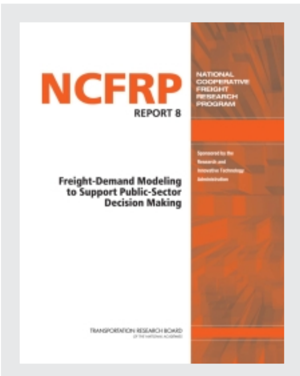

Freight-Demand Modeling to Support Public-Sector Decision Making

DETAILS

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Transportation Research Board

NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 8

Freight-Demand Modeling to Support Public-Sector Decision Making

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AND

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Subscriber Categories

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TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

America's freight transportation system makes critical contributions to the nation's economy, security, and quality of life. The freight transportation system in the United States is a complex, decentralized, and dynamic network of private and public entities, involving all modes of transportation—trucking, rail, waterways, air, and pipelines. In recent years, the demand for freight transportation service has been increasing fueled by growth in international trade; however, bottlenecks or congestion points in the system are exposing the inadequacies of current infrastructure and operations to meet the growing demand for freight. Strategic operational and investment decisions by governments at all levels will be necessary to maintain freight system performance, and will in turn require sound technical guidance based on research.

The National Cooperative Freight Research Program (NCFRP) is a cooperative research program sponsored by the Research and Innovative Technology Administration (RITA) under Grant No. DTOS59-06-G-00039 and administered by the Transportation Research Board (TRB). The program was authorized in 2005 with the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). On September 6, 2006, a contract to begin work was executed between RITA and The National Academies. The NCFRP will carry out applied research on problems facing the freight industry that are not being adequately addressed by existing research programs.

Program guidance is provided by an Oversight Committee comprised of a representative cross section of freight stakeholders appointed by the National Research Council of The National Academies. The NCFRP Oversight Committee meets annually to formulate the research program by identifying the highest priority projects and defining funding levels and expected products. Research problem statements recommending research needs for consideration by the Oversight Committee are solicited annually, but may be submitted to TRB at any time. Each selected project is assigned to a panel, appointed by TRB, which provides technical guidance and counsel throughout the life of the project. Heavy emphasis is placed on including members representing the intended users of the research products.

The NCFRP will produce a series of research reports and other products such as guidebooks for practitioners. Primary emphasis will be placed on disseminating NCFRP results to the intended end-users of the research: freight shippers and carriers, service providers, suppliers, and public officials.

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making presents an evaluation of possible improvements in freight demand models and other analysis tools and provides a guidebook to assist model developers in implementing these improvements. The report is especially valuable for its findings of general satisfaction with methods available to support freight planning, but concerns with the data available to support that planning. As such, the report focuses on ways to use existing data to develop data inputs for the model, showing that existing and readily available data can be used to develop the inputs required by freight models. The report will enable decisionmakers at a range of geographical levels to improve the usability of freight demand models.

While the private sector is largely responsible for developing and managing the nation's freight flow system, public agencies at all levels face important investment and policy decisions that may affect those flows. As a result, many states, metropolitan planning organizations, regional agencies, and federal government agencies have undertaken their own modeling efforts in order to better understand the large and shifting increases in traffic in the nation's freight flows. Given the projected growth in freight and its importance to national, state, and regional economies, public-sector agencies need improved capabilities to analyze freight demand.

Under NCFRP Project 6, Cambridge Systematics was asked to (1) investigate, identify, and report on high-priority, high-payoff improvements in freight-demand models and other analysis tools; (2) conduct further research on a selected number of these improvements; and (3) develop a guidebook to assist model developers in implementing these improvements.

To accomplish the project objectives, the research team (1) developed a framework for categorizing how current models are used; (2) interviewed public decisionmakers to gauge their satisfaction with current models; (3) conducted research on critical gaps in existing models to advance the state of freight modeling in the short term; and (4) developed a guidebook that describes a process that could be followed in the development and application of freight forecasts to support public decision making.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Freight-Demand Modeling to Support Public-Sector Decision Making

The private sector is largely responsible for development and management of the nation's freight flow system, but public agencies at all levels face important investment and policy decisions that may affect those flows. Decisionmakers need to understand the large and shifting increases in traffic generated, for example, by ports, inland terminals, and mega-destination centers.

In 2004, U.S.DOT launched the Freight Model Improvement Program (FMIP) as a joint effort with the U.S. Department of Agriculture, DOE, and the Army Corps of Engineers, and with support from Oak Ridge National Laboratory. Each of these agencies has developed models for national-level analysis in support of their own unique missions.

Some state and regional agencies have undertaken their own modeling efforts. Given the growth in freight and its importance to national, state, and regional economies, public-sector agencies need improved capabilities to analyze freight demand.

Study Objective

The objective of this project was to

- Investigate, identify, and report on high-priority, high-payoff improvements in freight-demand models and other analysis tools;
- Conduct research on several of these improvements; and
- Develop a guidebook to assist model developers in implementing freight transportation planning, including these improvements.

Current Needs and Practices

A framework for categorizing existing models was developed. This framework included not only the model categories but the status of how that model is being utilized. That framework and the general findings of the literature review are shown in Table S.1.

In-person interviews, telephone, and Web surveys were conducted to identify the freight transportation needs and concerns of public decisionmakers. The needs identified by those findings are shown in Figure S.1. The outreach showed general satisfaction with the methods available to support freight planning, but dissatisfaction with the data that are available to support freight planning.

Research

The review of the model framework and the survey responses suggested a number of research topics that could be improved through additional research. Those topics that were

Table S.1. Comparison of model development and implementation in the literature to public-sector applications.

Model Category	Description	Model Development	Model Implementation	Public Sector Applications
Time Series	Short-, medium-, and long-term forecasts of freight demand and freight activity	●	●	●
Behavioral	Models how companies perceive and select from the many available freight choices. Includes choice-based and survey-based demand models	◑	◑	◑
Commodity-Based and Input-Output	Estimate current and forecasted freight traffic generation and distribution by linking industrial activity through input-output models of economic activity	●	●	●
Multimodal Network	Link-node network representations of freight supply useful for determining travel times, costs, reliability, and overall level of service	●	◑	◑
Microsimulation and Agent-Based	Microsimulation models the individual movement of large numbers of units and their attributes, while agent-based modeling defines potential actors in freight transporatation and an allowable set of actions and interactions	●	●	◑
Supply Chain/ Logistics	Supply chains define the life cycle of products from raw materials to the final consumer, including production, inventory, and transportation	●	◑	○
Network Design	Private-sector models for locating factories, distribution centers, warehouses, and other freight generating facilities	●	○	○
Routing and Scheduling	Private-sector models for locating factories, distribution centers, warehouses, and other freight generating facilities	◑	○	○
Other and Emerging Topics	Hybrid models, real-time decision making	◑	◑	◑

● Widely used, state of the practice ◑ Emerging model, limited use ○ Lacking research or application

selected for additional research as part of this project will be discussed later. The topics identified but not selected include the following:

- Freight data to support model specification, calibration, and validation;
- Better methods to consider nonfreight trucks;
- Better incorporation of labor and equipment productivity in freight models;
- Improved methods for nonhighway freight assignment;
- Simplified methods for considering the economic impact of freight improvements; and
- Better consideration and forecasting of trip by empty and repositioning freight vehicles.

The three topics that were selected for additional research were as follows:

- Developing trip distribution and other chaining data through the use of GPS data;
- Developing temporal and seasonal commodity flow factors; and
- Developing mode-choice parameters using public datasets.

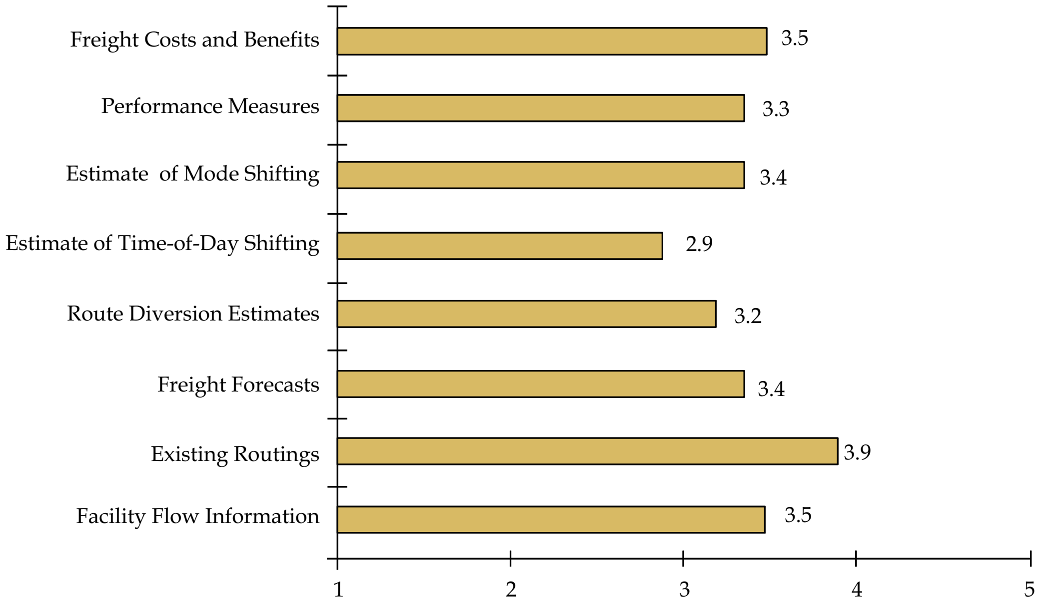


Figure S.1. Public-sector freight analysis needs.

The research on trip distribution and other chaining data through the use of GPS data suggested that it is possible to use unobtrusive GPS subscription data to obtain a large number of records containing information about truck trips. The locations and times of GPS readings can be used to determine truck stop locations, the land uses at those locations, the next land use served on a trip, and the travel time and distance to the next stop. The information was examined in four diverse metropolitan areas (Baltimore, Chicago, Los Angeles, and Phoenix). The data suggested similar patterns for all of the metropolitan areas. The land use at the origin was most often linked with the same land use at the destination. This ranged from a high of 65 percent of the truck trips from origins with residential land uses to destinations with residential land uses in Los Angeles to a low of 40 percent of the truck trips from origins with low-density land uses to destinations with low-density land uses in Chicago. Average trip characteristics ranged from a low of 38 min and 9.2 mi in Baltimore to 44 min and 11.3 mi in Los Angeles.

The research on temporal and seasonal commodity flow factors suggested that it is possible to assign truck commodity flows to the highway network and to compare the flows with observed truck counts. Although continuous count information was not available from every state, the information available suggests that commodity flow patterns are stable for all commodities throughout the year and that the annual traffic is approximately equivalent to 310 average weekdays (Monday through Friday) and 295 average mid-weekdays (Tuesday through Thursday). The peak hourly traffic is approximately 8 percent of daily traffic and that same percentage of daily traffic occurs during each of the hours beginning at 11 A.M. and ending at 5 P.M.

The research on mode-choice parameters using public datasets, which used commodity flow surveys as a revealed-preference survey for developing mode-choice models, suggests that for all commodities, distance is the most important decision variable for mode choice. The only other decision variables that appear to explain mode choice are size of shipment (e.g., tons shipped) and value of the shipment (e.g., dollar per tons), and those variables were only significant as cross products with distance. For many commodities, dividing the distance traveled into short-haul and long-haul markets slightly improved the ability to explain mode choice. Overall, for many commodities, none of the variables tested at the scale of geography were significant, suggesting that mode-choice decisions are subject to business decisions for which data are not available and are made based on conditions in geographies smaller than the Freight Analysis Framework Version 2 (FAF2) regions that were used.

Guidebook

Based on the literature review and model framework, the survey of public decisionmakers, and the additional research in support of this project, the study team developed a proposed 10-step process. This process follows standard practices used to support transportation analyses for public decisionmakers, and typically is a vehicle or commodity-based process. The process proposed for freight is generally similar to the process used by models to support other transportation decisions. The process includes the following steps:

Step 1—What freight policy alternatives need to be evaluated?
Step 2—What performance measures support those policy measures?
Step 3—What forecasting models can be used to support decisions?
Step 4—How much freight? Trip generation: productions and attractions by commodity in tons.
Step 5—Where does the freight go? Trip distribution: trip table Os and Ds.
Step 6—What mode does freight use? Mode choice: trip table Os and Ds by mode.
  Step 6a—Direct acquisition of commodity OD tables: alternate ways to get freight OD tables.
  Step 6b—Economic/land use model: alternate ways to get freight OD table by mode.
Step 7—How many freight trucks? Payload and temporal factors: trip table Os and Ds by mode by vehicle.
Step 8—What service and other trucks must be considered with freight? Nonfreight vehicle OD tables.
Step 9—What facilities do freight vehicles use? Assignment of modal vehicles to networks.
  Step 9a—What facilities do freight vehicles use? Direct estimation.
Step 10—How do freight vehicles perform on the network? Estimation of benefits.

Steps 4 through 10 follow the modeling steps shown in Figure S.2. This figure also shows the alternate paths that can be followed. These are indicated in the previous list of steps as alternatives (e.g., Step 6a) to the major steps.

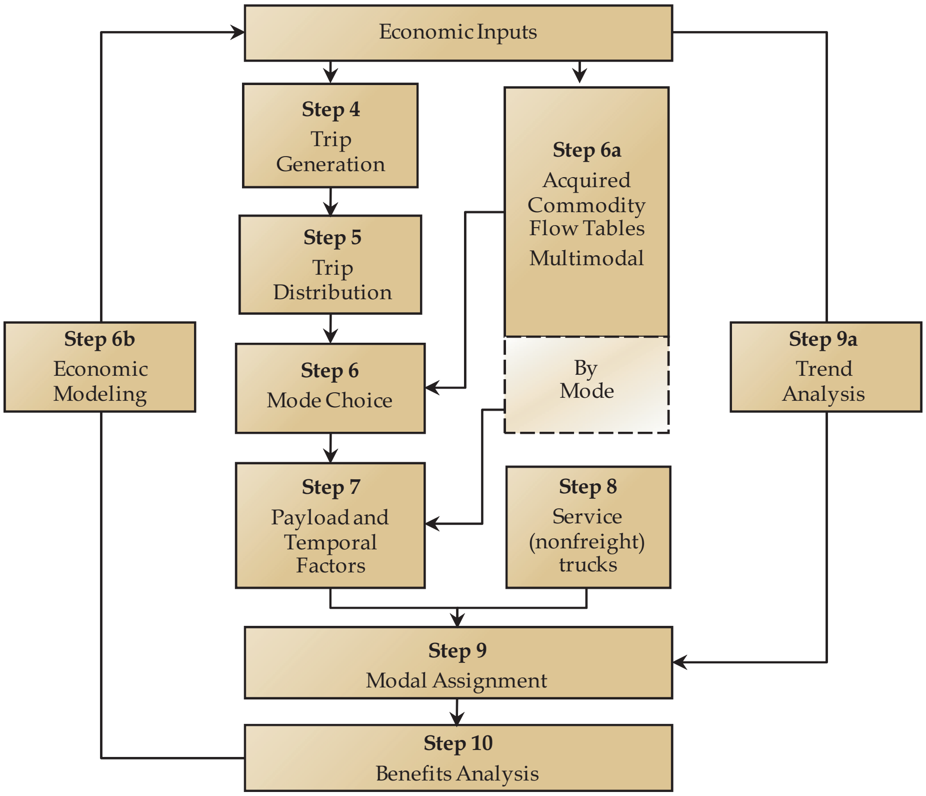


Figure S.2. Model methods.

Findings and Conclusions

Although models always can be improved, the freight planners who support public decision-makers expressed general satisfaction with available models but concern about the availability of freight data. Research concentrated on ways to use existing data to develop data inputs for the models. The research showed that existing and readily available data can be used to develop the inputs required by freight models.

CHAPTER 1

Introduction

The private sector is largely responsible for development and management of the nation's freight flow system, but public agencies at all levels face important investment and policy decisions that may affect those flows. Public sector transportation decisionmakers need to understand the large and shifting increases in traffic generated, for example, by ports, inland terminals, and mega-destination centers, in order to make informed decisions about mobility improvements and other investments.

Many states, metropolitan planning organizations (MPOs), and U.S.DOT have developed and implemented analytical tools and models to better understand the impacts of public and private freight investments and their associated impacts on economic development, environmental quality, and traffic operations. However, even with these tools, many agencies struggle to identify which freight mobility strategies will be most effective or even how to measure the success of different combinations. The goal of this project was to improve and expand the forecasting and analytical tools needed to evaluate freight mobility strategies, so that transportation decisionmakers faced with investment decisions can make more informed choices.

The objectives of this project were to

- Investigate, identify, and report on high-priority, high-payoff improvements in freight-demand models and other analysis tools;
- Conduct research on several of these improvements; and
- Develop a guidebook to assist model developers in implementing freight transportation planning, including these improvements.

The report is organized as follows:

- **Chapter 2—Current Needs and Practices** of states and MPOs in developing and applying freight models and analytical tools;
- **Chapter 3—Research to Fill Critical Gaps** lists the gaps developed from Section 2 and conducting additional research to fill three of those gaps; and
- **Chapter 4—Guidebook** outlines the steps that can be followed to prepare freight forecasts.
- **Chapter 5—Conclusions and Recommendations** provides this information from the research effort.

CHAPTER 2

Current Needs and Practices

2.1 Overview of Outreach Efforts

The approach to this study was driven by a desire to understand the needs of decisionmakers and planners and to assess the degree to which existing technical tools meet these needs. This is a departure from the more traditional method of reviewing existing models and determining the most feasible improvements. As a result, this approach relied heavily on information collected from a series of interviews conducted concurrently with freight modelers, planners, and decisionmakers from state DOTs and MPOs as shown in Figure 2.1.

These in-person and phone interviews were supported with a Web survey and a comprehensive review of freight demand forecasting literature that focused on models and analysis tools that enhance the understanding of freight demand and public-sector decisionmaking. Taken together, these outreach efforts allowed the development of an understanding of the types of tools currently used in practice, the key issues and challenges faced by practitioners, and the types of improvements to freight modeling capabilities that would be of the most interest to practitioners.

2.2 Public-Sector Freight Analysis Needs and Available Tools

Public-sector agencies have a wide range of freight analysis needs, including the following:

- Costs and benefits of freight programs and projects,
- Performance measures specific to freight movements,
- Mode shifts in response to program and policy changes,
- Time-of-day shifts in response to program and policy changes,
- Route diversion estimates in response to program and policy changes,
- Freight forecasts in response to program and policy changes,
- Existing routings of freight vehicles, and
- Facility flow information at important freight handling facilities.

As shown in Figure 2.2, public-sector freight planners, modelers, and decisionmakers place a premium on information describing existing freight routing; and also require information on freight costs and benefits and flows at individual freight facilities. To address this broad range of freight analysis needs, public agencies often require multiple freight analysis tools because a single model application is typically not appropriate to address all statewide or regional needs. As such, public agencies require a suite of models and analytical tools to apply to different problems and to address the questions asked by decisionmakers. Typical freight analysis tools, including the unique advantages and disadvantages of each, are described in the following subsections.

Time Series Models

Based on historical or observed data over a period of time, time series models provide short-, medium-, and long-term forecasts of freight demand and freight activity. Time series–based forecasts range in sophistication from simple regression modeling established on past freight activity levels to more complex multivariate autoregressive models. Examples of time series freight model development and implementation are common among public-sector agencies. Tools commonly are available as trend analysis tools in many commercial computer analysis packages, including the widely used Excel.

With high-frequency data, time series methods produce good short-term forecasts and require less time and fewer resources to develop than other modeling approaches. However, building a proper time series model requires a long series of observed data. Also, time series models assume that the underlying economic conditions on which the forecast is based remain the same throughout the duration of the time series data and continue forward through the forecast. As

Figure 2.1. Interview locations.

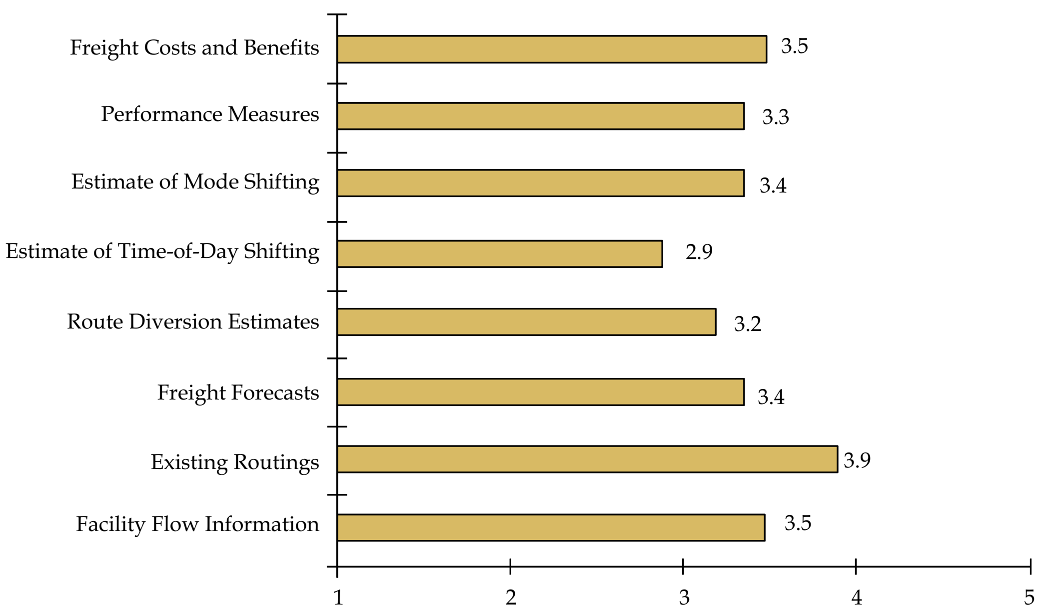


Figure 2.2. Public-sector freight analysis needs.

such, time series models are unable to account for changes to market factors, freight logistics, pricing, or policy that result in freight demand fluctuations.

