinery or Parts
33	Articles-Base Metal	3631	Household Cooking Equipment
33	Articles-Base Metal	3644	Noncurrent Wiring Devices
33	Articles-Base Metal	3914	Silverware or Plated Ware
33	Articles-Base Metal	3993	Signs or Advertising Displays
33	Articles-Base Metal	4299	Shipping Containers, n.e.c
34	Machinery	3499	Fabricated Metal Products, nec
34	Machinery	3429	Miscellaneous Hardware
34	Machinery	3433	Heating Equipment, Not Electrical
34	Machinery	3443	Fabricated Plate Products

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
34	Machinery	3494	Valves or Pipe Fittings
34	Machinery	3533	Oil Field Machinery or Equipment
34	Machinery	3537	Industrial Trucks, etc.
34	Machinery	3599	Miscellaneous Machinery or Parts
34	Machinery	2517	Cabinets or Cases
34	Machinery	2791	Svc Industrial for Print Trades
34	Machinery	3293	Gaskets or Packing
34	Machinery	3432	Plumbing Fixtures
34	Machinery	3511	Steam Engines, Turbines, etc.
34	Machinery	3519	Miscellaneous Internal Combustion Engines
34	Machinery	3522	Farm Machinery or Equipment
34	Machinery	3524	Lawn or Garden Equipment
34	Machinery	3531	Construction Machinery or Equipment
34	Machinery	3532	Mining Machinery or Parts
34	Machinery	3534	Elevators or Escalators
34	Machinery	3535	Conveyors or Parts
34	Machinery	3536	Hoists, Industrial Cranes, etc.
34	Machinery	3541	Machine Tools, Metal Cutting
34	Machinery	3542	Machine Tools, Metal Forming
34	Machinery	3544	Special Dies, Tools, Jigs, etc.
34	Machinery	3545	Machine Tool Accessories
34	Machinery	3548	Metalworking Machinery
34	Machinery	3551	Food Prod Machinery
34	Machinery	3552	Textile Machinery or Parts
34	Machinery	3553	Woodworking Machinery
34	Machinery	3554	Paper Industries Machinery
34	Machinery	3555	Printing Trades Machinery
34	Machinery	3559	Miscellaneous Special Industry Mach
34	Machinery	3561	Industrial Pumps
34	Machinery	3562	Ball or Roller Bearings
34	Machinery	3564	Ventilating Equipment
34	Machinery	3566	Mech Power Transmission Equipment
34	Machinery	3567	Industrial Process Furnaces
34	Machinery	3569	Miscellaneous General Industrial
34	Machinery	3576	Scales or Balances
34	Machinery	3581	Automatic Merchandising Machines
34	Machinery	3582	Commercial Laundry Equipment
34	Machinery	3585	Refrigeration Machinery
34	Machinery	3589	Misc. Service industry Machinery

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
34	Machinery	3592	Carburetors, Pistons, etc.
34	Machinery	3623	Welding Apparatus
34	Machinery	3632	Household Refrigerators
34	Machinery	3633	Household Laundry Equipment
34	Machinery	3634	Electric Housewares or Fans
34	Machinery	3636	Sewing Machines or Parts
34	Machinery	3639	Miscellaneous Household Appliances
34	Machinery	3714	Motor Vehicle Parts or Accessories
34	Machinery	3722	Aircraft or Missile Engines
34	Machinery	3999	Manufactured Prod, nec
35	Electronics	3357	Nonferrous Wire
35	Electronics	3631	Household Cooking Equipment
35	Electronics	3644	Noncurrent Wiring Devices
35	Electronics	2517	Cabinets or Cases
35	Electronics	3634	Electric Housewares or Fans
35	Electronics	3639	Miscellaneous Household Appliances
35	Electronics	3572	Typewriters or Parts
35	Electronics	3573	Electronic Data Proc Equipment
35	Electronics	3574	Accounting or Calculating Equipment
35	Electronics	3579	Miscellaneous Office Machines
35	Electronics	3612	Electrical Transformers
35	Electronics	3613	Switchgear or Switchboards
35	Electronics	3621	Motors or Generators
35	Electronics	3622	Industrial Controls or Parts
35	Electronics	3624	Carbon prod for Electric Uses
35	Electronics	3629	Miscellaneous Electrical Industrial Equipment
35	Electronics	3635	Household Vacuum Cleaners
35	Electronics	3641	Electric Lamps
35	Electronics	3643	Current Carrying Wiring Equipment
35	Electronics	3651	Radio or TV Receiving Sets
35	Electronics	3652	Phonograph Records
35	Electronics	3661	Telephone or Telegraph Equipment
35	Electronics	3662	Radio or TV Transmitting Equipment
35	Electronics	3671	Electronic Tubes
35	Electronics	3674	Solid State Semiconductors
35	Electronics	3679	Miscellaneous Electronic Components
35	Electronics	3691	Storage Batteries or Plates
35	Electronics	3692	Primary Batteries
35	Electronics	3694	Elect Equipment for Intern Comb Engine