Behavioral Models

Behavioral models, which include both choice- and survey-based demand models, capture how freight shippers perceive and select from the many available freight shipment choices. The models aim to depict the complex interactions between producers, shippers, carriers, and receivers that drive freight demand. Behavioral interactions, however, are usually commercially sensitive and difficult to observe. Behavioral data can be collected from shipper and carrier surveys; however, conducting behavior surveys can be prohibitively expensive.

The traditional four-step modeling approach has difficulty capturing the factors that influence shipper and carrier behavior. Although more common for forecasting passenger travel demand, examples of freight behavioral modeling remain relatively limited. Given the proprietary nature of private-sector decision making, understanding and modeling the logistics decisions that affect freight demand at a regional or statewide level remains a challenge for many public-sector agencies.

Commodity-Based and Input-Output (IO) Models

Commodity-based and IO models estimate current and forecasted freight traffic generation and distribution by linking economic activity to associated commodity flows. These models use economic data and IO tables to estimate the quantity of each commodity produced and consumed in a geographic area. The commodity flows are then converted to trucks or other freight vehicle trips using average payloads or more elaborate empty trip models. This modeling approach is well suited to representing the economic mechanisms that drive freight movements to and from manufacturers and movements into or out of a region. Similarly, elasticity in the models provides the ability to evaluate the effects of freight policy. Commodity-based and IO models, however, are not capable of capturing empty trips that factor into freight logistics decisions without the use of complementary empty trip models.

The data required to develop a commodity-based/IO model include existing and forecasted commodity flow data, traffic counts, employment data, characteristics of major freight generators, forecasts of economic activity, and technical coefficients to extrapolate existing production and trade patterns into the future. Although the data needs are extensive, generally these multimodal freight and economic activity data are readily available. Examples of commodity-based and IO model development and implementation are common among public-sector agencies. However, commodity-based and IO models do not account for many local truck moves, including trips from warehouses and distribution centers, fleet repositioning, empty return trips, and truck drayage moves, as well as service, utility, and construction trucks. Many of these missed truck trips are short trips within urban areas. Therefore, truck models based exclusively on commodity flow data tend to underestimate truck trips in the urban area. In addition, the commodity flow data generally are not available at the Traffic Analysis Zone (TAZ) level, and techniques of questionable accuracy must be used to disaggregate county-level data. Developing and implementing techniques to support analysis of finer geographic scales, empty vehicle usage, nonfreight truck trips, labor and vehicle productivity, and chaining of freight trips as vehicles or cargo may improve the functionality of existing models.

Multimodal Network Models

Multimodal network models forecast and optimize mode and route choice decisions for a specific OD combination based on various transportation cost attributes. They assign commodity flows to the mode (or combination of modes) and specific route within a network that minimizes total transport costs, taking into account the location of activities within the network. The models also are capable of estimating mode and route sensitivity to various cost factors. The link-node network representations of freight supply generated by multimodal network models are useful for determining travel times, costs, reliability, and overall level of service.

There are few examples of public-sector model implementation of multimodal network models. Although many public-sector freight models include a truck component to truck freight, few models include fully multimodal capabilities, because in many cases these models are designed to evaluate private-sector investments and operations, rather than those for the public sector.

Microsimulation and Agent-Based Models

Microsimulation models depict the individual movement of large numbers of units and their attributes, while agent-based modeling defines potential actors in freight transportation and an allowable set of actions and interactions. The models allow agencies to perform "what-if" analysis and study the behavior of a system without building it. The New York Metropolitan Transportation Council (NYMTC) uses a microsimulation approach to estimate travel patterns for their regional best practice model. Although microsimulation and agent-based model development and implementation are common among public-sector agencies, they are data intensive and expensive to build. In the absence of sufficient supporting data, modelers must make many distribution assumptions to build the models, which may or may not reflect how freight routing decisions are made by private-sector operators, shippers, and receivers, and this contributes to challenges in interpreting results.

Supply Chain and Logistics Models

Supply chain and logistics models aim to capture the upstream and downstream relationships between suppliers and customers and the decisions that drive freight demand. They actually estimate the total logistics cost of shipping, including direct transportation expense and inventory cost associated with modal lot sizes and service profiles. The models assume that customers (shippers) select the lowest-cost option, and they depend on information about logistical factors in transportation and industry. Shipments are assigned to one mode or another, while allowing for uncertainty associated with inventory risk, carrier performance, or unmeasured factors.

These models can help provide information on a number of topics that would be of interest to public-sector freight planners, particularly freight trip chaining and mode-choice decisions. However, most of these models were initially developed with the intention of helping producers (who ship goods) decide on the best choices among shipping options. Usefulness of these models for more general transportation planning is highly dependent on the actual availability of modal service options for the specific type of commodity being shipped and the shipper's specific set of customer destinations. Without that information, such models can overstate opportunities for modal diversion due to inability to sufficiently filter out modal options that are not really available.

Network Design Models

Network design models include private-sector models for locating factories, distribution centers, warehouses, and other freight-generating facilities. Freight logistics companies and freight carriers must consider the frequency, mode, routing, and scheduling of freight movement within a network to provide high-quality, low-cost, reliable service to their customers. Network design planning is very challenging given its scale, complexities, and decision interdependencies. Likewise, network design formulations are very difficult to solve, except in the simplest of scenarios.

As network design models inherently relate to private-sector operations and efficiencies, examples of public-sector model implementations or applications remain scarce. Given the proprietary nature of the data required to build and optimize a network design model, the public sector faces obstacles to applying network design techniques for their decision-making purposes.

Routing and Scheduling Models

Typically used by the private-sector freight community, routing and scheduling models optimize the routing and frequency of shipments. The objective of these models is to minimize vehicles, vehicle miles traveled, and labor; satisfy service requirements; maximize orders; and/or maximize the freight volume delivered per mile. Different types of routing and scheduling models solve problems that range in complexity as follows:

- **Traveling salesman problem**—Determines the shortest path routing through a tour of destinations, visiting each destination exactly once and returning to the starting origin.
- **Vehicle routing problem**—Allocates vehicles and assigns routings from a central location to serve a set of geographically dispersed customers while minimizing the total distance traveled.
- **Vehicle routing problem with time windows**—Schedules and allocates vehicles and assigns routings from a central location to serve a set of geographically dispersed customers with time-window requirements.
- **Pickup and delivery problem with time windows**—Determines vehicle assignments, routes, and schedules to transport loads of specific size from a location with a pickup time window to a delivery location with a specific delivery time window.

The models are customized on a case-by-case basis to reflect a company's operating environment and customer needs. Recently, dynamic routing and scheduling have grown in importance due to the availability of real-time information from GPS and wireless communication devices. Similar to the network design models described previously, there are few examples of routing and scheduling model implementation among public-sector transportation planning agencies. However, routing and scheduling information at intermodal facilities, distribution centers, ports, etc., could greatly improve the estimation of internal freight trips.

As shown in Table 2.1, most of these tools are widely used in practice and can be used to answer a number of freight-related planning and policy questions. The exceptions are supply chain/logistics, network design, and routing and scheduling models, each of which primarily serves private-sector functions.

2.3 Gaps, Issues, and Challenges

Despite the relatively wide use of several model types (time series, behavioral, commodity IO, multimodal network, and microsimulation), the models do not completely meet the

Table 2.1. A comparison of model development and implementation in the literature to public-sector applications.

Model Category	Description	Model Development	Model Implementation	Public Sector Applications
Time Series	Short-, medium-, and long-term forecasts of freight demand and freight activity	●	●	●
Behavioral	Models how companies perceive and select from the many available freight choices. Includes choice-based and survey-based demand models	◑	◑	◑
Commodity-Based and Input-Output	Estimate current and forecasted freight traffic generation and distribution by linking industrial activity through input-output models of economic activity	●	●	●
Multimodal Network	Link-node network representations of freight supply useful for determining travel times, costs, reliability, and overall level of service	●	◑	◑
Microsimulation and Agent-Based	Microsimulation models the individual movement of large numbers of units and their attributes, while agent-based modeling defines potential actors in freight transporatation and an allowable set of actions and interactions	●	●	◑
Supply Chain/ Logistics	Supply chains define the life cycle of products from raw materials to the final consumer, including production, inventory, and transportation	●	◑	○
Network Design	Private-sector models for locating factories, distribution centers, warehouses, and other freight generating facilities	●	○	○
Routing and Scheduling	Private-sector models for locating factories, distribution centers, warehouses, and other freight generating facilities	◑	○	○
Other and Emerging Topics	Hybrid models, real-time decision making	◑	◑	◑

● Widely used, state of the practice ◑ Emerging model, limited use ○ Lacking research or application

needs of public-sector freight planners, modelers, and decisionmakers. Key issues include the following:

- **Lack of a national vision for freight analysis—**Since states are conduits for freight movements and regions are impacted by policies and activities originating from outside areas, many DOTs and MPOs stress the need to establish a national vision for freight analysis. Establishment of a national vision for freight demand modeling would help coordinate and guide freight data collection, model consistency, and validation/calibration procedures across all public-sector agencies.
- **Limited ties between freight planning and economic development—**There is a need to fully integrate freight demand models with economic models to facilitate transportation strategies that maximize a state or region's economic advantage. Freight planners, modelers, and decisionmakers require quick and reliable methods to determine the economic benefits of transportation investments as well as how economic and accessibility constraints (bottlenecks and employment base) are hindering statewide and regional economic development efforts.
- **Data limitations—**Since freight models often are developed and validated with insufficient data, public-sector agencies and decisionmakers often lack confidence in model results. To improve the statistical validity of their freight models, agencies require more observed data that is generated with greater frequency and accuracy, to conduct more robust model validation. Similarly, agencies require freight data at the appropriate level of detail to support the level of sophistication at which the model is expected to perform. Many agencies that have not yet developed a freight demand

model, or are considering an upgrade to a more sophisticated model indicated that data limitations are a primary obstacle. Specific data needs include

- Seasonal trucking variations to account for crop harvest cycles (in rural areas) and consumer demand (in urban areas and around trade gateways);
- Time-of-day factors to help evaluate the impacts of policy actions designed to shift truck traffic to off-peak periods or other congestion mitigation strategies; and
- Private-sector data to better understand routing and supply chain decisions and impacts of railroads, trucking companies, ports, and shippers.

• **Limitations of existing tools—**As described in Table 2.1, existing freight demand modeling and analysis tools are often insufficient to answer freight-related questions being posed by freight planners, freight decisionmakers, and other stakeholders. Critical limitations include

- Multimodal network modeling—Agencies need the ability to model multimodal freight flows and interactions, not just light, medium, and heavy trucks. Also needed are dynamic modeling capabilities to evaluate logistics-driven, market-driven, and/or policy-driven mode shifts. Multimodal network modeling would also allow agencies to quantify and compare the burden of each freight mode on the system's infrastructure.
- Behavioral modeling—The conventional four-step travel demand models cannot accurately capture the complexities of supply chains and freight systems. They neglect the importance of tour-based and activity-based modeling. However, few public-sector agencies have developed behavioral models that capture trip chains, less than truckload movements, local truck deliveries, and their associated routings.
- Freight routing and route diversion—Existing models are deficient in their ability to assign trucks to the routes they actually use. Similarly, agencies need the ability to estimate freight diversion in response to dedicated truck lanes and tolls under different pricing and policy scenarios.
- Model adaptability and responsiveness—Freight demand models are too complex, unwieldy, and time-intensive to respond quickly to changing economic conditions as they arise, such as rising fuel costs or facility closures. The time required to develop or update a model is not aligned with the short timeline of freight market demands. There is a need for additional analytical tools that can piggyback on existing models to provide quick-response answers to time-sensitive questions. Similarly, freight models need to be capable of performing various applications and adaptable to the dynamic nature of the freight industry. However, given the complexity of many freight demand models, incorporating new tools or changes into the model is often beyond the capabilities of in-house staff. The subset of people that can actually run the model gets smaller as the model gets more sophisticated.
- Temporal variability—Particularly relevant to urban truck models, current freight demand models often lack the ability to evaluate temporal variability, such as time of day and seasonal demand. Regional travel demand models originally developed to support long-range planning did not require time-of-day sensitivities.

CHAPTER 3

Research to Fill Critical Gaps

From the gaps identified in Chapter 2, the research team identified research topics that would represent an advance in the state of freight modeling in the short term, be consistent with the topics identified throughout the outreach process, and could utilize available data sources. At the research panel's direction, the freight model research considered for this project concentrates on short-term model application improvements (rather than completely new methods). Other research efforts, such as the Strategic Highway Research Program (SHRP) 2 C20 Project on freight model improvement, will consider long-term model improvements to develop over the next 10 years or more.

From the list of research topics developed by the research team, the research panel selected the following three topics that address critical gaps in existing freight demand models:

- Chaining of freight activities,
- Temporal and seasonal impacts, and
- Modal diversion consistent with the geographies of public agencies.

The selected topics would develop transferable parameters for models that can then be applied to various settings. They also are intended to identify techniques for quickly and inexpensively developing model parameters that could be employed by others who might be developing or applying freight models to support public decision-making. Although this section focuses on the three topics selected for further research, it also includes a discussion of why the remaining topics were not recommended for advancement.

3.1 Topics Selected for Further Research

Chaining of Freight Activities

Chaining of freight activities could be addressed by use of GPS data. Trip chaining of commercial trucks, including those moving freight, requires information on the nature of truck tours, particularly the number of stops, the average impedance between stops (e.g., time), and the nature of the land use at each stop on the tour. Many truck fleet operators subscribe to GPS services provided by vendors that collect and electronically distribute the GPS information provided by trucks equipped with units they sell. Although their business model is to provide GPS information to truck fleet operators, many vendors currently store the historical GPS information, and in all cases it would be easy to store these data. It should be possible to process the historic GPS information to obtain better truck trip chaining data.

Temporal and Seasonal Impacts

The methods to collect GPS data discussed above include the ability to identify the time of day at which a truck stops and starts its trips. This information could be used to develop time-of-day allocation tables for a number of urban areas. These allocations may be borrowed for use in other urban models, or the GPS methods developed may be used to develop or update truck time-of-day allocation tables for models that consider time of day assignments. Additionally, the GPS information could be used to determine the behavior of specific types of trucks (e.g., long-haul trucks). It has been observed that long-haul trucks may make intermediate stops in urban areas to rest during congested time periods, or to wait until loading docks or port states are open to receive trucks. Documentation of this behavior and the intermediate stop locations could improve the time-of-day response of urban models.

The seasonal movement of freight could be addressed by using information on the monthly flow of trucks from state weigh in motion stations, border crossings, and FHWA's Vehicle Travel Information System (VTRIS). Although this information does not provide any information about the commodities carried by these trucks, the FHWA's Freight Analysis Framework, Version 2 (FAF2), Highway Link and

Truck Data[1] provides data on freight and nonfreight truck volumes. The assignment of disaggregation of the FAF2 origin-destination (OD) database to the network can provide estimates of truck volumes by Standard Classification of Transportation Goods two-digit (SCTG2) commodity. By identifying the link flows at the locations with seasonal truck percentages as freight, nonfreight, and/or by SCTG2 commodity, it may be possible to identify the appropriate seasonal factors that should be used for these commodities.

Modal Diversion Consistent with the Geographies of Public Agencies

Modal diversion requires data outside of the area covered by most DOT and MPO models supporting public decisions. The development of national multimodal databases of flows, behavioral characteristics, and networks may be needed to address this issue. Research needs to be undertaken into the variables that are considered in the mode choice of freight decisionmakers. Behavioral characteristics typically are determined though a preference survey. There are national freight flow databases that could be adapted as revealed-preference databases. Other national databases exist that could provide values for some of the decision variables that might be part of the modal decision. An analysis of the modal choices, as revealed in existing freight databases together with available information on explanatory variables using standard mode-choice regression software, may provide useful insights into which variables are important in modal-choice decisions for freight, as well as the degree to which these explanatory variables are considered.

3.2 Topics Not Selected for Further Research

The topics presented in Section 3.1 were the focus of additional research as documented in the remainder of this section. Topics that were not selected for additional research, but were identified as addressing critical gaps, are described in this section.

Freight Data to Support Model Specification, Calibration, and Validation

The focus of NCFRP Project 6 was intended to exclude data needs. Although the quality and availability of data was a principal issue raised by the interview respondents, there are other ongoing TRB and U.S.DOT projects and programs to address this issue, both as short-term incremental improvements and long-term improvements.

Better Methods to Consider Nonfreight Trucks

Expanding on a paradigm developed by Hunt and Stefan,[2] trucking activity in a model area can be considered to have the following four components:

1. **Interregional freight,** typically trips with at least one trip end external to the region that is being modeled. Examples include long-haul truckload, less than truckload, and private trucks.
2. **Intraregional freight truck tours,** those trucks that move individual shipments of goods locally within a model region. Examples include parcel pickups and delivery trucks distributing goods to retail, office, and commercial establishments, as well as homes.
3. **Intraregional service truck tours,** those trucks that move in individual movements to offer services locally within a model region, to support construction, service, utility, and other service operations. Examples include trucks operated by telephone and cable companies, contractors, and repair and service companies.
4. **Fleet allocations and patrols,** those trucks that are assigned to patrol or operate on fixed routes within a specific geographic area or road links within the model region, rather than to move individual shipments of goods or services. Examples include garbage trucks, newspaper or mail delivery, as well as roads and parks maintenance.

Methods exist to address all of these components singly or in combination. For example, the FHWA's *Accounting for Commercial Vehicles in Urban Transportation Models* already outlines procedures to better account for commercial truck activity, exclusive of intercity trucking, particularly Components 3 and 4 above. (It should be noted that *Accounting for Commercial Vehicles* identified many other commercial vehicle trips for business services—e.g., realtors, salesmen—that involve automobiles. Although this travel is a substantial portion of total commercial vehicle travel, it does not overlap with freight truck trips and these automobile commercial trips are not included in this proposed topic.) NCHRP 606 addresses methods to account for Component 1. The *Quick Response Freight Manuals* (1996 and 2007 editions)[3–4] address

[1] *FAF2 Highway Link and Truck Data and Documentation: 2002 and 2035,* Federal Highway Administration, Office of Freight Management and Operations, http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm.

[2] Hunt, J. D., and K. J. Stefan, "Tour-Based Microsimulation of Urban Commercial Movements," *Transportation Research Part B* 41, (2007): 981–1,013.

[3] Cambridge Systematics, Inc., Comsis Corporation, and University of Wisconsin–Milwaukee, *Quick Response Freight Manual;* Federal Highway Administration, Office of Planning and Environment, September 1996.

[4] Cambridge Systematics, Inc., *Quick Response Freight Manual II;* Federal Highway Administration, November 2007.

methods to account for Components 2 and 3. What is not available is some indication of the expected size of these truck components in model regions.

It is possible to determine the base-year existing truck activity within a region from FHWA's Highway Performance Monitoring System (HPMS). HPMS provides statistically based estimates of truck activity for the states and urban areas typically covered by models. The FAF network flow datasets, or improvements to those datasets, can be used to provide estimates of Component 1, and that portion of Component 2 covered by the FAF. FHWA's *Accounting for Commercial Vehicles in Urban Transportation Models*[5] outlines methods where vehicle registration data and/or air quality mobile source inventory data can be used to provide individual estimates for Component 4, and Components 2 and 3, respectively.

For at least some urban areas, it may be possible to use all of these methods and data simultaneously to arrive at estimates of the total HPMS reported truck VMT in each region, which should be coming from the sum of the trucking components identified. This information on the allocation of freight and nonfreight truck VMT in the areas served by models should be of value in the calibration and validation of the truck components of those models.

Better Incorporation of Labor and Equipment Productivity in Freight Models

The economic activities that produce or consume freight can be expected to become more productive, such that the relationship between economic activity and the freight required to support this activity may not match the relationships incorporated into existing models. Similarly, the carriers who transport freight also continue to increase productivity such that the relationships between the volume of freight and the number of vehicles required to move the freight, as included in existing models, would no longer be applicable.

Although it might be possible to develop this information using time series of equipment and/or labor availability together with time series data of commodity flow, such datasets are not readily available. Where times series of commodity flow databases do exist (e.g., Commodity Flow Survey [CFS], FAF, TRANSEARCH), either there have been significant changes in the methods used to collect the data, or the commodity classification scheme has changed (e.g., Standard Transportation Commodity Code [STCC] to SCTG). That same issue exists for the potential regression datasets (e.g., employment classified by the North American Industry Classification System [NAICS] versus Standard Industrial Classifications [SICs] industries). Local commodity, employment databases, and surveys fare no better.

Improved Methods for Nonhighway Freight Assignment

In addition to truck freight activity on highways, domestic freight is carried by rail, barge, and other domestic water vessels, air, pipeline, and combinations of these same modes to travel between an origin and a destination. Air travel is not constrained to specific network links. Although water is constrained to specific systems of public waterways, the options to divert from these waterways are limited and assignment by water is a trivial problem. Rail travel operates almost exclusively on privately owned tracks where the assignment serves the business needs of the railroad trains, not the freight being carried. Although improved rail routing methods would seem desirable, this topic is being pursued by other research, including research by the railroads. Additionally, rail assignments serve the multistate business interests of the railroads and those interests are not easily confined to the areas served by a state or MPO model.

Simplified Methods for Considering the Economic Impact of Freight Improvements

Although transportation projects advanced as freight projects may have significant impact on the economy, those projects also have benefits to passenger and other travel. Additionally, transportation projects intended to benefit general travel may have significant impacts on the transport of freight; those benefits to the transport of freight may have significant impacts on freight-dependent industries as well as other sectors of the economy. Given that the scope of this topic transcends freight, the subject may be pursued more appropriately in conjunction with more comprehensive methods to better account for the economic impacts of transportation projects and to properly attribute those benefits to all sectors of travel demand, including freight.