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
35	Electronics	3699	Electrical Equipment, nec
35	Electronics	4111	Miscellaneous Freight Shipments
36	Motorized Vehicles	2399	Miscellaneous Fabricated Textile Products
36	Motorized Vehicles	3461	Metal Stampings
36	Motorized Vehicles	3522	Farm Machinery or Equipment
36	Motorized Vehicles	3531	Construction Machinery or Equipment
36	Motorized Vehicles	3714	Motor Vehicle Parts or Accessories
36	Motorized Vehicles	4111	Miscellaneous Freight Shipments
36	Motorized Vehicles	1931	Armored Tanks and Vehicles
36	Motorized Vehicles	3711	Motor Vehicles
36	Motorized Vehicles	3712	Passenger Motor Car Bodies
36	Motorized Vehicles	3713	Motor Bus or Truck Bodies
36	Motorized Vehicles	3715	Truck Trailers
36	Motorized Vehicles	3751	Motorcycles, Bicycles, or Parts
36	Motorized Vehicles	3791	Trailer Coaches
36	Motorized Vehicles	3799	Transportation Equipment, nec
37	Transport Equipment	2399	Miscellaneous Fabricated Textile Products
37	Transport Equipment	3531	Construction Machinery or Equipment
37	Transport Equipment	4111	Miscellaneous Freight Shipments
37	Transport Equipment	1925	Missiles and Rockets
37	Transport Equipment	3721	Aircraft
37	Transport Equipment	3723	Aircraft Propellers or Parts
37	Transport Equipment	3729	Miscellaneous Aircraft Parts
37	Transport Equipment	3732	Ships or Boats
37	Transport Equipment	3741	Locomotives or Parts
37	Transport Equipment	3742	Railroad Cars
37	Transport Equipment	3769	Missile or Space Vehicle Parts
37	Transport Equipment	4211	Empty Containers
37	Transport Equipment	4221	Empty TOFC/COFC
37	Transport Equipment	4231	Empty Containers, Revenue
37	Transport Equipment	4321	Freight , Passenger Coaches and Service Vehicles
38	Precision Instruments	3861	Photographic Equipment or Supplies
38	Precision Instruments	1941	Aiming Circles
38	Precision Instruments	3611	Electric Measuring Instruments
38	Precision Instruments	3693	X-Ray Equipment
38	Precision Instruments	3811	Engineering, Lab, or Scientific Equipment
38	Precision Instruments	3821	Mechanical Measuring or Control Equipment
38	Precision Instruments	3822	Automatic Temperature Controls
38	Precision Instruments	3831	Optical Instruments or Lenses