Better Consideration and Forecasting of Trip by Empty and Repositioning Freight Vehicles

Although understanding the movement of empty and repositioning freight trucks is important, it is a subtopic to developing a better understanding of the chaining of freight activities discussed previously. Thus, additional research on this topic should be deferred, unless subsequent research on truck chaining does not adequately advance the understanding of the movement of empty vehicles, including the repositioning of trucks for the next trip.

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

3.3 Truck Trip Generation, Distribution, and Chaining Information

Trip chaining of commercial trucks, including those moving freight, requires specialized data not readily available to apply these methods in common usage. Information on the nature of truck tours, particularly the number of stops, the average impedance between stops (e.g., time), and the nature of the land use at each stop on the tour can only be established though expensive surveys.

GPS data has been used in a number of passenger surveys to collect data on passenger tours to assist in developing passenger models.[6,7,8] This information has included the deployment of GPS devices in passenger vehicles, by passengers, and the processing of that GPS data to determine information concerning tours, including trip ends, the nature of the land use at trip ends, the time between trip ends or stops, and the organization of stops into tours. The use of GPS in these surveys improved the quality of the information collected, increased the response rate, eased the burden of data entry by the passengers, and added additional information that could not otherwise be collected.

Although it was necessary to deploy GPS units in these passenger studies, it is possible to collect much of the same information for truck activities without the need to deploy new GPS units. Many truck fleet operators subscribe to GPS services provided by vendors. These vendors currently collect and electronically distribute GPS information provided by trucks equipped with units they sell. Although their business model is to provide GPS information to truck fleet operators, many vendors store the historical GPS information, and in all cases it would be easy to retrieve these data. It should be possible to process the historic GPS information to obtain data to use in better defining truck trip chaining.

GPS data maintained by vendors typically will have an anonymous vehicle identifier, geographic latitude/longitude and coordinates, and time. In order to successfully process GPS information for this purpose, it will be necessary to identify stops and starts from truck GPS data, and to identify the land use at these stops and starts (e.g., in the Calgary truck chaining model, land uses are classified by five categories: low-density, residential, retail and commercial, industrial, and other high-density employment).

Most metropolitan areas maintain land use maps in the form of shapefiles. Using standard geographic information system (GIS) processing tools, it is possible to match the GPS records of stops and starts by latitude and longitude with these land use records to determine the land use of the truck trip end. Sequential stops can then be grouped using the anonymous vehicle identifier and the sequence of stops; it may be possible to determine time between stops or stops per day.

The information that could be available from providers of GPS data for truck operators is considerable, both in the number of firms involved and the geographies that are covered. In order to prepare the data to be used in this topic, it was necessary to determine which vendors of GPS services to truck operators could provide historical information with sufficient detail to determine basic information concerning trucking behavior, at a reasonable cost. In order to determine if the information collected could be adapted to a number of geographic settings, it was necessary to choose metropolitan areas with various geographic locations, representing a variety of sizes and densities.

Selection of GPS Vendors

For the purpose of this research topic, the selection of a GPS vendor had to satisfy several criteria. The GPS vendor must provide services nationally in order to have similar GPS data for the variety of metropolitan areas that would be considered. Selection of different GPS vendors for each metropolitan area was not practical because of the differing reporting formats and standards that might be used by those vendors, as well as the administrative effort in acquiring data from various sources. The GPS vendor must not only offer GPS tracking services to truck operators, it also must store and be able to provide this information from a historical database. The truck operators that are the customers of the GPS vendor must include firms that primarily offer services within the metropolitan area, in order to provide the desired information on trucking operations within metropolitan areas. The historical data provided by the GPS vendor must include, at a minimum, information on GPS events identified by vehicle, which includes the date, time, and location. Ideally, the status of the truck associated with the GPS event (e.g., moving or stopped) also will be available. Of the GPS data vendors assessed for this study, it was determined that one best met the research parameters, for the following reasons:

- Meets the basics technical requirements (time stamped latitude/longitude data tracking truck trips and stop/start activities);
- Serves mostly metropolitan area short-haul trucks, which would be those most likely to have frequent daily stops within the same metro area;
- Provides substantial archived historical data for truck movements within U.S. metropolitan regions; and
- Is available for a reasonable cost ($12,000 per month).

[6] Bricka, S., and C. R. Bhat, *A Comparative Analysis of GPS-Based and Travel Survey-Based Data*, Technical Paper, Department of Civil Engineering, University of Texas at Austin, July 2005.

[7] NuStats, *Kansas City Regional Household Travel Survey: GPS Study Final Report.* Mid-America Regional Council, Kansas City, 2004.

[8] Lawson, T., et al., *GPS Pilot Project: Phase VI Final Report,* New York Metropolitan Transportation Council, May 2009.

Selection of Metropolitan Areas

The research team selected four pilot cities for GPS data collection and processing. Although there were no technological limitations influencing the number of metropolitan areas that could be investigated, constrained project resources required a limited sampling. Metropolitan areas with active truck and/or freight studies were considered desirable because the data may have immediate application. To ensure that the data developed could be broadly applied, it was desirable to select metropolitan areas with various sizes, densities, and geographic locations. Similarly, it was desirable to select metropolitan areas that have existing data for comparison against the GPS findings. Finally, the metropolitan area must have a shapefile of land uses, with attributes of land use coded in a conventional format, which could be used in processing the GPS data. Based on these criteria, GPS data were obtained for the following metropolitan areas:

- Los Angeles, which currently is processing GPS data from October 2008 whose results could be compared to this study. This is a large metropolitan area, with low-density land use development. It has an active freight study that may be able to utilize any data developed. It has a land use shapefile available that could be used to process the data.
- Chicago, which has active freight and truck studies. This is a large metropolitan area with high-density land use development. It has a land use shapefile available that could be used to process the data.
- Phoenix, which has active freight and truck studies. It has recently completed a commercial vehicle survey that included the development of a land-use-to-land-use interchange matrix. It is a mid-sized metropolitan area with low-density land use development. It has a land use shapefile available that could be used to process the data.
- Baltimore, which has active freight and truck studies. It is a mid-sized metropolitan area with low-density land use development. It has a land use shapefile available that could be used to process the data.

Although these four cities were selected, for preliminary research, duplication of the data collection and processing techniques described below could be completed by other metropolitan areas relatively easily with minimal resources.

GPS File

The GPS vendor provides data feeds of its subscribers for a user-specified period of time (typically in one-month increments, within user-specified bounding "boxes" of latitude and longitude). These GPS products use wireless technologies to transmit GPS location and engine condition information to its central locations for transmittal to its subscribers, and provides its subscribers with a number of product lines based on how often the data is transmitted. In addition to regular transmittals of data, the subscriber may query (i.e., "ping") the GPS unit, which will generate and transmit information. All GPS and engine information received from these products is centrally stored and available for a historical period of 5 years.

The information is provided in both XML and CSV file formats. The primary difference between the file formats is in the manner in which the data are stored and accessed. Some attributes are meaningless when the status of the unit is "parked" or "stopped" (e.g., heading or speed would have no meaning for a stopped unit). Similarly, other information is meaningless when the vehicle is moving (e.g., stop duration is meaningless for a moving unit). The XML format includes only the data items appropriate for the specified status, defined as

- Stop-Not Moving/Engine On;
- Park-Not Moving/Engine Off;
- Moving-Vehicle in Motion; and
- Status-0 for moving, 1 for short stop, 2 for medium stop, 3 for long stop.

For determining information about truck stops, records with a status of "Moving" or "Status-0" need not be processed.

For this study, GPS records were acquired for the month of September 2009. Latitude and longitude boxes were defined to encompass the areas covered by the metropolitan area land use shapefiles. GPS records falling outside of this area were dropped. All remaining records were processed and sorted to provide the required information by metropolitan area (and land use). GPS records for Saturdays, Sundays, and the Labor Day holiday (September 7, 2009) were excluded in the calculation of average weekday truck information. The remaining records were processed to produce the following information:

- **Number of trucks—**Number of unique GPS IDs.
- **Number of GPS events—**Transmittals that trigger a GPS event.
- **Number of stops—**Number of GPS event records excluding moving and maintenance records. In a chain of trips by the same vehicle, a stop is both the destination of one trip and the origin of the next trip.
- **Number of stops per truck per day—**Number of stops divided by the number of trucks, adjusted by the operating days of the trucks.
- **Airline distance to next stop—**From records in time sequence sorted by ID and by date. Records include fields indicating event time. Travel time is the difference between event times for a given stop and the next stop in sequence for that same GPS unit (truck). For information by land use stop, the next stop need not be of the same land use.
- **Airline distance to next stop—**From records in time sequence sorted by ID and by date. Records include fields

indicating event time. Airline distance is the difference, expressed in miles as the great circle distance between the latitude and longitude of a given stop and the latitude and longitude of the next stop in the sequence for that vehicle on that day for the GPS unit (truck). For information by land use stop, the next stop need not be of the same land use.

- **Mileage to next stop**—From records in time sequence sorted by ID and by date. Records include fields indicating cumulative vehicle mileage (odometer reading). Highway distance between stops is the difference between cumulative mileage for a given stop and the next stop in sequence for that same GPS unit (truck). For information by land use stop, the next stop need not be of the same land use.

For the four pilot cities, processed data for GPS events and stops are included in Table 3.1, and for distances in Table 3.2 (number of event and number of stops). Although not presented, these data could be processed to determine additional

Table 3.1. GPS-derived truck characteristics.

Metro Area	Land Use	Number of Trucks	Number of GPS Events	Number of Origins	Percent of Origins by Land Use	Number of Origins per Truck per day
Los Angeles	**Total**	**6,901**	**3,926,611**	**853,049**	**100%**	**9.05**
	Industrial	5,702	640,084	202,187	24%	3.32
	Low density	4,631	230,703	44,876	5%	2.10
	Other high-density employment	5,830	1,420,470	164,858	19%	3.73
	Residential	4,919	773,228	176,728	21%	3.56
	Retail and commercial	6,083	862,126	264,400	31%	3.92
Chicago	**Total**	**3,290**	**1,955,033**	**432,311**	**100%**	**10.59**
	Industrial	2,730	357,130	116,749	27%	4.38
	Low density	2,441	241,271	39,584	9%	2.28
	Other high-density employment	2,650	554,915	77,209	18%	4.14
	Residential	2,298	348,463	76,076	18%	3.29
	Retail and commercial	2,888	453,254	122,693	28%	3.97
Baltimore	**Total**	**2,797**	**1,044,132**	**258,578**	**100%**	**8.61**
	Industrial	1,894	186,544	52,747	20%	3.24
	Low density	2,058	273,476	36,396	14%	2.53
	Other high-density employment	1,310	59,669	18,996	7%	2.75
	Residential	1,917	287,941	78,102	30%	3.84
	Retail and commercial	2,343	236,502	78,937	28%	4.25
Phoenix	**Total**	**2,851**	**1,491,659**	**436,758**	**100%**	**10.80**
	Industrial	2,446	179,345	54,718	13%	0.90
	Low density	2,554	409,615	92,673	21%	4.33
	Other high-density employment	2,163	146,677	43,062	10%	0.97
	Residential	2,258	418,321	135,281	31%	2.72
	Retail and commercial	2,693	337,701	111,024	25%	3.49

Table 3.2. GPS-derived average trip characteristics.

Metro Area	Land Use	Travel Time to Next Stop (Minutes)	Airline Distance to Next Stop (Miles)	Mileage to Next Stop (Miles)	Circuity Ratio
Los Angeles	**Total**	**43.61**	**7.44**	**11.27**	**1.51**
	Industrial	54.59	8.71	13.19	1.51
	Low density	43.36	8.26	12.62	1.53
	Other high-density employment	41.11	8.56	12.75	1.49
	Residential	37.96	4.88	7.47	1.53
	Retail and commercial	41.27	7.58	11.48	1.51
Chicago	**Total**	**40.90**	**5.73**	**10.82**	**1.89**
	Industrial	44.81	5.97	13.37	1.88
	Low density	43.28	7.40	13.92	2.06
	Other high-density employment	36.77	5.38	11.11	1.52
	Residential	43.07	4.73	7.18	1.68
	Retail and commercial	37.80	5.85	9.86	2.24
Baltimore	**Total**	**37.92**	**4.64**	**9.53**	**2.05**
	Industrial	44.16	4.97	10.27	2.07
	Low density	37.84	5.13	9.22	1.80
	Other high-density employment	36.43	3.87	6.57	1.70
	Residential	37.43	4.14	11.03	2.67
	Retail and commercial	34.73	4.93	8.32	1.69
Phoenix	**Total**	**40.61**	**4.72**	**7.73**	**1.64**
	Industrial	54.46	6.09	10.95	1.80
	Low density	40.08	5.26	8.45	1.61
	Other high-density employment	44.80	4.66	7.01	1.50
	Residential	34.14	3.24	4.99	1.54
	Retail and commercial	40.10	5.30	8.92	1.68

information, such as median, standard deviation, and distribution around the median. Similarly, in addition to calculating information for average stops, the same information can be calculated by stop sequence (1st, 2nd, 3rd, etc.). The ability to develop this information may assist in developing chaining and/or distribution models.

As can be seen in Table 3.1, the GPS data provide a tremendous number of records on events. The number of records processed ranged from more than 1 million records in Baltimore to more than 3.9 million in Los Angeles. A large number of these records were GPS events in which the vehicle was moving. For this research, only records in which the vehicle was stopped are of interest. The number of records that are stop events, where a trip originates, ranges from more than 258,000 in Baltimore to more than 853,000 in Los Angeles. The number of origins per truck per day of operation ranged from a low of 8.6 origins per day in Baltimore to a high of 10.8 origins per day in Phoenix. The differences could indicate different levels of truck activities in that metropolitan area, but may indicate that the subscribers of GPS services in these metropolis areas represent a different mix of fleets with different truck activity.

Although the number of events by land use do add to the metropolitan totals, the truck rates by land use are not additive. This is due to the fact that some truck trips may begin in one land use type and end in another land use type. The land use activity reported by the GPS data varies by metropolitan area. Stops by truck in industrial land uses are 24 percent of the total in Los Angeles, 27 percent in Chicago, 20 percent in Baltimore, and 13 percent in Phoenix. Stops by trucks in retail and commercial land uses are 31 percent of the total in Los Angeles, 28 percent in Chicago, 28 percent in Baltimore, and 25 percent in Phoenix. Stops by trucks in residential land uses are 21 percent of the total in Los Angeles, 18 percent in Chicago, 30 percent in Baltimore, and 31 percent in Phoenix. This could represent different patterns of truck usage in these areas, but more likely reflects the bias of different fleets of trucks that make up the GPS vendor's customer base in these metropolitan areas.

Land Use Interchange Matrix

Trip chaining recognizes that the probability of making a truck trip in a tour depends both on the type of activity the truck is serving at its current stop, as well as the type of activity at the next stop. For example, a truck that is currently stopped at a manufacturing facility might be expected to make its next stop at another manufacturing facility. This information could be used to weight the attractiveness of truck trip distribution for individual trips, and to organize these trips into chains (tours). The data on the probability of making a truck trip from one activity, as determined by the land use in which the GPS stop event was located, to the activity serving the next stop for the same vehicle was determined by examining and processing the GPS records. The results of the interchanges of individual truck trips, based on the land use activity at the originating stop and the terminating stop, are shown in Table 3.3.

The percentage of truck trips by the land use in interchange at the origin and the destination of trips in Table 3.3 total to 100 percent within each metropolitan area. Even on this basis, the tables show similar patterns of interchanges. If the cells are weighted based on the total trips to or from that land use pattern, the data appear even more consistent. In each case, as would be expected, the activity within a land use (e.g., trips with a manufacturing land use as the origin and a manufacturing land use as the destination) is the highest value

Table 3.3. GPS-derived land use interchange matrix.

Los Angeles		Destination				
		Industrial	Other High-Density Employment	Retail and Commercial	Residential	Low Density
Origin	Industrial	**14.80%**	**2.20%**	**4.00%**	**1.70%**	**0.50%**
		64.00%	*9.50%*	*17.20%*	*7.20%*	*2.20%*
		63.30%	12.40%	13.00%	7.10%	10.10%
	Other High-Density Employment	**2.40%**	**10.80%**	**2.90%**	**1.30%**	**0.50%**
		13.20%	*60.60%*	*16.20%*	*7.10%*	*2.90%*
		10.10%	61.30%	5.50%	5.50%	10.20%
	Retail and Commercial	**4.10%**	**1.00%**	**18.40%**	**5.10%**	**1.00%**
		13.10%	*3.00%*	*58.40%*	*16.20%*	*3.00%*
		17.60%	19.00%	60.20%	21.80%	19.00%
	Residential	**1.50%**	**1.20%**	**4.40%**	**14.50%**	**0.70%**
		6.90%	*5.20%*	*19.60%*	*65.10%*	*3.30%*
		6.60%	6.60%	14.30%	62.20%	14.80%
	Low-Density	***0.60%***	***0.50%***	***0.90%***	***0.80%***	***2.30%***
		11.30%	10.20%	17.70%	15.60%	45.20%
		2.50%	2.90%	2.90%	3.40%	45.90%
Chicago		**Destination**				
		Industrial	Other High-Density Employment	Retail and Commercial	Residential	Low Density
Origin	Industrial	**15.30%**	**2.10%**	**3.50%**	**1.50%**	**1.20%**
		64.80%	*8.90%*	*15.00%*	*6.40%*	*4.90%*
		64.30%	13.60%	12.60%	6.30%	13.70%
	Other High-Density Employment	**2.20%**	**9.10%**	**2.40%**	**1.10%**	**0.90%**
		13.90%	*57.70%*	*15.40%*	*7.20%*	*5.90%*
		9.20%	59.00%	4.70%	4.70%	10.90%
	Retail and Commercial	**3.70%**	**2.40%**	**15.60%**	**5.40%**	**1.70%**
		12.80%	*8.40%*	*54.10%*	*18.70%*	*5.90%*
		15.60%	15.70%	55.20%	22.40%	20.10%
	Residential	**1.50%**	**1.00%**	**4.90%**	**14.70%**	**1.20%**
		6.90%	*4.40%*	*21.00%*	*63.50%*	*5.30%*
		6.60%	6.60%	17.20%	61.00%	14.50%
	Low-Density	***1.30%***	***0.80%***	***1.80%***	***1.30%***	***3.50%***
		14.80%	9.30%	20.60%	15.50%	39.80%
		5.40%	5.30%	6.40%	5.60%	40.80%

Table 3.3. (Continued).

Baltimore		Destination				
		Industrial	Other High-Density Employment	Retail and Commercial	Residential	Low Density
Origin	Industrial	**11.90%**	**0.80%**	**3.20%**	**2.30%**	**1.60%**
		60.40%	*3.80%*	*16.10%*	*11.40%*	*8.20%*
		60.60%	11.00%	11.90%	6.80%	12.30%
	Other High-Density Employment	**0.80%**	**2.90%**	**1.40%**	**1.20%**	**0.60%**
		10.80%	*42.10%*	*20.30%*	*17.70%*	*9.00%*
		3.80%	42.70%	3.70%	3.70%	4.80%
	Retail and Commercial	**3.20%**	**1.40%**	**14.30%**	**6.50%**	**2.60%**
		11.30%	*5.10%*	*51.00%*	*23.20%*	*9.30%*
		16.10%	20.80%	53.00%	19.50%	19.80%
	Residential	**1.50%**	**1.10%**	**5.60%**	**20.50%**	**2.70%**
		6.90%	*3.50%*	*17.50%*	*64.20%*	*8.40%*
		6.60%	16.30%	20.70%	61.40%	20.30%
	Low Density	***1.80%***	***0.60%***	***2.50%***	***2.90%***	***5.70%***
		13.10%	4.70%	18.50%	21.60%	42.10%
		9.00%	9.20%	9.20%	8.70%	42.80%
Phoenix		**Destination**				
		Industrial	Other High-Density Employment	Retail and Commercial	Residential	Low Density
Origin	Industrial	**6.30%**	**0.60%**	**2.70%**	**1.10%**	**1.40%**
		52.20%	*5.30%*	*22.00%*	*9.40%*	*11.10%*
		52.60%	6.60%	10.80%	3.50%	6.60%
	Other High-Density Employment	**0.60%**	**4.00%**	**2.00%**	**1.70%**	**1.10%**
		6.70%	*42.50%*	*21.50%*	*17.60%*	*11.60%*
		5.20%	41.50%	5.10%	5.10%	5.40%
	Retail and Commercial	**2.50%**	**2.10%**	**12.40%**	**5.40%**	**2.90%**
		10.10%	*8.20%*	*48.80%*	*21.40%*	*11.50%*
		21.10%	21.40%	49.60%	16.50%	14.20%
	Residential	**1.50%**	**1.80%**	**5.10%**	**21.20%**	**3.20%**
		6.90%	*5.50%*	*15.60%*	*65.50%*	*10.00%*
		6.60%	18.40%	20.30%	64.50%	15.90%
	Low Density	***1.40%***	***1.20%***	***2.80%***	***3.50%***	***11.80%***
		6.90%	5.70%	13.40%	16.70%	57.20%
		11.90%	12.10%	11.20%	10.50%	57.90%

Note: For each cell in the table: the first value, shown in bold, is the percent of the total table, the second value, shown in italic, is the percent of the origin, and the third value, shown in regular type, is the percent of the destination.

within origins and destinations, and in all but a few cases (low-density interchanges in Los Angeles, Chicago, and Baltimore, and other high-density employment in Baltimore and Phoenix) it is the majority of trips to or from that land use. Even when those intra land use exchanges are not the majority of truck trips, they are still the highest percentage.

Trip Characteristics

As discussed previously, trip chaining recognizes that the probability of making a truck trip in a tour depends both on the type of activity the truck is serving at its current stop and the type of activity at the next stop. It also depends on the characteristics of trips between these stops. In addition to being able to identify the land use at the destination for trips from a given land use origin, the GPS information can be used to estimate the travel time and distances between stops in the chain. The averages of these times and distances in total also can be used to develop friction factors for truck trip distribution models. This same information by land use can be used to develop friction factors between specific types of land uses that might be used in trip chaining. The distance for a trip was calculated both as the airline distance between the latitudes and longitudes reported for the GPS records, as well as the difference in odometer readings reported by these GPS records. It is worth noting that the GPS odometer reading may be an actual odometer reading read directly from the truck's equipment. It may also be a computed odometer reading based on the continuous GPS readings, in addition to the recorded and reported readings. The truck-generated odometer reading was used in this research to compute truck trip characteristics. This is because the GPS odometer reading will be incorrect when the device loses a satellite signal lock (e.g., if travelling in a tunnel or due to other sky blockages). The difference between the average airline distance and the actual highway mileage shown is an indication of the amount of circuity of the trip on the highway network.

The travel time was computed as the time difference between stop event times, adjusted to account for the dwell time at a stop. In order to calculate the dwell time at a stop, the GPS data were examined to identify the first moving GPS event record after a stop. The GPS vendor recorded this event when the vehicle speed after a stop reached 5 mph. This was considered to be a reasonable approximation of when the outbound trip began. A flaw was discovered when it was determined that the recorded stop events could include both business stops and stops captured due to congested traffic. For the purposes of this research, only business stops were of interest. Despite efforts to apply filters to exclude traffic stops, no consistently successful filter was identified. Based on this feedback, the GPS vendor is intending to change the recording logic to distinguish between stops with ignition on (a stop in traffic) and a stop with the ignition off (an activity stop). This may be a better way to address this issue in the future.

The processed data for the four selected metropolitan areas are included in Table 3.2. Although not presented, these data could be processed to determine additional information (e.g., median, standard deviation, and distribution around the median). Similarly, in addition to calculating average times and distances between stops, the same information can be calculated by stop sequence (1st, 2nd, 3rd, etc.). The ability to develop this information may assist in developing chaining and/or distribution models.

This research shows that subscription GPS data from trucks may be an inexpensive way to determine a variety of characteristics that could be used in truck trip distribution and chaining. The data developed appear reasonably consistent and credible. Before these data—or other data that would be developed in a similar manner—could be fully utilized, questions regarding data expansion need to be addressed. GPS subscription data are made anonymous before release in order to protect the identity of trucking clients. In order to develop meaningful disaggregations or expansions to types of trucks, more detailed information should be developed. Based on this research project, the GPS vendor is investigating methods to store information (e.g., the first eight characters of a Vehicle Identification Number [VIN], which could provide sufficient information to develop disaggregations and survey expansion factors while preserving anonymity).

3.4 Consideration of Temporal and Seasonal Impacts

Freight flows are traditionally expressed as tons per year. This is true when freight flows are reported as multimodal flows (in CFS or FAF), as modal flows (e.g., in the STB Waybill for railroads), or facility flows (as in the U.S. Army Corp of Engineers' Waterborne Commerce Statistics for ports). Conversely, freight flows, particularly vehicle flows, are typically expressed in vehicles per day for capacity expansion and design decisions, and as vehicles per hour to support operational decisions. In order to use existing freight and truck modeling processes to support infrastructure decisions, it would be useful to develop factors that can be used to convert annual freight flows to daily and hourly flows.

Databases of truck vehicle movements are for specific geographic locations on highway networks. These databases of truck classification counts can not distinguish trucks by body type or by the contents or type of freight being carried. The annual modal and multimodal commodity freight flows reported by trucks are for origins and destinations of the freight flows, not for the highway locations along the routes between origins and destinations that would correspond to the truck counts.

To address this difference, the research team first identified methods to assign commodity truck OD flows to the highway network. This would allow the identification of freight flows by commodity at highway locations corresponding to the truck counts. These truck counts could be used to develop monthly and hourly factors. These factors could then be applied to commodity flows at each specific location.

The flows by commodity will vary on the highway network, and the monthly and hourly factors from counts will vary by location. However, if the commodity flow is principally of a specific commodity, the variation in truck counts should also reflect variation for this commodity. For example, if the commodity truck flows at a location hypothetically consisted of only a single commodity, then the monthly and hourly vehicle counts at this location could be expected to represent the monthly and hourly factors for that commodity. Where no single commodity dominates, it is proposed that the truck flow pattern at any single location will reflect the seasonal and temporal flow pattern of the underlying commodities. Although this method cannot be expected to develop factors that would apply to specific locations, the aggregation of the resulting pattern across all locations and commodities is expected to reflect an average national distribution of commodity freight flows by month and by hour.

For this research topic, the first step will be to develop a method to assign the truck commodity flows to the highway network. The second step will be to develop monthly and hourly factors from national databases of truck counts. The third step will be to apply those factors to the commodity flows on the network corresponding to the count locations. The fourth step will be to aggregate those monthly and hourly flows and develop average national adjustment factors.

Development of a Commodity Assignment

The 1998 version of the Freight Analysis Framework (FAF1) produced maps of truck flows on the FAF1 highway network and made available (via download) highway network files of daily freight truck volumes on the highway links, in two widely used platforms, ESRI and TransCAD. These flows were produced by converting the county-to-county tonnage flows by truck to daily truck flows through the use of annual-to-daily factors as well as tons-to-truck-payload factors. Although these data could have been used to produce highway flows by commodity, the proprietary nature of the FAF1 data prevented the disclosure of highway link flows with this information. It also prevented the disclosure of the origin/destination/commodity (O/D/C) table at a county-to-county level, which could have been used to assign the truck flows to the highway network. Only the reporting of state-to-state flows was publicly available.

The FAF2 flow database, which is the 2002 update to the FAF1 flow database, can be considered as a basic O/D/C table for 114 very aggregate zones, called FAF2 regional zones. Those FAF2 zones consist of the state portion of the largest metropolitan areas, and the remainder of states or whole states outside of these metropolitan zones. FAF2 separately developed a highway network, which included updated information and additional detail beyond the FAF1 highway network. However, the regional zone structure of the OD table by commodity is not consistent with the assignment scripts for the FAF1 or the detail of the FAF2 highway network. In order to be compatible with the assignment scripts developed for the FAF1, the O/D/C table must be disaggregated to smaller geographic zones (e.g., counties, as used in the FAF1). The FAF2 documentation[9] describes a procedure for disaggregating the FAF2 regional zones to counties and other freight activity centers. That procedure is based on the share of the number of establishments in the activity center as a ratio of the number of establishments in the zone and the share of the HPMS truck VMT in the activity center as a ratio of the HPMS truck VMT in the zone.

There is no reason to think that truck trip ends in an activity center should be related to truck VMT in that activity center. For example, a major truck route with considerable truck VMT passing through an otherwise empty activity center (e.g., county) does not indicate that there should be trip ends in that activity center. Similarly, a measure of the level of intensity of the establishments within an activity center (e.g., employment), not the number of establishments should be used to disaggregate freight flows.

For FHWA, Cambridge Systematics developed a procedure that disaggregates FAF2 regional flows to county flows using the employment data for the zones that produce and consume freight. This procedure relies on county business patterns' employment, for each county, in the industries that produce and consume freight. The level of use by each industry for each SCTG2 commodity in the FAF2 was established by regression. Additionally, flows through ports, airports, and border crossings were disaggregated based on the county in which the facility was located and the share of reported activity at that facility from other modal databases. This procedure is documented in an unpublished FHWA report.[10]

These disaggregation methods were used to convert the 144-zone by 144-zone FAF2 flows (where the regional zones beyond 114 represent ports, border crossings, and international zones) into flows among the 3,140 counties in the United States. The FAF2 database is available for download from the FHWA website as a Microsoft Access database. This database was converted to a set of TransCAD matrices, one for each SCTG2 commodity.

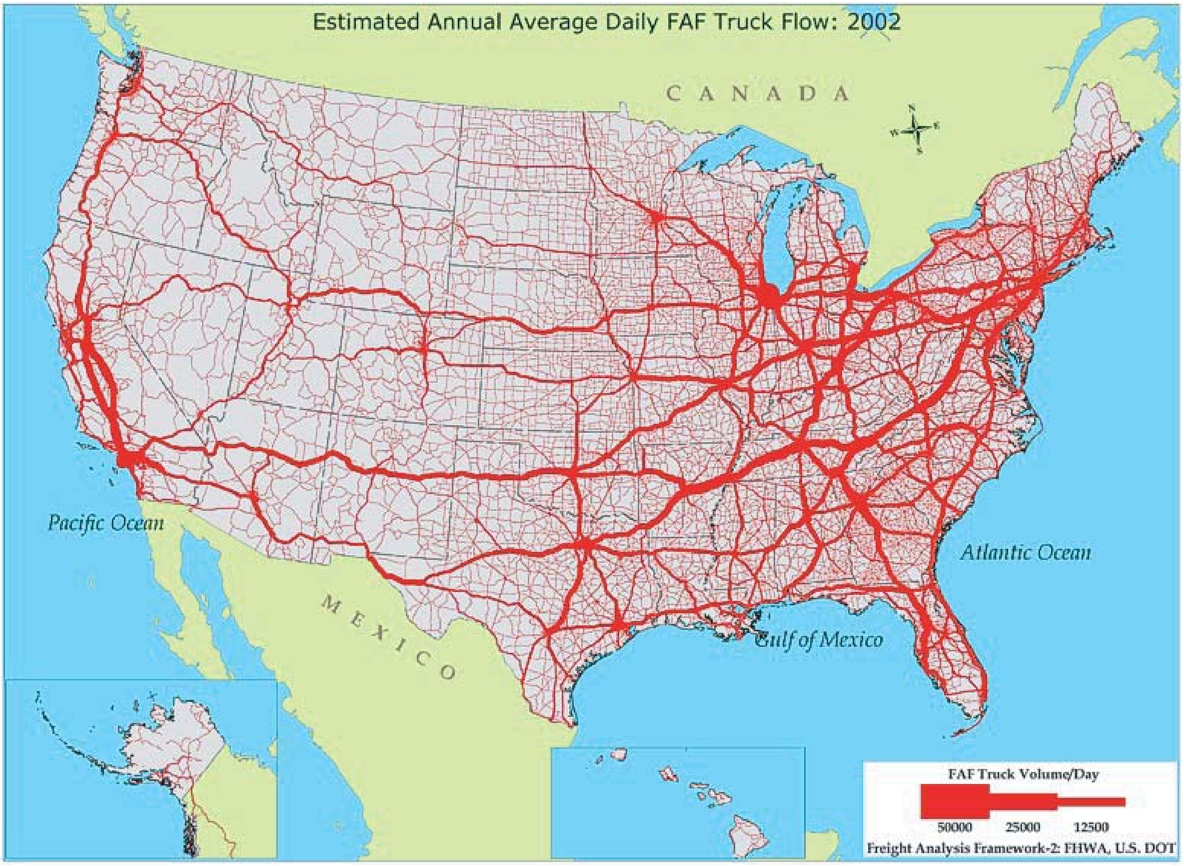
The FAF2 technical documentation also describes a procedure for assigning truck flows to the FAF2 highway network.[11] That procedure uses the stochastic user equilibrium (SUE) assignment routine in TransCAD to assign the freight flow tables. This assignment procedure uses the information available in the FAF2 network (such as capacity, total vehicle volumes, and free-flow speed) to calculate a congested time on each link. That congested time is used as the basic link impedance. That basic impedance is modified by additional information for each link, such as the number of lanes, the location of the link in urban areas, truck restrictions, truck route designations, tolls, and any interstate designation of the link. The SUE assignment is based on that modified impedance. The results of the assignment using the Battelle FAF2 disaggregated database and this procedure is shown in Figure 3.1.

For this research topic, TransCAD scripts were developed to implement the documented assignment procedure and were used to assign the county-to-county flows for each of the 42 SCTG2 commodities disaggregated from the FAF2 database. The resulting assignment of total truck tonnage is shown in Figure 3.2. The flow pattern appears similar to that of Figure 3.1 where most flows are concentrated on major interstate highways and the trip ends are concentrated in the counties

[9] Battelle Memorial Institute, "Chapter 4: FAF2 Truck O-D Data Disaggregation," in *FAF2 Freight Traffic Analysis,* FHWA, June 27, 2007, http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c4_data.htm.

[10] Cambridge Systematics, Inc., *Development of a Computerized Method to Subdivide the FAF2 Regional Commodity OD Data to County-Level OD Data,* prepared for FHWA, January 2009, unpublished.

[11] Battelle Memorial Institute, "Chapter 5: Freight Truck Assignment and Calibration," in *FAF2 Freight Traffic Analysis,* Federal Highway Administration, June 27, 2007.



Source: FAF2 Freight Traffic Analysis, Figure 3.3.

Figure 3.1. Base-year 2002 FAF2 truck flow on FAF2 highway network.

with large populations or production and/or consuming industries.

This assignment procedure provides link volumes for each of the 42 SCTG2 commodity flows that are not publicly available for the FAF2 network. Although the assignment routine can produce flows for each of the 42 disaggregated SCTG2 commodities, there are known errors in the creation of flows for certain import and export flows. For example, in translating from the Performance Monitoring System (PMS) commodity classifications used in waterborne commerce to the SCTG2 commodity classification system used in FAF2, all manufactured goods were reported to move in SCTG 34, machinery. As shown in Figure 3.3, this results in higher than expected flows to and from ports such as Savannah, Georgia, and Charleston, South Carolina.

This error is more pronounced at the SCTG2 level of detail and is less of an issue at higher levels of commodity aggregation. Additionally, the level of detail for 42 SCTG commodities has additional processing and reporting issues. Rather than processing the flows at the SCTG2 level, the flows were grouped to the nine classes of commodities used in the 2002 CFS. For these CFS commodity groups, the ton-miles of flow were calculated from the assigned link volumes and the distances of those links. The result of this calculation is shown in Table 3.4. As shown, the total ton-miles calculated for trucks are approximately twice the reported value in the CFS. This is to be expected since the CFS has several major commodity gaps, referred to by the FAF2 as out-of-scope commodities. In addition, the CFS undercounts some categories of trade and movements of freight (e.g., in-transit movements, petroleum products, and exports). The FAF2 includes these additional flows.

This summary of ton-miles indicates that the flows on the FAF2 network are reasonable and can be used in processing the later steps.

Development of Monthly and Hourly Truck Factors

FHWA maintains the VTRIS database of traffic counts taken at stations by automatic traffic recorders (ATRs), vehicle classification counters, weight-in-motion equipment, and weight enforcement stations as submitted by state DOTs. The VTRIS database includes the station description, vehicle classification, and the time of the counts in a consistent format for all 50 states. Although this does not provide any information

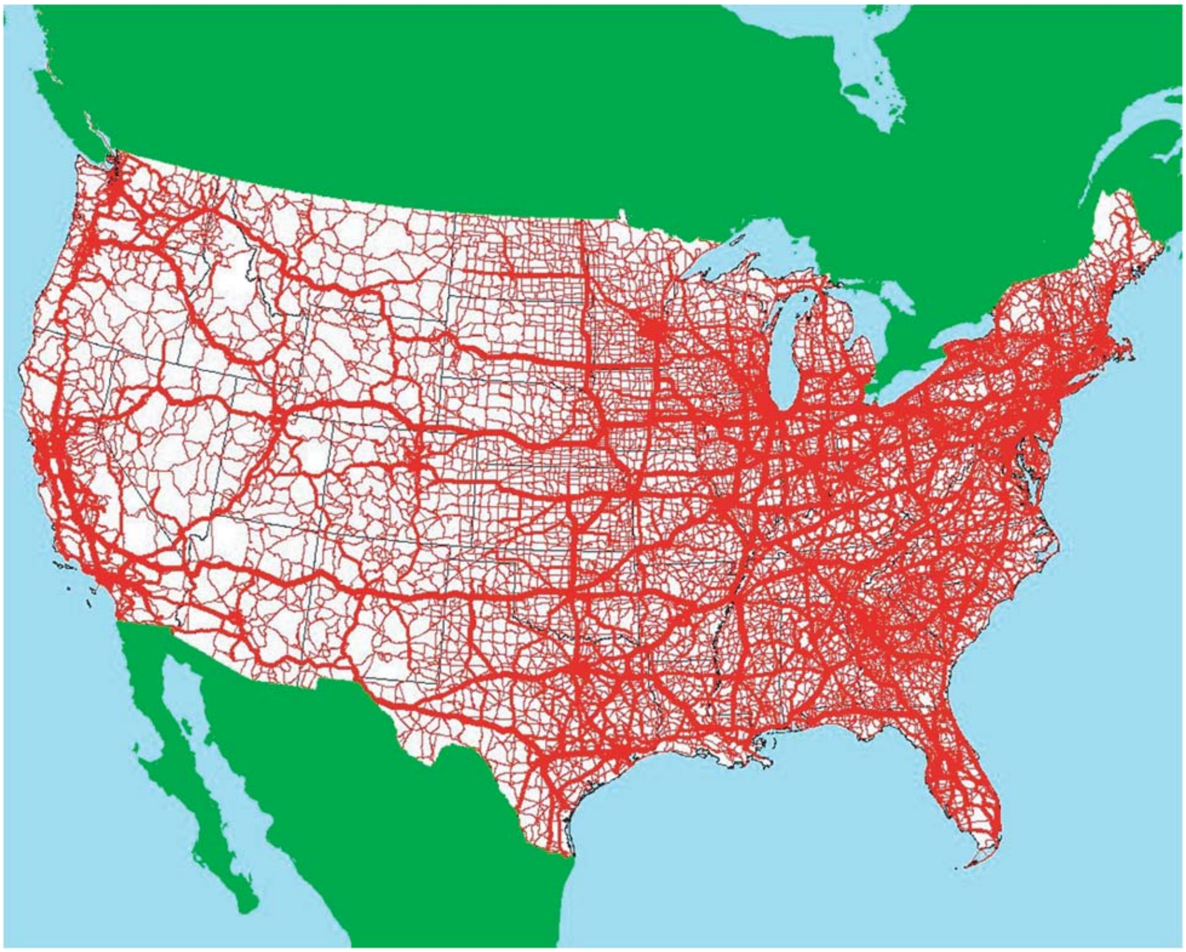


Figure 3.2. Disaggregated FAF2 truck ton flows (all commodities).

about the commodities carried by these trucks, it is possible to develop hourly and monthly factors from the stations in VTRIS. Weigh-in-motion and weight information stations do not provide the continuous readings that would be required to develop monthly and hourly factors. The ATR counts are of total vehicles and do not differentiate between trucks and other vehicles, including automobiles. The vehicle classification counts do provide the ability to distinguish trucks from other vehicles and include locations that are counted continuously. The information in VTRIS for classification counts is recorded by hour and by date. The complete VTRIS database for 2007 was obtained from FHWA's Office of Highway Policy Information. From that VTRIS database, the tables of vehicle classification counts were selected.

VTRIS contains records for 13,862 classification stations for the United States. However, in order to develop hourly allocation factors, a station needs to be operated without hourly gaps for weekdays. There were only 798 stations without gaps, and these could be used to develop hourly factors. Only stations that are on the FAF2 network links can be applied to the commodity flows and multiple stations on the same FAF2 link have to be combined before they can be used. As a result, hourly factors could be developed for 623 links on the FAF highway network. The location of these stations is shown in Figure 3.4.

To develop monthly allocation factors, a station needs to be operated without daily gaps for the year. There were only 200 stations without gaps that could be used to develop monthly factors. Only stations that match the FAF2 network links can be applied to the commodity flows and multiple stations on the same FAF2 link have to be combined before they can be used. Monthly factors can be developed for 177 links on the FAF2 highway network. The location of these stations is shown in Figure 3.5.

For each station, factors were developed for combination trucks—Vehicle Classes 8 through 13—according to FHWA's Scheme F classification. These vehicles are those that would most likely carry freight.