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
38	Precision Instruments	3841	Surgical or Medical Instruments
38	Precision Instruments	3843	Dental Equipment or Supplies
38	Precision Instruments	3851	Ophthalmic or Opticians Goods
39	Furniture	2421	Lumber or Dimension Stock
39	Furniture	2431	Millwork or Cabinetwork
39	Furniture	3299	Miscellaneous Nonmetallic Minerals
39	Furniture	3499	Fabricated Metal Products, nec
39	Furniture	2542	Metal Lockers, Partitions, etc.
39	Furniture	3429	Miscellaneous Hardware
39	Furniture	3993	Signs or Advertising Displays
39	Furniture	2517	Cabinets or Cases
39	Furniture	3811	Engineering, Lab or Scientific Equipment
39	Furniture	3841	Surgical or Medical Instruments
39	Furniture	2434	Kitchen Cabinets, Wood
39	Furniture	2511	Benches, Chairs, Stools
39	Furniture	2512	Tables or Desks
39	Furniture	2513	Sofas, Couches, etc.
39	Furniture	2514	Buffets, China Closets, etc.
39	Furniture	2515	Bedsprings or Mattresses
39	Furniture	2516	Beds, Dressers, Chests, etc.
39	Furniture	2518	Children’s Furniture
39	Furniture	2519	Household or Office Furniture, nec
39	Furniture	2531	Public Building or Related Furniture
39	Furniture	2541	Wood Lockers, Partitions, etc.
39	Furniture	2599	Furniture or Fixtures, nec
39	Furniture	3642	Lighting Fixtures
40	Miscellaneous Manufacturing Products	1041	Gold Ores
40	Miscellaneous Manufacturing Products	1042	Silver Ores
40	Miscellaneous Manufacturing Products	3952	Pencils, Crayons, or Artists Materials
40	Miscellaneous Manufacturing Products	2433	Prefab Wood Buildings
40	Miscellaneous Manufacturing Products	2392	Textile House furnishings
40	Miscellaneous Manufacturing Products	3949	Sporting or Athletic Goods
40	Miscellaneous Manufacturing Products	3961	Costume Jewelry or Novelties
40	Miscellaneous Manufacturing Products	3339	Miscellaneous Prim Nonferr Smelter Products
40	Miscellaneous Manufacturing Products	3356	Miscellaneous Nonferrous Basic Shapes
40	Miscellaneous Manufacturing Products	3499	Fabricated Metal Products, nec
40	Miscellaneous Manufacturing Products	3429	Miscellaneous Hardware
40	Miscellaneous Manufacturing Products	3449	Miscellaneous Metal work
40	Miscellaneous Manufacturing Products	3599	Miscellaneous Machinery or Parts