Apply Factors to the Commodity Flows on the Network

For each of the 623 links that have complete hourly factors developed from counts, those factors were applied to the

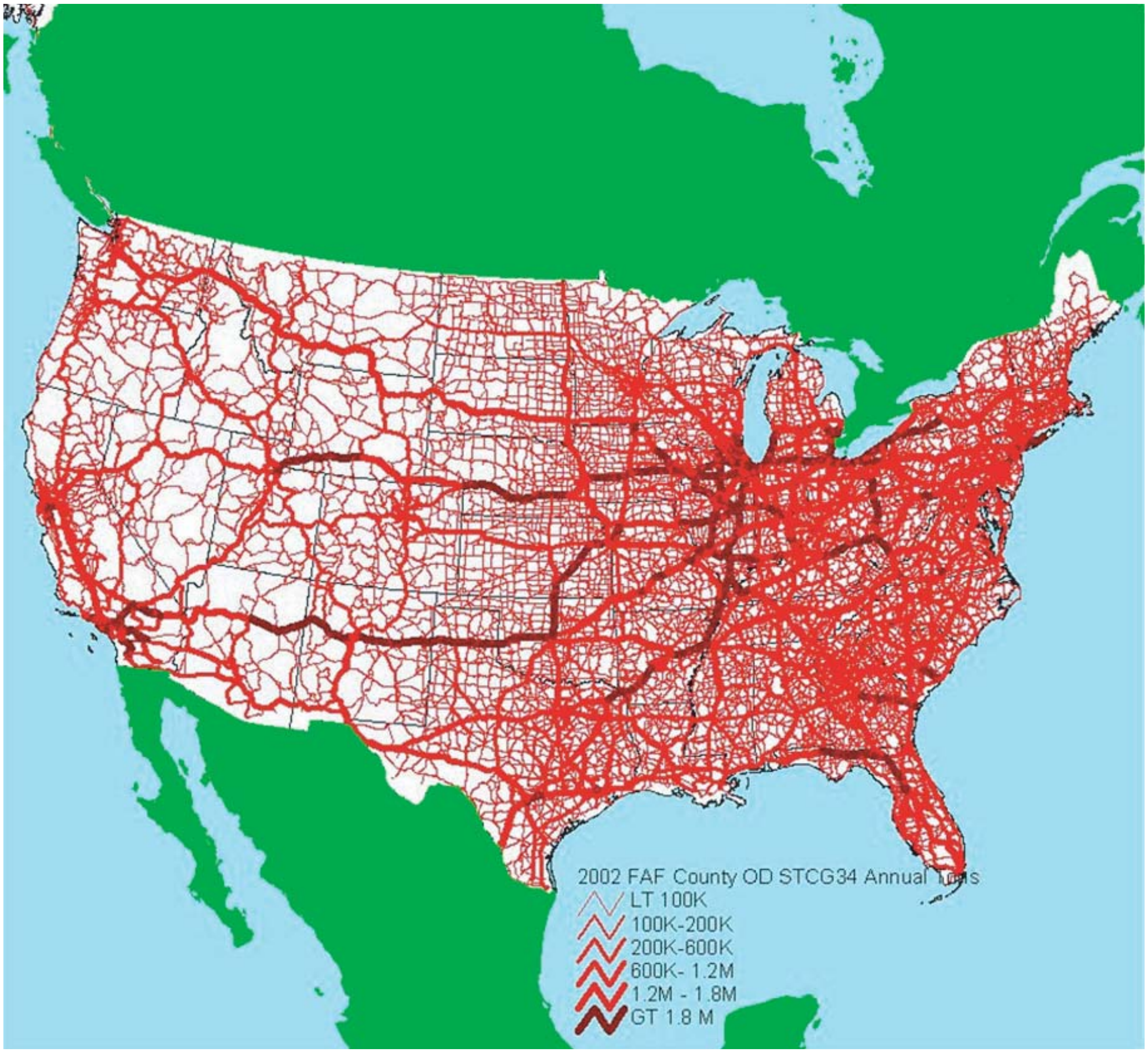


Figure 3.3. Disaggregated FAF2 truck ton flows (SCTG 34, machinery).

Table 3.4. Annual ton-miles traveled by each CFS commodity group.

CFS Commodity Group	SCTG Code	Description	Annual Ton-Miles (Millions)
CFS1	01 to 05	Agriculture Products and Fish	398,154
CFS2	06 to 09	Grains, Alcohol, and Tobacco Products	210,034
CFS3	10 to 14	Stones, Nonmetallic Minerals, and Metallic Ores	382,451
CFS4	15 to 19	Coal and Petroleum Products	222,452
CFS5	20 to 24	Pharmaceutical and Chemical Products	268,038
CFS6	25 to 30	Logs, Wood Products, and Textile and Leather	330,683
CFS7	31 to 34	Base Metal and Machinery	437,008
CFS8	35 to 38	Electronic, Motorized Vehicles, and Precision Instruments	87,758
CFS9	39 to 43	Furniture, Mixed Freight, and Miscellaneous Manufactured Products	245,299
Total			**2,581,876**
		Truck Ton-Miles—2002 CFS Table 2a	1,261,813

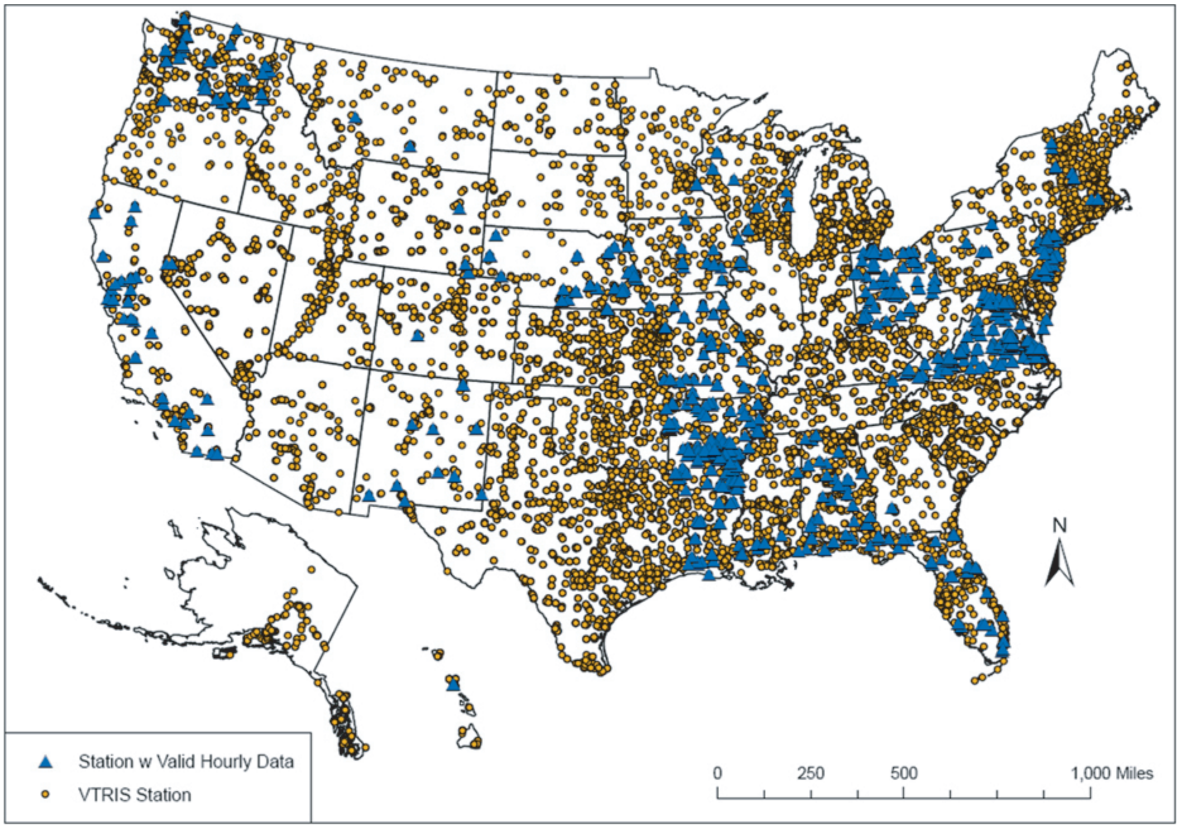


Figure 3.4. VTRIS stations with valid hourly factors.

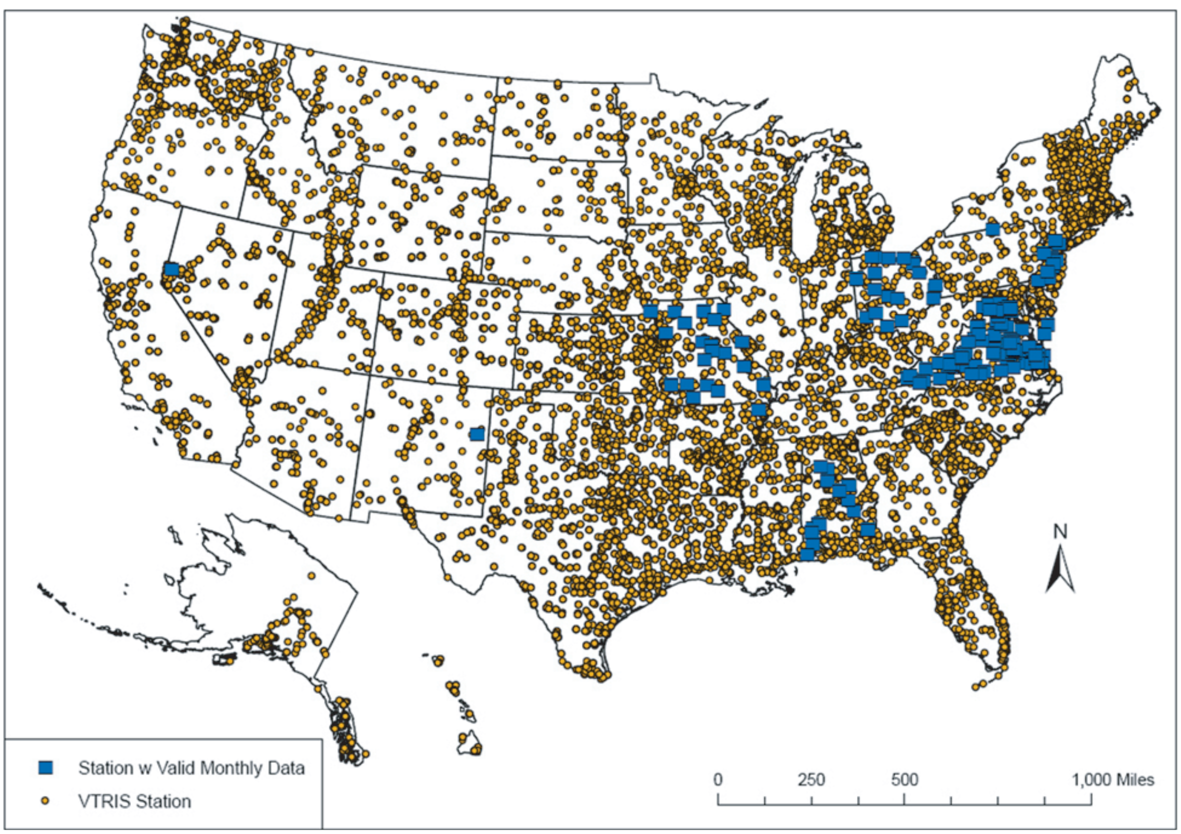


Figure 3.5. VTRIS stations with valid monthly factors.

annual tonnage flows to produce estimated hourly flows for each of the SCTG commodities. For each of the 177 links that have complete monthly factors developed from counts, those factors were applied to the annual tonnage flows to produce estimated monthly flows for each of the SCTG commodities.

Develop Average National Adjustment Factors

The hourly flows for each location were used to develop a national hourly summary of freight flows. The resulting hourly freight flows were aggregated to the nine CFS commodity groups. An hourly distribution of the summary of freight flows was developed and that distribution is shown in Figure 3.6. It is noted that averaged over all locations, the hourly distribution of each of the nine CFS commodity groups appears to be virtually identical.

The monthly flows for each location were used to develop a national monthly summary of freight flows. The resulting monthly freight flows were aggregated to the nine CFS commodity groups. A monthly distribution of the summary of freight flows was developed and that distribution is shown in Figure 3.7. It is noted that averaged over all locations, the monthly distribution of each of the nine CFS commodity groups appears to be virtually identical.

As noted, for both hourly and monthly factors, the resulting distribution showed little variation by commodity group. This finding was not expected. It seems to suggest that while individual locations could show distribution patterns that differ significantly from national averages, absent any other local information, it is reasonable to assume that commodity groups all follow the same distribution pattern for both hourly and monthly flow. Although this pattern could be true for large commodity groups, it might not hold true for the very different SCTG2 commodities with these groups. The pharmaceutical and chemical commodity group includes two commodities (SCTG 21, pharmaceuticals, and SCTG 22, fertilizers) that could be expected to follow very different patterns. However, the development of hourly factors from the commodity flow data for each of these commodities produces very similar results, as shown in Figure 3.8. It is therefore assumed that the method used to estimate the average hourly distribution of commodities would yield the same results for any commodity.

Monthly flow patterns should be related to monthly patterns of production by commodity. This information can be verified from separate sources. The Federal Reserve Board tracks this information in its industrial production and capacity utilization statistics. The U.S. Census Bureau tracks this information in the Manufacturers' Shipments, Inventories, and Orders Survey (M3). The data were examined for 2007, which was prior to the current economic recession. Both data sources show similar results, but the Census Bureau data is easier to use since it tracks data for the entire year, not by fiscal quarter. The Census Bureau survey reports shipments as dollar values not tonnage, but if there is stability in commodity prices, the flow patterns for tons and value should be similar. Additionally, the Census Bureau reports these shipments by NAICS industry, which is similar, but not identical, to the

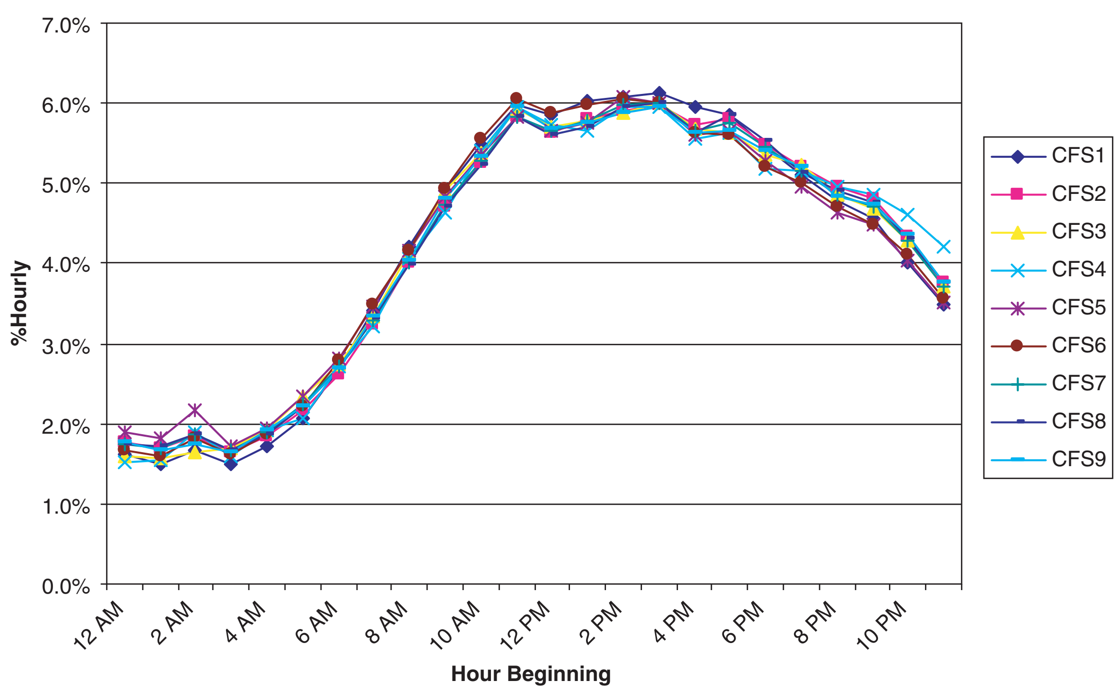


Figure 3.6. Hourly distribution of truck commodity flows.

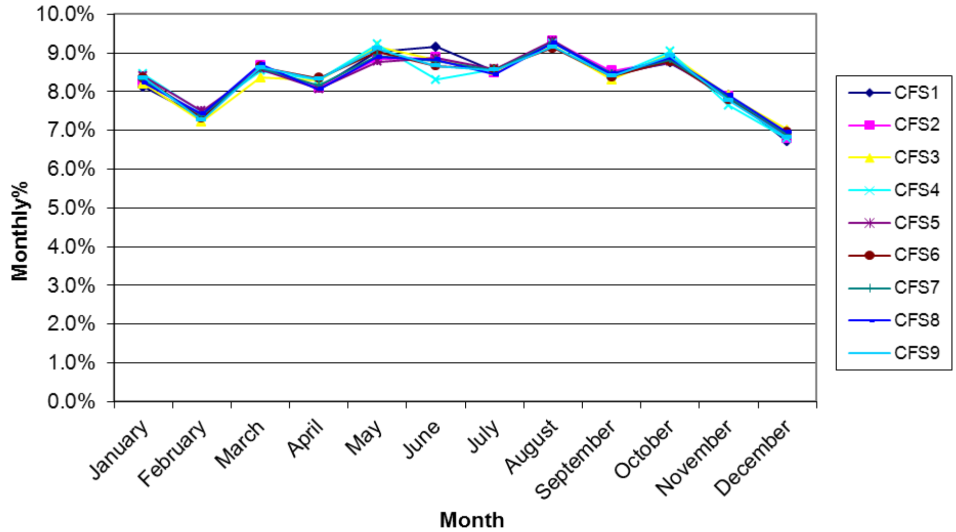


Figure 3.7. Monthly distribution of truck commodity flows.

SCTG commodities in the FAF. Table 3.5 shows the reported value of shipments by industry by months as well as the calculated standard deviation of those monthly flows as a percentage of average monthly flows. For all but a few industries, which are shown on five shaded rows, monthly variation as a standard deviation is less than 10 percent of the average monthly flow.

For the industries excluding those in Table 3.5's shaded rows, the distribution of the U.S. Census Bureau reported monthly shipments is shown in Figure 3.9. Similar to the estimated monthly distribution of flows by commodity shown in Figure 3.7, there is little variation of flows across the months. The industries, whose monthly standard deviation of flows exceeds 10 percent of the average, are shown in Figure 3.10.

Even for most of the industries with the most variation, that variation is minimal. For those industries with the most variation, since the reported data is shipment value not tons, it is conceivable that the variation is due to fluctuations in com-

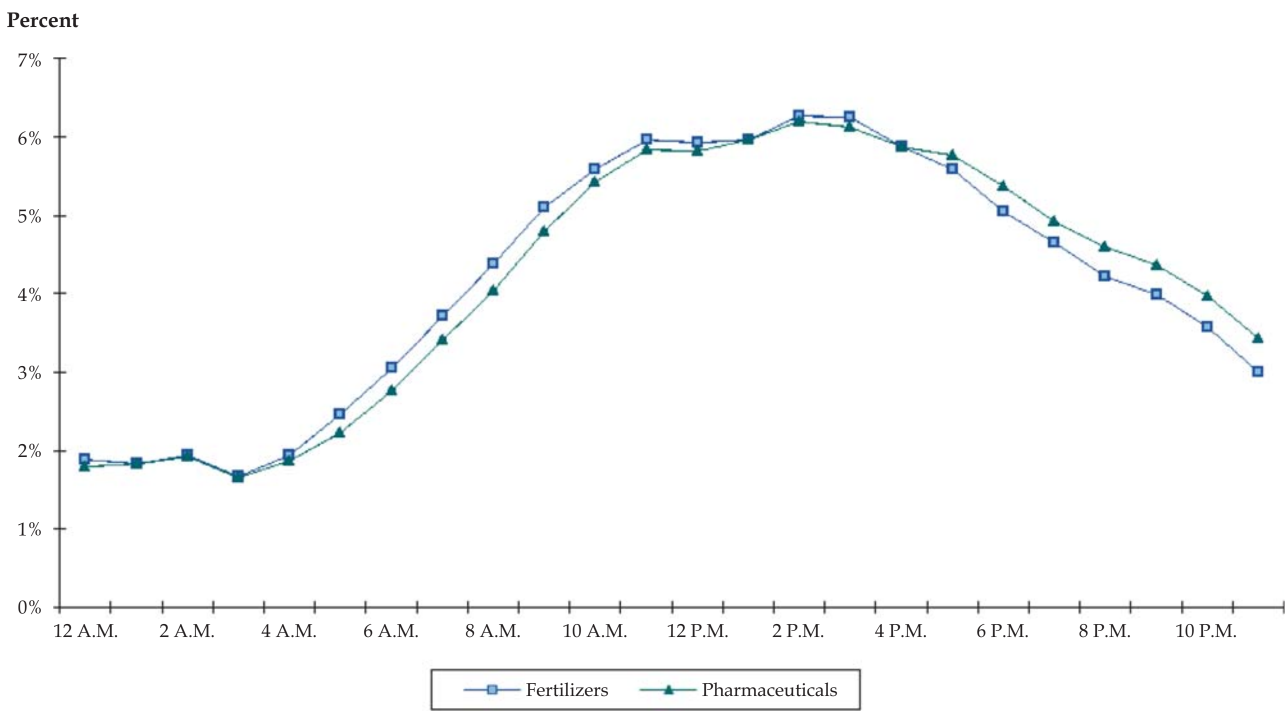


Figure 3.8. Hourly distribution of pharmaceutical and fertilizer flows.

Table 3.5. Value of shipments by industry (2007, in billions of dollars).

Industry	January	February	March	April	May	June	July	August	September	October	November	December	Standard Deviation as Percentage of Average
Food Products	44.1	44.3	47.1	44.7	47.7	47.9	46.3	50.2	49.9	51.3	50.6	49.4	5%
Beverage and Tobacco Products	9.4	9.6	10.7	10.6	12.1	11.8	11.2	12.3	10.9	11.7	11.4	10.6	8%
Textiles	3.0	3.1	3.2	3.1	3.2	3.2	2.9	3.2	3.1	3.1	2.9	2.6	6%
Textile Products	2.4	2.5	2.7	2.6	2.6	2.8	2.6	2.7	2.5	2.6	2.4	2.1	7%
Apparel	2.2	2.5	2.5	2.3	2.4	2.3	2.4	2.8	2.6	2.8	2.9	2.3	9%
Leather and Allied Products	0.4	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.5	10%
Wood Products	7.3	7.5	8.4	8.6	9.3	9.6	8.8	9.4	9.0	8.8	7.8	7.4	10%
Paper Products	14.0	13.2	14.1	13.6	14.4	14.5	14.0	14.5	14.0	14.5	14.0	13.8	3%
Printing	8.0	7.8	8.7	8.2	8.3	8.4	8.0	8.7	8.7	9.4	9.1	8.5	6%
Petroleum and Coal Products	36.6	36.4	43.1	45.2	50.4	49.1	49.9	47.8	47.7	50.2	54.7	53.0	12%
Chemical Products	51.8	50.8	58.0	55.9	58.2	57.1	55.2	56.9	53.7	58.0	54.3	54.3	4%
Plastics and Rubber Products	16.5	16.0	18.1	17.7	18.9	18.6	17.4	18.9	17.3	18.8	17.1	15.3	7%
Nonmetallic Mineral Products	9.1	9.0	10.4	10.4	11.0	10.7	10.2	10.9	9.8	10.6	9.4	7.9	9%
Primary Metals	19.5	18.8	21.0	20.8	21.9	21.3	19.5	20.9	19.9	21.3	19.1	17.5	6%
Fabricated Metal Products	25.3	25.3	28.0	27.3	28.8	28.9	26.7	30.0	27.7	28.6	25.9	24.1	7%
Machinery	23.2	24.6	30.1	29.0	28.9	30.1	26.8	27.7	28.5	28.2	25.9	28.5	8%
Computer and Electronic Products	28.4	29.6	35.7	30.1	30.4	36.3	27.4	31.0	35.9	31.5	32.4	38.1	11%
Electronic Equipment, Appliances, and Components	9.3	9.6	11.3	10.6	10.9	11.3	10.0	11.2	11.3	11.0	10.3	10.1	7%
Transportation Equipment	50.3	55.9	65.9	55.2	61.9	63.7	45.3	64.5	58.5	60.6	57.2	54.0	11%
Furniture and Related Products	6.5	6.7	7.1	6.7	6.8	7.0	6.8	7.4	6.9	7.1	6.7	6.5	4%
Miscellaneous Products	11.7	11.7	13.6	11.9	12.6	13.6	11.6	12.9	12.9	13.4	13.2	13.9	7%

Source: U.S. Census Bureau, Manufacturers' Shipments, Inventories, and Orders Survey (M3).

Note: Shaded rows indicate those industries with a standard deviation of 10 percent or greater.

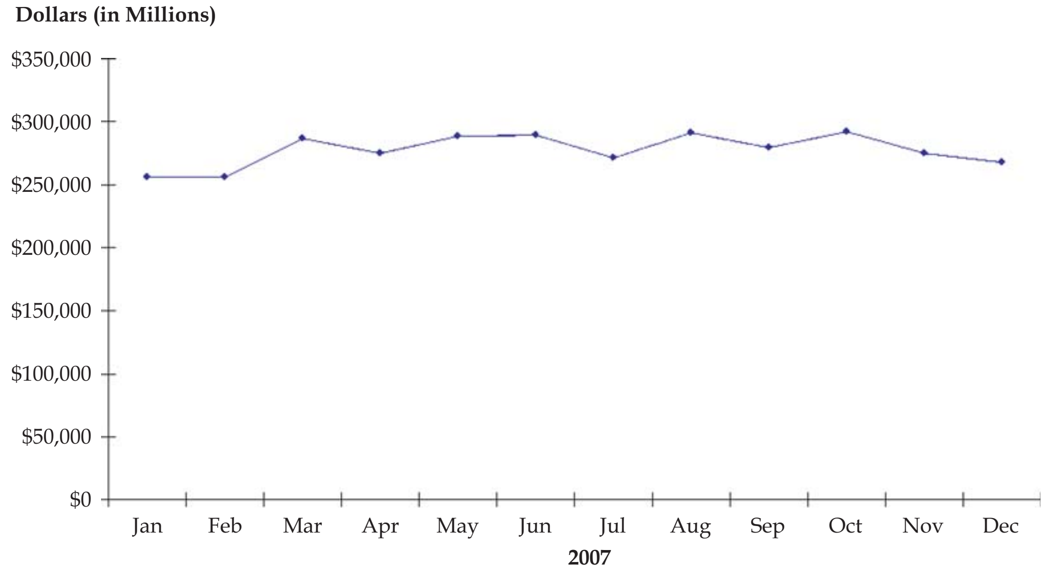


Figure 3.9. Industries with minimal monthly variation.

modity price (e.g., the value per ton of petroleum) or in international currencies. The U.S. Census Bureau data generally confirms the findings of the proposed method, that there is little variation in commodity flows, on average, throughout the year. In the absence of local data showing specific local variations, any policy considerations of commodity truck flows that have been converted from annual to daily flows based on averages need not be concerned about seasonal variations in those commodities.

Similarly, when policy decisions need to consider the hourly variation of commodity flows, absent any specific local information, the hourly distribution of commodity flows according

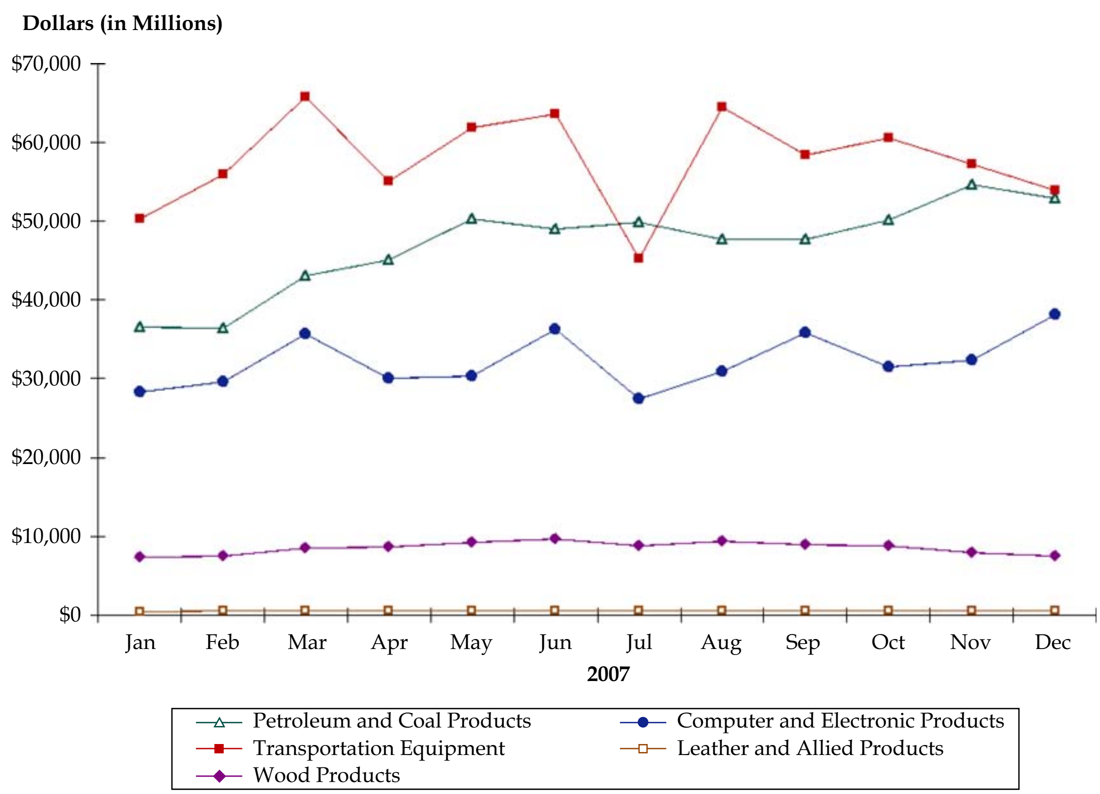


Figure 3.10. Industries with the most monthly variation.

to Figure 3.8, should be considered to be approximately constant at 6 percent each hour for all hours from 1:00 A.M. to 5:00 P.M. This drops to only 5.5 percent in each of the hours before and after that period. Although this may appear inconsistent with conventional wisdom that trucks travel at night, it should be recognized that the national average truck trip length reported in the 2002 CFS is only 173 mi. At this distance, which can easily be completed during one business day, it should be expected that the majority of truck commodity activity would occur during normal business hours, if not prevented by local conditions.

Annual-to-Daily Factor

The assumption of this research was that different commodities have different seasonal and temporal variations. Because the finding was that, on average, all commodities have similar seasonal and temporal variations, the VTRIS data were examined to address an additional issue—the factor that should be applied to all annual ton flows to convert to daily flows.

Different practitioners use different adjustments to convert annual commodity flows to daily flows. Some practitioners merely divide the annual tons by 365, the number of days in a year, neglecting any lower flow on Saturdays and Sundays. Some practitioners divide the annual flows by 250 as an estimate of the number of working weekdays, which makes the assumption that there is no flow on Saturdays and Sundays. The proper factor is expected to fall within that range that would imply there is flow on Saturdays and Sundays but that the flow is less than the flow occurring on weekdays.

The VTRIS data, for those stations that had continuous counts for the entire year, were examined to determine how those truck volumes vary during an average week. The 542 million trucks that were observed at the 177 stations with complete counts have the weekday distribution shown in Figure 3.11.

Forecasting models most often deal with average weekday conditions. From Figure 3.11, the average daily flow is 85 percent of the average weekday flow. The annual conversion to average weekday would then be 85 percent of the days in the year, or 310. It also is observed that there is variation in truck volumes during the week, with similar volumes on Tuesday through Thursday and lower truck volumes on Mondays and Fridays. The average of Tuesday through Thursday truck volumes is 81 percent of the average daily volumes. The annual conversion to midweek daily flows would be 81 percent of 365 days or 295.

It should be noted that other qualitative estimates of the conversion of annual to daily flows have relied on evidence from other sources in which total flow on both weekend days is almost equal to the average weekday flow which, over 52 weeks, would mean a flow equivalent to 312 days. This is often reduced by an estimate of the number of holidays on which little flow is expected, a number ranging from 6 to 12 days, which would reduce the annual-to-daily conversion to a number between 300 and 306. This practice would appear to be consistent with the values derived from Figure 3.11.

3.5 Developing Mode-Choice Models for Freight Forecasting

Policy decisions for freight commonly consider alternatives that could change the mode-choice decision for domestic freight, most often those that would shift freight from highway modes (truck) to nonhighway modes (rail, inland water, or air). These policy alternatives would benefit from a better understanding of the factors that affect the mode-choice decision for freight, including the relative importance of these factors and how they should be considered in freight forecasting. To address this need, this research topic investigated the variables used in mode-choice decisions and attempted to find

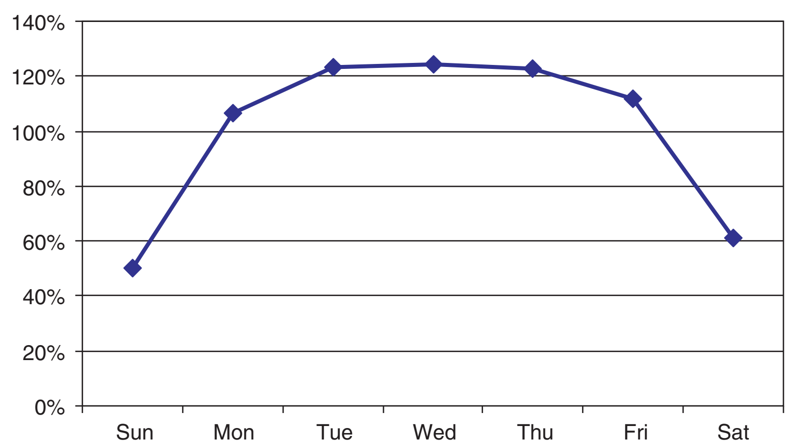


Figure 3.11. Weekday trucks at VTRIS stations as percentage of average daily trucks.

how those variables can be used in estimating a freight mode-choice model.

In choice modeling, equations representing the choice decision are most often in the form of logit choice equations. These logit models may be multinomial, that is several variables are considered simultaneously in the choice decision, and where there is no correlation between those variables. In order to determine the variables that are important in the choice decision, as well as to determine the relative importance of these variables, it is necessary to examine a survey of those choices together with the values of variables that are relevant to those choices. When the survey reflects observed choices as well as the observed relevant variables, this is called a revealed-preference (RP) survey. When the survey is made of decisionmakers to determine their stated choices given a hypothetical set of values for relevant variables, this is called a stated-preference (SP) survey.

Stated-preference surveys in the mode-choice decision for freight would require the identification of a statistically relevant sample of decisionmakers. An SP survey requires providing those decisionmakers with sufficient hypothetical choice experiments. From their responses, the relevant variables in the freight mode-choice decision would be determined. That determination would be made by estimating the coefficients and parameters associated with those variables in a logit choice model. The freight mode choice is most often national in scope, which would require that the geographic scope of such a survey also be national in scope. Identifying these decisionmakers and conducting the choice experiments is an expensive undertaking that is beyond the resources of all but the largest freight studies.

In order for RP surveys to support the development of a freight mode-choice model, it is necessary for the survey to report flows for all modes in a consistent manner, over a period of time that is long enough, and for a geography that is large enough to capture modal decisions. Because the values of the choice variables will differ between different origins and destinations, the RP survey must report information for both the origins and destinations of freight. Because freight mode-choice decisions are assumed to be similar for freight that shares the same characteristics, the freight flows also should be reported separately for freight (e.g., by commodities) that is expected to behave similarly. Additionally, the choice variable and the observed decisions can not be expected to be the same over very large geographies. The reported geographies in the RP database must be at a scale where modal availability and modal characteristics can be assumed to be similar within the reported geography. Finally, the choice in the RP database should be complete trips between and origin and destination—that is, linked trips—that may involve several modes as well as the transfers between modes at intermediate points. Mode-choice decisions should not be made using unlinked trips that are separately reported for each modal component of a trip between an origin and a destination. Given these requirements, only a few commodity flow databases should be considered for use as RP databases, as follows:

- Databases that are limited to single modes (for example, the STB Carload Waybill Survey for rail) can not be used because they reveal no information about the decisions for competing nonrail freight modes.
- The publicly available CFS provides flows for both origins and destinations only as state-to-state movements, and entire states are not a scale of geography over which modal availability and characteristics can be considered similar.
- The privately available TRANSEARCH database does provide flows for seven modes between zones chosen as part of the data purchase, which can be as small as counties or, synthetically, as zip codes. The flows are reported in unlinked form, which although more suitable for determining the proper assignment to modal networks, provides incomplete information for trips that use multiple modes. Additionally, the cost of obtaining the entire TRANSEARCH database as county-to-county flows for the nation would be prohibitive. A single state database with flows at the county level within that state typically costs from $50,000 to $100,000 for a single year.
- The FAF2 database provides information for all modes in a consistent format, including linked multimodal trips. However, the zones in the FAF2 database are very large and some modes—especially water and rail—cannot be expected to be uniformly available throughout these zones.

Although some records in the FAF2 commodity flow database may not be suitable for use in an RP survey, it contains enough suitable records that it might be processed for use as an RP survey.

Variables in Freight Mode Choice

A literature review was conducted to determine variables that would be important in the mode-choice decision for freight. Although not intended to be exhaustive, the variables that were determined to be important in the mode-choice decision for freight are

- Characteristics of the mode, including capacity, trip time, reliability, cost;
- Characteristics of the goods, including shipment size, shelf life, density, value;
- Characteristics of the shipper, including production processes and shipper size;
- Characteristics of the receiver, including receiver size and other consumption processes such as operating hours; and

- Other logistic characteristics, including shipment frequency, inventory costs, loss and damage costs, etc.

Although these variables might be important in the mode-choice decision for freight, determining values for many of these variables requires detailed information about shipments, which might be obtained from an SP survey but can not be expected to be available for all shipment records in an RP survey. Publicly available information was identified that could be used to develop data for the variables to support the use of an RP survey, including

- Modal distances and impedances between U.S. counties from the Center for Transportation Analysis (CTA) at Oak Ridge National Laboratory (ORNL);
- Detail by commodity, including shipment size and value from the FAF2 commodity flow database;
- Employment by industry for the shipper and receiver regions from the U.S. Census county business patterns; and
- Population by destination region from the U.S. Census.

The utility equations developed for use in logit mode-choice equations include a constant for each mode, expressed as a difference from a base mode. The base mode, for which no modal constant will be estimated, is trucking. Separate equations were developed for similar commodities.

The generally important mode-choice variables, as well as how those variables will correspond to the publicly available data and parameters in the RP estimation, are shown in Table 3.6.

Table 3.6. Freight mode-choice variables.

Category	Utility Variable	Corresponding Variable to be Used in Revealed-Preference Utility Estimation
Modal Characteristics	Capacity	Modal Constant
	Trip Time	Modal Distance/Impedance
	Reliability	Modal Constant
	Equipment Availability	Modal Constant
	Customer Service and Handling Quality	Modal Constant
	Modal Cost	Modal Distance/Impedance
Goods Characteristics	Shipment Size	Commodity Total Tons
	Package Characteristics	Commodity Modal Constants
	Shipment Shelf Life	Commodity Modal Constants
	Shipment Value	Commodity Value per Ton
	Shipment Density	Commodity Modal Constants
Shipper Characteristics	Production Processes	Industry Employment at Origin
	Shipper Size	Industry Employment at Origin
Receiver Characteristics	Consumption Requirements	Industry Employment/Population at Destination
	Receiver Size	Industry Employment/Population at Destination
Other Logistic Characteristics	Inventory Costs	Commodity Modal Constants
	Loss and Damage Costs	Commodity Modal Constants
	Service Reliability Costs	Commodity Modal Constants
	Length of Haul	Truck Distance
	Shipment Frequency	Commodity Total Tons

Preparing the FAF2 for Use as an RP Survey

The FAF2 commodity flow database provides separate tables for domestic freight flows, seaborne international freight flows, land border crossing flows, and air and other international modal flows. The designation of the international tables provides information about the mode used internationally (e.g., sea, land border, or air) while the attributes within the table provide information about the mode used for domestic flows between a U.S. FAF zone and the U.S. port of entry/exit. The seven zones outside of the United States are very large and include the entire countries of Canada and Mexico, which leaves only five zones for all of the rest of the world. Additionally, these files are prepared from other commodity flow files and it has been confirmed by the FHWA Office of Freight Management that the correspondence between the commodity codes used in some of the international flow data files and the SCTG commodities codes used in the FAF2 is not correct (e.g., SCTG 34, machinery, actually includes flows for all manufactured products for international water flows and there are no international water flows assigned to other SCTG codes for manufactured goods). Because of the errors in commodity assignments, because the flows only include the domestic mode used, and because the international geographies are too large to ensure consistent modal characteristics and availability for the entire international zone, it was determined that only the records in the FAF2 domestic tables would be suitable for use in an RP survey.

The FAF2 domestic table reports flows between 114 FAF2 regions. These regions include the state portions of the largest metropolitan areas, as well as whole states, or remainders of states outside of those metropolitan areas. The FAF2 regions representing whole states, or remainders of states outside of the metropolitan regions, are too large to ensure consistent modal characteristics and availability throughout the region. Therefore, all records that contain a whole state or a remainder of a state zone as an origin or destination were not included for use in the RP survey. Finally, the separation of metropolitan areas into their state portions was intended to aid in developing summaries of freight flows at the state level. The reported FAF2 flows between FAF2 regions in the same metropolitan area but in different states will involve short distances over which modal choice decisions most likely reflect production or logistic processes unique to the commodity and not decisions that should be considered in an RP survey. Therefore, records that are of freight flows within the same metropolitan area were not included for use in an RP survey. Finally, while the FAF2 includes records for Hawaii and Alaska, the mode-choice decision for shipment to or from these regions includes unique considerations and modes, and they were dropped from use in an RP survey.

The FAF2 records that were included for use in an RP survey include those domestic flows between metropolitan regions, excluding flows that are reported as shipments within the same metropolitan area. It is assumed that the flows reported for these records are consistently available with the same characteristics for all modes.

In order to use as an RP database, total flows between and origin and destination, as well as the flows by each mode, must be determined. The FAF2 database was reformatted to include the flow by each mode for each origin, destination, and SCTG2 commodity. Appended to these were the variables for that origin and destination that were to be tested as explanatory variables in the choices represented by the observed modal flows.

Modal distances were obtained from the CTA at ORNL. The CTA provides skim tables of distances and impedances between U.S. counties for highway (truck), rail, and water, as well great circle distances for air travel. These skim times are based on the paths identified using the ORNL modal freight networks. In addition to distances, the CTA skims include estimated impedances for each of the modes, as well as rail highway rail (RHR) impedances that represent the impedance using the respective rail and highway networks connecting through the intermodal terminals that are expected to serve that origin and destination pair.

These CTA distances and impedances are for U.S. county-to-county movements. In order to use these distances with the FAF-region-to-FAF-region records in the RP data, a representative county had to be associated with each FAF region included in the RP survey, which includes only FAF2 metropolitan regions. The county with the largest employment in a FAF metropolitan region was chosen as the representative county for use in selecting distance and impedances from the CTA skim files.

County employment, the surrogate for shipper characteristics, was obtained from county business patterns. The employment total for all of the counties in the FAF region was selected to test as an explanatory variable. In the same manner, the Census of Population was used to calculate the population of the region, the surrogate for receiver characteristics. From the FAF2 database itself, the total flow for the O/D/C record was added for use as a surrogate for shipment size. From that same FAF2 database, the value of the shipment by all modes also was added to the RP data for use as a surrogate for shipment value.

An investigation of the RP database indicated that the SCTG two-digit level for commodities had insufficient records to use in estimating models for some commodities. The records were aggregated to the commodity groups used in the 2002 CFS as shown in Table 3.4 in order to provide sufficient records to estimate the mode-choice equations by commodity group.

Estimation of Mode-Choice Utility Equation

Utility equations were estimated from the RP flows and the variables associated with those flows. The software used was an object-oriented software package designed for the maximum likelihood estimation of generalized extreme value (GEV) models including multinomial logit models.

Each of the RP variables listed in Table 3.4 were tested singly, as simple functions, as simple cross products (e.g., tons multiplied by distance, or as cross products functions with other variables such as distance multiplied by the natural logarithm of value per ton). The initial estimation runs were used to determine which variables did not contribute significantly to the utility equations, as indicated by uniformly poor t-statistics.

It was found that the surrogate for producer characteristics, employment at the origin and for receiver characteristics, and population at the destination, were not significant explanatory variables at the geographies tested. This does not necessarily indicate that these variables are unimportant, only that they are unimportant at the actual geographic scales as used in the RP survey. It is possible that at smaller geographic scales and for specific shippers (which, of course, would not be correlated with the total of all employment over an entire FAF region), these variables might be significant.