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
40	Miscellaneous Manufacturing Products	3914	Silverware or Plated Ware
40	Miscellaneous Manufacturing Products	3993	Signs or Advertising Displays
40	Miscellaneous Manufacturing Products	3999	Manufactured Prod, nec
40	Miscellaneous Manufacturing Products	4111	Miscellaneous Freight Shipments
40	Miscellaneous Manufacturing Products	1931	Armored Tanks and Vehicles
40	Miscellaneous Manufacturing Products	3791	Trailer Coaches
40	Miscellaneous Manufacturing Products	1911	Guns
40	Miscellaneous Manufacturing Products	1929	Ammunition
40	Miscellaneous Manufacturing Products	1951	Small Arms Ammo
40	Miscellaneous Manufacturing Products	1961	Cartridges and Ammo
40	Miscellaneous Manufacturing Products	1991	Other Ordnance
40	Miscellaneous Manufacturing Products	3871	Watches, Clocks, etc.
40	Miscellaneous Manufacturing Products	3931	Musical Instruments or Parts
40	Miscellaneous Manufacturing Products	3941	Games or Toys
40	Miscellaneous Manufacturing Products	3942	Dolls or Stuffed Toys
40	Miscellaneous Manufacturing Products	3943	Children’s Vehicle or Parts, nec
40	Miscellaneous Manufacturing Products	3951	Pens or Parts
40	Miscellaneous Manufacturing Products	3953	Marking Devices
40	Miscellaneous Manufacturing Products	3962	Feathers, Plumes, etc.
40	Miscellaneous Manufacturing Products	3963	Buttons
40	Miscellaneous Manufacturing Products	3964	Apparel Fasteners
40	Miscellaneous Manufacturing Products	3991	Brooms, Brushes, etc.
40	Miscellaneous Manufacturing Products	3992	Linoleum or Other Coverings
40	Miscellaneous Manufacturing Products	1900	Ordnance or Accessories
40	Miscellaneous Manufacturing Products	2551	Furniture Masc.
40	Miscellaneous Manufacturing Products	4903	Explosives
40	Miscellaneous Manufacturing Products	4950	Mixed Loads
41	Waste/Scrap	2821	Plastic Mater or Synthetic Fibers
41	Waste/Scrap	2429	Miscellaneous Sawmill or Planing Mill
41	Waste/Scrap	3331	Primary Copper Smelter Products
41	Waste/Scrap	3332	Primary Lead Smelter Products
41	Waste/Scrap	3333	Primary Zinc Smelter Products
41	Waste/Scrap	3334	Primary Aluminum Smelter Products
41	Waste/Scrap	3339	Miscellaneous Prim Nonferr Smelter Products
41	Waste/Scrap	2294	Textile Waste, Processed
41	Waste/Scrap	3994	Morticians Goods
41	Waste/Scrap	4011	Slag, Ash, and Residues
41	Waste/Scrap	4021	Metal Scrap or Tailings
41	Waste/Scrap	4022	Non-Metallic Waste

SCTG2	SCTG2 Name	SCTG4	SCTG4 Name
41	Waste/Scrap	4023	Non-Metallic Waste
41	Waste/Scrap	4024	Paper Waste or Scrap
41	Waste/Scrap	4025	Chemical Waste
41	Waste/Scrap	4026	Rubber and Plastic Waste
41	Waste/Scrap	4027	Stone Product Waste
41	Waste/Scrap	4028	Leather Waste
41	Waste/Scrap	4029	Miscellaneous Waste or Scrap
41	Waste/Scrap	4890	Regulated Waste Stream
41	Waste/Scrap	4891	Regulated Waste Stream
41	Waste/Scrap	4807	Waste Flammable Liquids
41	Waste/Scrap	4809	Hazardous Chemical Waste
41	Waste/Scrap	4810	Hazardous Flammable Waste
41	Waste/Scrap	4812	Waste Flammable Liquids
41	Waste/Scrap	4815	Waste Flammable Liquids
41	Waste/Scrap	4816	Waste Flammable Liquids
41	Waste/Scrap	4821	Regulated Waste Group A
41	Waste/Scrap	4825	Regulated Waste Group A
41	Waste/Scrap	4830	Regulated Waste Group B
41	Waste/Scrap	4831	Regulated Waste Group B
41	Waste/Scrap	4835	Regulated Waste Group B
41	Waste/Scrap	4836	Regulated Waste Group B
41	Waste/Scrap	4845	Regulated Waste Group C
41	Waste/Scrap	4850	Regulated Waste Group D
41	Waste/Scrap	4860	Regulated Waste Group E
41	Waste/Scrap	4862	Regulated Waste Group E
41	Waste/Scrap	4875	Regulated Waste Stream
43	Mixed Freight	2099	Miscellaneous Food Preparations, nec
43	Mixed Freight	3429	Miscellaneous Hardware
43	Mixed Freight	4111	Miscellaneous Freight Shipments
43	Mixed Freight	2039	Canned or Preserved Food, Mixed
43	Mixed Freight	4121	Coins, Art, and Precious Metals
43	Mixed Freight	4611	FAK Shipments
43	Mixed Freight	4621	Mixed Shipments

U.S. Department of Transportation
1200 New Jersey Avenue, S.E.
Washington, DC 20590
http://www.fhwa.dot.gov

Publication No.: FHWA-HOP-08-010
EDL 14396

Publication Date: September 2007