The CTA impedances were found to be highly correlated with distance and, in fact, the CTA describes how they are computed from distances. Because impedances were so highly correlated with distance, only modal distances were retained as utility variables.

Modal constants by commodity were estimated and found to be significant and large. However, because these modal constants are associated with a number of general variables, it is not possible to determine which of the general variables are the most significant. Additionally, the estimation method only provides an indication that these modal constants are significant relative to an assumed zero value for the base mode, which was chosen to be "truck." It provides no indication of what the absolute modal constant is for that mode because there is no ability to estimate the modal constant for the base truck mode. For example, the estimation that the rail modal constant is significant might indicate that any rail capacity, rail reliability, rail equipment availability, or rail customer service and handling quality are important considerations in mode choice but that does not indicate the relative importance of each, nor does it indicate the absolute utility for any of these, only the total relative utility compared to that of the truck mode.

The results show that modal distance, whether singly or in combination with other variables, is the most important variable as estimated from the RP survey. Since distance in this estimation serves as a surrogate for both modal cost and modal time, this is an expected finding. What the estimation also shows is that the size of the shipment, as indicated by the surrogate of annual tons moving between markets, is only significant as a cross product with the natural logarithm of distance. This indicates that the impact of shipment size increases as distance increases, but it does so at a logarithmically decreasing rate. The estimation also shows that value per ton is only significant as a cross product with the natural logarithm of distance. This indicates that the impact of value increases as distance increases but it does so at a logarithmically increasing rate.

The results of the estimation are shown in Table 3.7. The variables were chosen to provide, where possible, uniform consistency across commodity groups. Thus, a chosen variable might have lower than desirable significance, as indicated by its t-statistic where absolute values greater than 2.0 are generally considered to be significant. However, that variable was retained to allow for comparison with other modes and commodities. For those commodities where the variable clearly degrades the estimation, they were excluded.

Although the estimation model was used primarily to show which variables are significant in freight mode choice, the estimated coefficients themselves can be used to gain insights as to how mode-choice decisions might change as these variables change.

The sign of the variable coefficients in Table 3.7 indicates whether the modal utility increases (has a positive sign) or decreases (has a negative sign) as the variable increases. Thus, for SCTG 01-05, agricultural products commodity group, the truck utility for distance decreases (coeff. = –0.00423/mi) as distance increases. As expected and shown in Table 3.7, the modal utility decreases as distance (serving as a surrogate for modal cost and time) increases.

The value of the modal coefficient for all modes within a commodity group relative to other modes within that same commodity group is an estimate of the relative utility of that mode to other modes. Thus for the agricultural products commodity group, the rail distance coefficient of –0.00397 (which is a smaller negative number compared to the truck distance coefficient of –0.00423) estimates that rail as a mode has a higher utility compared to truck as distance increases—that is, its utility increases by 6 percent per mile, –0.00432/–0.00397, compared to truck mode, as distance increases.

The size of a modal coefficient, compared to all modes in a commodity group, indicates the preference for that mode. Thus, for truck mode, the estimation from the RP data is that as distance increases, truck utility decreases the most for furniture and miscellaneous products (–0.01110) and decreases the least for pharmaceutical and chemical products (–0.00309).

A review of the modal constants for each nontruck mode within each commodity group shows that for all commodity groups, the utility of nontruck modes compared to truck mode is estimated to have a lower utility, which means that it is less likely to be chosen than the truck mode. The size of the modal

Table 3.7. Results of revealed-preference mode-choice estimation.

Commodity Group		Truck		Truck and Rail		Water		Rail		Water and Rail		Air		Statistics
		Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	
SCTG 01–05, agriculture products and fish	Constant	0	*0*	-10.4	*-7.72*	-4.91	*-14.21*	-4.37	*-25.83*	-4.17	*-23.41*	-5.82	*-18.15*	Number of records: 3,280
	Distance	-0.00423	*-0.85*	-0.00188	*-0.41*	-0.00123	*-0.44*	-0.00397	*-0.85*	-0.00127	*-0.27*	-0.00418	*-0.74*	
	dist * log(kton)	-0.00099	*-1.75*	-0.00062	*-1.14*	-0.00131	*-2.53*	-0.00020	*-0.37*	0.00024	*0.78*	-0.00269	*-3.37*	
	dist * log($/ton)	0.00069	*1.11*	0.00058	*1.03*	0.00048	*0.82*	0.00050	*0.87*	-0.00024	*-0.63*	0.00098	*1.38*	Rho-square: 0.866
SCTG 06–09, grains, alcohol, and tobacco products	Constant	0	*0*	-5.72	*-30.44*	#N/A	*#N/A*	-3.78	*-34.79*	-3.15	*-21.27*	-6.68	*-14.72*	Number of records: 4,790
	Distance	-0.00821	*-1.68*	-0.00602	*-1.33*	#N/A	*#N/A*	-0.00567	*-1.25*	-0.00606	*-1.36*	-0.00707	*-1.2*	
	dist * log(kton)	0.00033	*0.55*	0.00041	*0.73*	#N/A	*#N/A*	0.00061	*1.09*	-0.00177	*-2.63*	-0.00065	*-0.85*	
	dist * log($/ton)	0.00058	*1.09*	0.00046	*0.94*	#N/A	*#N/A*	0.00021	*0.42*	0.00054	*1.11*	0.00064	*1.01*	Rho-square: 0.820
SCTG 10–14, stones, nonmetallic minerals, and metallic ores	Constant	0	*0*	#N/A	*#N/A*	#N/A	*#N/A*	-4.57	*-27.88*	-4.47	*-13.98*	#N/A	*#N/A*	Number of records: 2,242
	Distance	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	
	dist * log(kton)	0.00067	*1.28*	#N/A	*#N/A*	#N/A	*#N/A*	0.00105	*2.26*	0.00041	*0.71*	#N/A	*#N/A*	
	dist * log($/ton)	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	#N/A	*#N/A*	Rho-square: 0.879
SCTG 15–19, coal and petroleum products	Constant	0.00000	*0*	#N/A	*#N/A*	-3.17	*-9.83*	-3.66	*-24.56*	-4.45	*-17.45*	#N/A	*#N/A*	Number of records: 1,594,
	Distance	-0.00615	*-1.33*	#N/A	*#N/A*	-0.00781	*-2.88*	-0.00653	*-1.62*	-0.00701	*-1.63*	#N/A	*#N/A*	
	dist * log(kton)	-0.00118	*-3.20*	#N/A	*#N/A*	0.00059	*2.66*	-0.00020	*-0.66*	-0.00060	*-1.53*	#N/A	*#N/A*	
	dist * log($/ton)	0.00109	*1.83*	#N/A	*#N/A*	0.00058	*2.08*	0.00110	*2.11*	0.00132	*2.4*	#N/A	*#N/A*	Rho-square: 0.706
SCTG 20–24, pharmaceutical and chemical products	Constant	0	*0*	-1.80	*-12.18*	#N/A	#N/A	-2.73	*-47.49*	-1.21	*-24.57*	-2.76	*-33.54*	Number of records: 10,302
	Distance	-0.00309	*-1.73*	-0.00685	*-3.62*	#N/A	#N/A	-0.00266	*-1.59*	-0.00351	*-2.17*	-0.00642	*-2.97*	
	dist * log(kton)	-0.00105	*-3.50*	-0.00010	*-0.35*	#N/A	#N/A	-0.00020	*-0.70*	-0.00269	*-9.62*	-0.00250	*-6.39*	
	dist * log($/ton)	0.00032	*1.92*	0.00025	*1.5*	#N/A	#N/A	0.00001	*0.09*	0.00047	*3.12*	0.00070	*3.55*	Rho-square: 0.682

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Table 3.7. (Continued).

Commodity Group		Truck Coeff	Truck t-stat	Truck and Rail Coeff	Truck and Rail t-stat	Water Coeff	Water t-stat	Rail Coeff	Rail t-stat	Water and Rail Coeff	Water and Rail t-stat	Air Coeff	Air t-stat	Statistics
SCTG 25–30, logs, wood products, and textile and leather	Constant	0	*0*	-6.40	*-37.05*	#N/A	#N/A	-4.91	*-47.38*	-1.51	*-37.81*	-6.23	*-36.67*	Number of records: 13,689
	Distance	-0.00886	*-3.89*	-0.00601	*-2.81*	#N/A	#N/A	-0.00608	*-2.91*	-0.01050	*-5.14*	-0.00931	*-3.25*	
	dist * log(kton)	-0.00109	*-2.47*	-0.00069	*-1.70*	#N/A	#N/A	-0.00046	*-1.13*	-0.00171	*-4.22*	-0.00168	*-3.12*	
	dist * log($/ton)	0.00103	*4.43*	0.00074	*3.39*	#N/A	#N/A	0.00065	*3.07*	0.00125	*6.03*	0.00122	*4.18*	Rho-square: 0.778
SCTG 31–34, base metal and machinery	Constant	0	*0*	-6.95	*-35.31*	#N/A	#N/A	-4.13	*-47.08*	-1.36	*-20.96*	-4.56	*-27.94*	Number of records: 10,949
	Distance	-0.00822	*-3.05*	-0.00746	*-2.99*	#N/A	#N/A	-0.00885	*-3.58*	-0.00685	*-2.76*	-0.01070	*-3.31*	
	dist * log(kton)	0.00026	*0.61*	0.00060	*1.50*	#N/A	#N/A	0.00101	*2.50*	-0.00196	*-4.83*	-0.00121	*-27.94*	
	dist * log($/ton)	0.00083	*3.25*	0.00080	*3.37*	#N/A	#N/A	0.00075	*3.19*	0.00082	*3.47*	0.00122	*3.99*	Rho-square: 0.785
SCTG 35–38, electronic, motorized vehicles, and precision instruments	Constant	0	*0*	-5.26	*-41.36*	#N/A	#N/A	-3.95	*-52.78*	-0.76	*-22.98*	-3.09	*-53.35*	Number of records: 10,546
	Distance	-0.00725	*-4.14*	-0.00929	*-5.58*	#N/A	#N/A	-0.00917	*-5.44*	-0.00635	*-3.98*	-0.01070	*-5.21*	
	dist * log(kton)	0.00005	*0.15*	0.00087	*2.62*	#N/A	#N/A	0.00081	*2.41*	-0.00124	*-3.89*	-0.00072	*-1.74*	
	dist * log($/ton)	0.00063	*4.33*	0.00078	*5.68*	#N/A	#N/A	-0.00917	*5.51*	0.00064	*4.86*	0.00103	*6.08*	Rho-square: 0.575
SCTG 39–43, furniture, mixed freight and misc. manufactured products	Constant	0	*0*	-5.77	-34.26	#N/A	#N/A	-4.59	-34.32	-1.90	-40.64	-5.74	-29.15	Number of records: 12,940
	Distance	-0.01110	-5.56	-0.00982	-5.26	#N/A	#N/A	-0.01090	-5.85	-0.01370	-7.6	-0.01690	-7.08	
	dist * log(kton)	-0.00217	-6.14	-0.00131	-3.95	#N/A	#N/A	-0.00116	-3.42	-0.00265	-8.22	-0.00250	-5.95	
	dist * log($/ton)	0.00131	5.78	0.00110	5.14	#N/A	#N/A	0.00110	5.16	0.00165	8.05	0.00201	7.49	Rho-square: 0.836

Note: #N/A means that no value is given.

constant estimates how much less useful that mode is than the truck mode. Thus for the truck/rail mode, the worst utility compared to truck mode is for agricultural products (–10.4) and the best comparison to truck mode is for pharmaceutical and chemical products (–1.8).

When no value is given for a mode in a commodity group (the value is shown as #N/A), there were an insufficient number of records in the RP data for values to be estimated for that mode. Thus, for the water mode, data were only sufficient to estimate coefficients for the agricultural products and the coal and petroleum products commodity groups. When no value was given for a variable within a commodity group, the RP data did not show that this variable was a significant explanatory variable for that commodity group. Thus, for the stone commodity group, only the cross product of distance times the natural logarithm of tons in thousands (ktons) was found to be a significant explanatory variable.

As mentioned previously, the variables for thousands of annual tons shipped (ktons) and the value in dollars per tons were found to be significant explanatory variables for the mode-choice decision for any commodity group, but only as the natural logarithm of that variable taken as a cross product with distance. Thus, both the impact on the utility from shipment sizes (as shown by annual ktons) and value vary with distance, but that effect decreases, varies logarithmically, as the variable increases. As before when the coefficient of the variable is negative, the utility increases as the variable increases, and when the value is negative, modal utility decreases as the variable increases.

Although the statistical ability of the estimated model to explain the variation in mode choice was generally good, ranging from a Rho-square of 0.575 to 0.879, those estimates must be compared against observed mode shares. An examination of the model estimates was made where only distance varies, by setting the value in the model for ktons and dollars/ton equal to the average value for that commodity group. This allows the variation of distance, which was the most significant explanatory variable singly and in combination with the other variables, to be plotted and examined against observed mode shares in the RP data. For the agricultural products commodity group, Figure 3.12 shows the results of varying distance on the mode-choice estimates (shown as curves) against the observed mode shares (shown as bars). The model not only has a good statistical fit, it also appears to generally match observed mode shares.

This is not the case for all commodity groups. For the stones and ores commodity group, Figure 3.13 shows the results of varying distance on the mode-choice estimates (shown as curves) against the observed mode shares (shown as bars). The model has a good statistical fit, but it does not appear to match observed mode shares. It generally also overestimates the truck mode share at large distances. As shown in Figure 3.14, the observed flows for this commodity group are most heavily represented by flows of less than 500 mi. An investigation was undertaken to see if the introduction of variables of distance by class would approve the ability of the model to estimate mode choice.

For the re-estimation, the distance variable was estimated according to the following formula: if the distance is less than 500 mi, then distance1 would be equal to the distance and distance2 would be equal to 0; if the distance is greater than 500 mi, then distance1 would be equal to 500 mi and distance2 would be equal to the distance minus 500 mi. Thus, for a distance of 400 mi, distance1 would take on a value of 400, and distance2 would take on a value of 0, while for a distance of 1,600 mi, distance1 would take on a value of 500 mi, and distance2 would take on a value of 1,100 mi. As shown in Table 3.8, this did not significantly improve the model estimation. For two commodity groups, agricultural products and wood products, shown as shaded rows in the table,

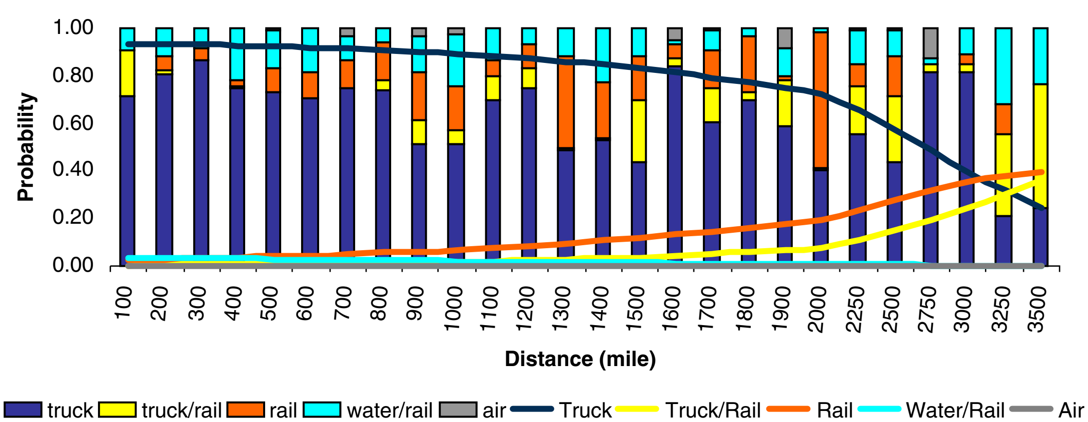

Figure 3.12. Mode share by distance for CFS Commodity Group 2 (estimated and observed).

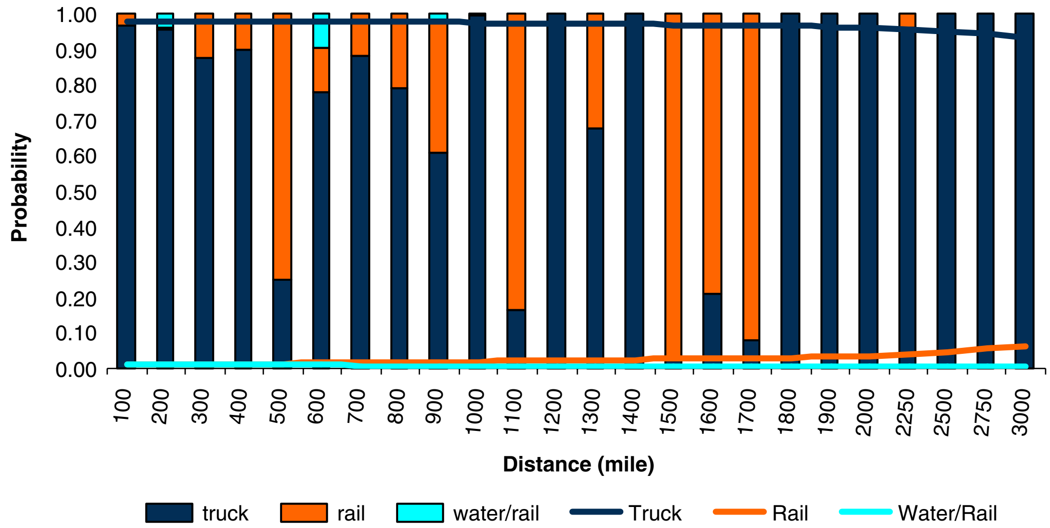

Figure 3.13. Mode share by distance for CFS Commodity Group 3 (estimated and observed).

the ability of the model to explain the variation in the data, as shown by the value of Rho-squared, decreased relative to those estimations with a single-distance variable. For all other commodities, the statistical fit improved only slightly, with increases in Rho-squared, between those shown in Table 3.8 and the single-distance variable estimates shown in Table 3.7, of at most 0.039. That increase was in the stone and ores commodity group.

Figure 3.15 shows the results for the stones and ores commodity group using the two distance variable estimations. The results of varying distances on the mode-choice estimates are shown as curves and the observed mode shares are shown as stacked column bars. Again, the model has a good statistical fit, but it does not appear to match observed mode shares. Generally, it also overestimates the truck mode share at mid-range distances. It appears to better explain mode share below 500 mi, but as distance increases, it still does not show the expected decrease in truck mode share and increase in non-truck mode share.

Because the two-distance class estimation did not produce the desired results, an additional investigation was undertaken where SCTG 14, sand and gravel, which represents most of the

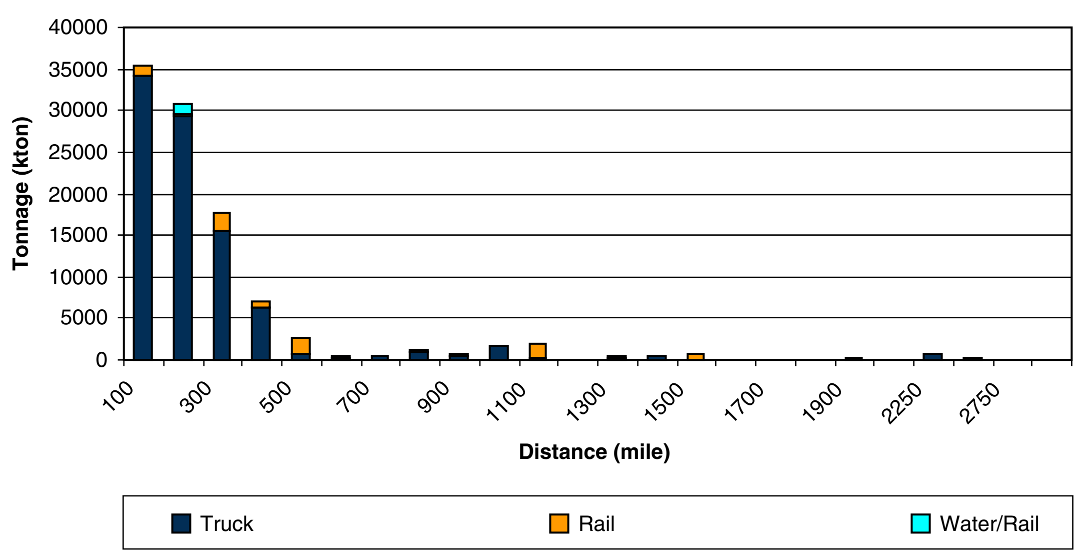

Figure 3.14. Volume by mode share by distance for CFS Commodity Group 3.

Table 3.8. Results of revealed-preference mode-choice estimation with two distance classes.

Commodity Group		Truck		Truck and Rail		Water		Rail		Water and Rail		Air		Statistics
		Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	
SCTG 01–05, agriculture products and fish	Constant	0	*0*	-18.6	-5.92	-12.10	-3.47	-9.8	-8.60	-6.06	-9.27	-9.64	-8.11	Number of records: 3,280 Rho-square: 0.848
	Distance <500	-0.00765	-3.74	0.011900	1.26	0.0107	1.45	0.00641	1.96	-0.00105	-0.36	0.00215	0.73	
	Distance >500	-0.00120	-2.13	0.00077	1.00	-0.00115	-5.37	-0.00141	2.62	-0.00060	-1.12	-0.00006	-0.09	
	dist * log(kton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	
	dist * log($/ton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	
SCTG 06–09, grains, alcohol, and tobacco products	Constant	0	0	-34.10	-4.71	#NA	#NA	-6.59	-13.25	-7.64	-7.32	-10.40	-5.83	Number of records: 4,790 Rho-square: 0.829
	Distance <500	-0.01010	-7.06	0.04940	3.35	#NA	#NA	-0.00104	-0.58	0.00289	1.21	0.00100	0.24	
	Distance >500	-0.00119	-1.95	0.00004	0.06	#NA	#NA	0.00024	0.33	-0.00002	-0.22	0.00093	0.93	
	dist * log(kton)	-0.00011	-0.85	-0.00017	-1.27	#NA	#NA	0.00004	0.10	-0.00012	-1.11	-0.00146	-2.43	
	dist * log($/ton)	-0.00032	-0.78	-0.00019	-0.50	#NA	#NA	-0.00044	-3.18	-0.00266	-4.97	-0.00019	-1.13	
SCTG 10–14, stones, nonmetallic minerals, and metallic ores	Constant	0	0	#NA	#NA	#NA	#NA	-7.31	-11.15	-8.26	-6.61	#N/A	#N/A	Number of records: 2,242 Rho-square: 0.908
	Distance <500	-0.01470	-4.79	#NA	#NA	#NA	#NA	-0.00550	-1.59	-0.00385	-1.08	#N/A	#N/A	
	Distance >500	-0.00200	-1.90	#NA	#NA	#NA	#NA	-0.00530	-4.28	-0.00007	-0.19			
	dist * log(kton)	-0.00200	-1.90	#NA	#NA	#NA	#NA	-0.00530	-4.28	-0.00007	-0.19	#N/A	#N/A	
	dist * log($/ton)	0.00139	2.99	#NA	#NA	#NA	#NA	0.00205	4.73	0.00020	1.50	#N/A	#N/A	
SCTG 15–19, coal and petroleum products	Constant	0	0	#NA	#NA	-4.19	-7.31	-5.87	-11.06	-7.48	-5.58	#N/A	#N/A	Number of records: 1,594 Rho-square: 0.725
	Distance <500	-0.00867	-4.44	#NA	#NA	-0.00744	-3.26	-0.00173	-0.74	-0.00031	-0.09	#N/A	#N/A	
	Distance >500	0.00091	1.08	#NA	#NA	-0.00537	-3.05	-0.00033	-0.33	-0.00015	-0.09			
	dist * log(kton)	-0.00122	-6.01	#NA	#NA	0.00046	2.81	-0.00049	-2.96	-0.00095	-3.54	#N/A	#N/A	
	dist * log($/ton)	0.00027	1.14	#NA	#NA	0.00015	0.73	0.00027	1.21	0.00047	2.37	#N/A	#N/A	
SCTG 20–24, pharmaceutical and chemical products	Constant	0	0	-8.01	-9.48	#NA	#NA	-5.34	-21.75	-4.12	-23.16	-6.97000	-19.90	Number of records: 10,302 Rho-square: 0.717
	Distance <500	-0.00750	-4.21	-0.00188	-0.78	#NA	#NA	-0.00161	-0.93	-0.00082	-0.49	-0.00274	-1.23	
	Distance >500	-0.00074	-0.39	0.00019	0.11	#NA	#NA	-0.00051	-0.29	-0.00172	-1.02	-0.00269	-1.2	
	dist * log(kton)	-0.00105	-3.25	-0.00057	-1.90	#NA	#NA	-0.00022	-0.72	-0.00277	-9.27	-0.00212	-5.36	
	dist * log($/ton)	0.00008	0.5	-0.00003	-0.2	#NA	#NA	-0.00020	-1.25	0.00025	1.59	0.00038	1.89	

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Table 3.8. (Continued).

Commodity Group		Truck Coeff	Truck *t-stat*	Truck and Rail Coeff	Truck and Rail *t-stat*	Water Coeff	Water *t-stat*	Rail Coeff	Rail *t-stat*	Water and Rail Coeff	Water and Rail *t-stat*	Air Coeff	Air t-stat	Statistics
SCTG 25–30, logs, wood products, and textile and leather	Constant	0	0	-7.78	-11.97	#NA	#NA	-7.19	-15.13	-4.71	-23.48	-8.66	-8.58	Number of records: 13,689 Rho-square: 0.772
	Distance <500	-0.00659	-18.56	-0.00287	-2.00	#NA	#NA	-0.00158	-1.48	0.00179	3.3	-0.00005	-0.02	
	Distance >500	-0.00057	-7.94	-0.00024	-1.71	#NA	#NA	-0.00107	-8.71	-0.00006	-2.52	0.00028	1.61	
	dist * log(kton)	-0.00057	-7.94	-0.00024	-1.71	#NA	#NA	-0.00107	-8.71	-0.00006	-2.52	0.00028	1.61	
	dist * log($/ton)	#N/A	#N/A	#N/A	#N/A	#NA	#NA	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
SCTG 31–34, base metal and machinery	Constant	0	0	-12.90	-12.04	#NA	#NA	-5.48	-21.73	-5.78	-20.42	-7.42	-14.42	Number of records: 10,949 Rho-square: 0.792
	Distance <500	-0.01320	-4.92	0.00027	0.08	#NA	#NA	-0.01060	-4.22	-0.00204	-0.8	-0.00911	-2.73	
	Distance >500	-0.00771	-2.84	-0.00726	-2.89	#NA	#NA	-0.00876	-3.52	-0.00685	-2.74	-0.01060	-3.23	
	dist * log(kton)	0.00046	1.06	0.00078	1.96	#NA	#NA	0.00120	2.99	-0.00165	-4.09	-0.00094	-1.66	
	dist * log($/ton)	0.00075	2.93	0.00072	3.08	#NA	#NA	0.00068	2.92	0.00075	3.18	0.00113	3.69	
SCTG 35–38, electronic, motorized vehicles, and precision instruments	Constant	0	0	-13.70	-13.89	#NA	#NA	-7.86	-17.37	-3.72	-32.45	-6.29	-32.60	Number of records: 10,546 Rho-square: 0.597
	Distance <500	-0.01260	-7.51	0.00348	1.34	#NA	#NA	-0.00559	-3.00	-0.00439	-2.83	-0.00811	-4.04	
	Distance >500	-0.00561	-3.22	-0.00835	-5.01	#NA	#NA	-0.00825	-4.88	-0.00541	-3.4	-0.00938	-4.57	
	dist * log(kton)	0.00013	0.42	0.00093	3.13	#NA	#NA	0.00087	2.91	-0.00114	-3.98	-0.00063	-1.69	
	dist * log($/ton)	0.00049	3.42	0.00066	4.86	#NA	#NA	0.00064	4.69	0.00051	3.95	0.00087	5.17	
SCTG 39–43, furniture, mixed freight and misc. manufactured products	Constant	0	0	-8.86	-8.16	#NA	#NA	-5.11	-14.94	-5.31	-26.91	-6.86	-15.24	Number of records: 12,940 Rho-square: 0.841
	Distance <500	-0.01390	-7.19	-0.00549	-1.88	#NA	#NA	-0.01220	-6.08	-0.00865	-4.73	-0.01700	-6.84	
	Distance >500	-0.01090	-5.62	-0.00991	-5.49	#NA	#NA	-0.01080	-6.06	-0.01390	-8.07	-0.01700	-7.34	
	dist * log(kton)	-0.00185	-5.31	-0.00100	-3.04	#NA	#NA	-0.00085	-2.50	-0.00226	-7.08	-0.00209	-5.04	
	dist * log($/ton)	-0.00185	-5.31	-0.00100	-3.04	#NA	#NA	-0.00085	-2.50	-0.00226	-7.08	-0.00209	-5.04	

Note: #N/A means that no value is given.

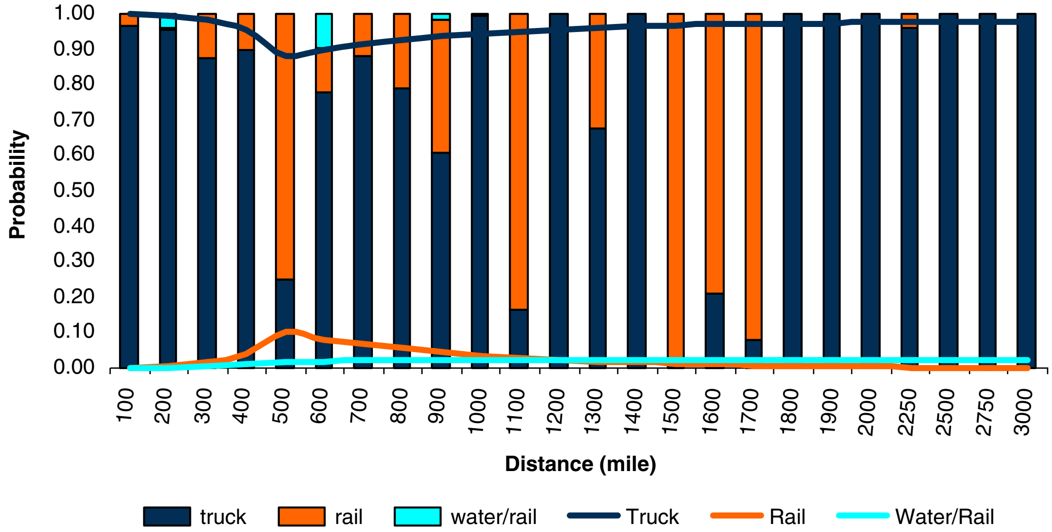

Figure 3.15. Mode share by distance for CFS Commodity Group 3 (estimated with two distance classes and observed).

short-distance flows within that commodity group, was separated for estimation and new estimates were made for the remaining commodities in that group. Those results are shown in Table 3.9.

Although the model's ability to explain the variance in mode choice is very high for SCTG 14, sand and gravel, when treated separately, as can be seen in Figure 3.16, that is due almost entirely to the fact that the share by modes other than truck is extremely limited for this commodity at all distance ranges. Additionally, with fewer records available for the estimation, the model cannot successfully estimate coefficients for the distance across products with shipment size and value, used as logarithms of total tons and total value per ton. Those few distance ranges where other modes are observed to be used do not fall into a pattern. The estimated mode share for distances greater than 500 mi is relatively constant above 1,500 mi. Mode choice for this commodity must be assumed to be largely related to modal availability or processes unique to the production and/or consumption of this commodity.

For the remaining flows in this commodity group, the exclusion of the records for SCTG 14 results in a poorer model estimation, as indicated by a decline in the Rho-square compared to that in Table 3.8. Additionally with fewer records available, this estimation for the remaining commodities in this group cannot successfully develop coefficients for the distance across products with shipment size and value, as logarithms of total tons and total value per ton. As shown in Figure 3.17, for the distances below 500 miles, the observed flows do appear to correspond to the estimated mode share, but again this may be largely due to the dominance of truck mode share over this distance range. At distances greater than 500 miles, the share of other modes used do not fall into a discernible pattern with distance and the estimated mode share for distances greater than 500 miles is relatively constant above 1,500 miles. Mode choice for the remainder of this commodity group must be assumed to be largely related to modal availability, or processes unique to the production and/or consumption of this commodity.

The research has shown that it is possible to develop RP databases from existing, publicly available sources. It has shown that modal distance, which is expected to be highly correlated with modal time and costs, is the single most important consideration in mode choice. When local policy decisions can only impact the local component of modal costs and distances, and those local costs and times are only a small fraction of total modal costs and distances, the difficulty of influencing mode-choice decisions by local policies can be seen. The policy decisions that might be more subject to local control, such as shipper, and receiver characteristics, were not found to be significant variables in freight mode-choice decisions, at least as estimated by this RP survey.

Table 3.9. Results of revealed-preference mode-choice estimation with two distance classes (STCG 14 and remainder of stone and ore commodity group).

Commodity Group		Truck		Truck and Rail		Water		Rail		Water and Rail		Air		Statistics
		Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	Coeff	*t-stat*	*t-stat*
SCTG 14, sand and gravel	Constant	0	0	#NA	#NA	#NA	#NA	-151.00	-4.36	-9.76	-4.04	#NA	#NA	Number of Records: 3,280
	Distance <500	-0.00945	-1.26	#NA	#NA	#NA	#NA	0.28700	3.82	0.00122	0.20	#NA	#NA	
	Distance >500	-0.00174	-1.31	#NA	#NA	#NA	#NA	-0.00224	-1.42	0.00023	0.53	#NA	#NA	
	dist * log(kton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	Rho-square: 0.954
	dist * log($/ton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	
SCTG 10–13, stone, nonmetallic and metallic ore	Constant	0	0	#NA	#NA	#NA	#NA	-7.21	-10.66	-8.33	-6.01	#NA	#NA	Number of Records: 4,790
	Distance <500	-0.01210	-3.81	#NA	#NA	#NA	#NA	-0.00152	-0.42	-0.00194	-0.49	#NA	#NA	
	Distance >500	-0.00110	-0.95	#NA	#NA	#NA	#NA	-0.00132	-1.26	-0.00005	-0.13	#NA	#NA	
	dist * log(kton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	Rho-square: 0.884
	dist * log ($/ton)	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	

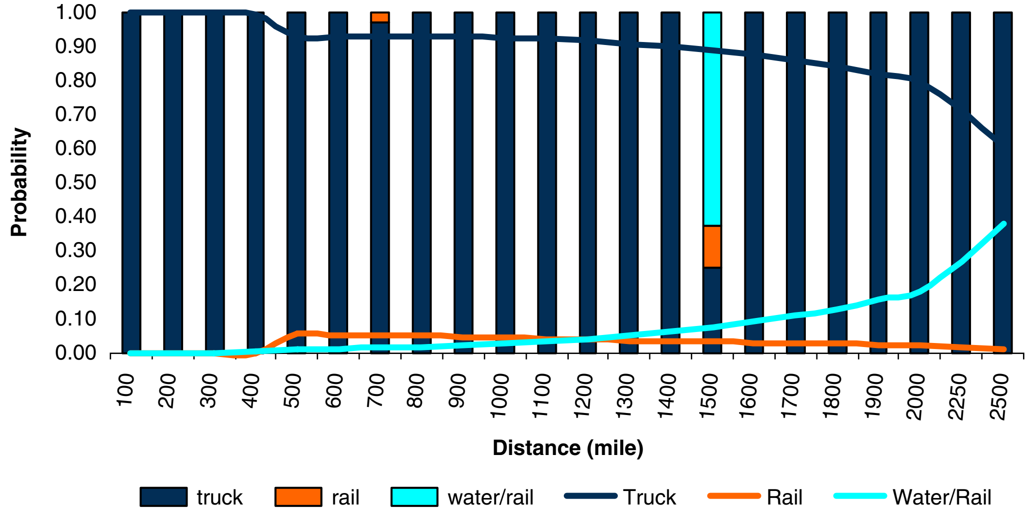

Figure 3.16. Mode share by distance for CFS Commodity Group 3, SCTG 14 (estimated with two distance classes and observed).

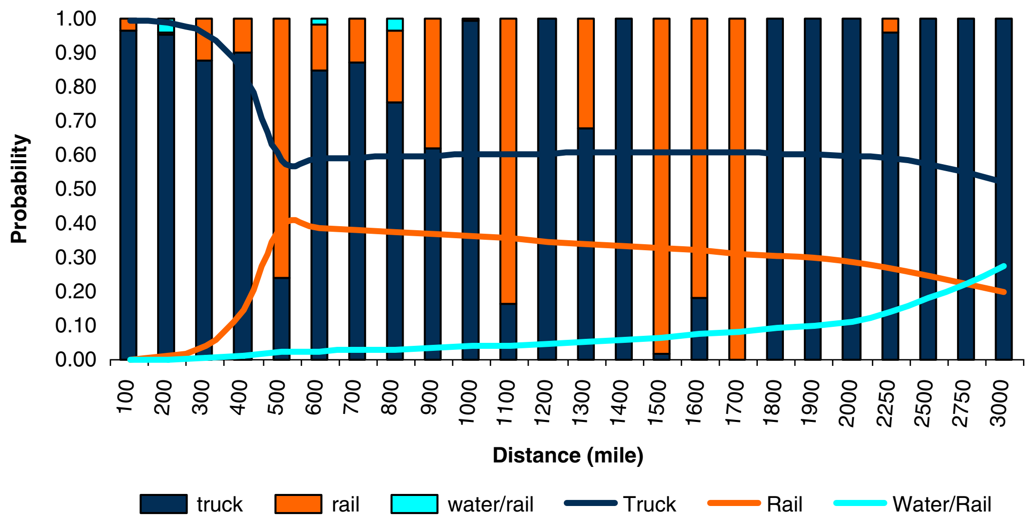

Figure 3.17. Mode share by distance for CFS Commodity Group 3, SCTG 10-13 (estimated with two distance classes and observed).

CHAPTER 4

Guidebook

The interviews with transportation practitioners found that freight forecasting methods generally are supportive of public decisionmaking. The literature review of existing models suggests that, although refinements of processes are in order, particularly for simulation and logistics models that might support operational and public–private investment decisions, the models that do exist can support public decisionmaking. The largest gap in the application of these models that was identified from the interview process was data to support the models. The research topics in Section 3 were selected not only to develop data that might be used to support these models, but also to show that publicly available data or low-cost data acquisitions can be used to develop data that can improve freight forecasting models.

The review process also has led to an identification of a standard process that could be documented as a guidebook to be followed in the development and application of freight forecasts that can support public decisionmaking. This section is intended to outline the steps that should be followed by practitioners. The discussion is not intended to be exhaustive. These topics have been addressed in detail in other reports such as the QRFM, the National Highway Institute (NHI) course on Freight Forecasting, FHWA's *Accounting for Commercial Vehicles in Urban Transportation Models,* and *NCHRP Report 606: Forecasting Statewide Freight Toolkit.* The purpose of this section is to outline the steps to be followed, not to describe the details of the steps.

4.1 Step Outline

Step 1. What Freight Policy Alternatives Need to be Evaluated?

Forecasting fulfills two purposes. First and most typically, forecasts are prepared to evaluate future conditions. For example the employment in certain industries in a region, which are known to be drivers of freight, might be used in a model that was validated to current conditions to forecast future freight demand and performance.

The second purpose of forecasting is to estimate information that is difficult or costly to determine by direct measure during the current period. For example, information about the commodities carried by truck is not readily available from vehicle classification counts or other observations of general truck performance. However, models that are developed to forecast freight movement by commodity, as well as other nonfreight truck movements, can be used to calculate the performance of these various types of flows that otherwise could not be reported.

The policy alternatives to be analyzed will dictate the need for forecasts. Some policies are short-term in nature but require a great deal of detail. Some policies are long-term and long-term forecasts of demand and performance are needed, but with less detail. Table 4.1 shows general policy needs that transportation planners are asked to address. Although other policy needs do exist (e.g., project design, safety, infrastructure, and maintenance planning), most often these are subsets of general and long-range planning. These unlisted needs differ only in the precision and amount of detail to be included in the forecasts.

- **General and long-range planning** can require "forecasts" of current conditions, primarily to add details not otherwise available (e.g., performance by commodity flows). The long-range forecasts are, of course, long-term and will require information about economic and other conditions that give rise to freight demand, as well as the future system that will be serving freight demand (the existing plus committed system). The demand for freight is compared to supply that can carry that freight in order to determine performance. The system is examined to determine where performance is below standard. Projects, programs, and policies are developed to address these needs, and forecasts are prepared with these elements in place. The perfor-

Table 4.1. Policy needs.

Need	Description
General and Long-Range Planning	Transportation planning including preparation of multimodal transportation plans and/or freight plans; includes forecasts in support of design, asset management, safety, operations, financial planning, and all transportation agency needs
Project Prioritization	Project prioritization and transportation improvement plan development
Modal Diversion	Modal diversion analysis
Policy and Economic	Policy and economic studies
Rail Planning	Rail planning

mance of the system with various scenarios (which are combinations of projects, programs, and policies) in place is used to evaluate these scenarios. The forecasting method must be robust enough to develop useful information for this policy analysis.

- **Project prioritization** generally has the same requirements and issues as general and long-range planning. It does require more precision than general and long-range planning because it is intended to allow the ranking and scheduling of the projects identified during long-range planning. It will require performance by project, rather than systemwide. It is listed separately because it may be a separate focus to address certain emphasis areas and/or legal requirements.
- **Modal diversion** also generally has the same requirements and issues as general and long-range planning. It may require more detail for certain corridors and/or geography. The forecasting process itself may not be different, but the detail of the output and the manner in which it is presented may be different. It is listed as a separate need because it may have a separate policy and/or legal focus. Additionally, general plans traditionally are developed for the transportation system owned, maintained, and operated by the public. For freight, this is primarily the highway system. Modal diversion as a policy alternative may address how much freight will be expected on the highway system by shifting demand to alternative modes not the focus of traditional highway-oriented planning. It also is listed separately because modal diversion of freight is often of interest when reviewing energy and environmental policies, such as the emissions by freight, the energy required to move freight and the greenhouse gases associated with the movement of freight.
- **Policy and economic** needs, like the preceding needs, also can be considered as a subset of general and long-range planning. These analyses may require more detail by corridor or geography. The forecasting process itself may not be different, but the detail and manner in which it is presented is different and additional processing may be required. The focus of these policy alternatives will be those projects and programs that, by improving the capacity or operations of the freight system, create new economic activity or expand or retain the existing economic activities in a region. It is listed separately because it may be the focus of separate policy and/or legislative requirements.
- **Rail planning** also generally has forecasting needs that are similar to those of general and long-range planning. It is listed separately because it may be the focus of legislative or administrative actions and funding. It differs from other freight issues in that the infrastructure supporting rail freight is generally privately owned and therefore it may be necessary to report separately on public and private demand and performance. These policy analyses may also support the specialized needs and precision required of public–private partnership funding agreements.

Defining the freight polices that need to be evaluated is the first step in identifying the appropriate freight forecasting procedures that should be followed.

Step 2. What Performance Measures Support Those Policy Measures?

As transportation planning and operating agencies strive to improve their efficiency and effectiveness, they have increasingly turned to performance measures to provide credible, quantitative information to support their analysis and decisionmaking. Measurement of transportation system condition and performance has become an explicitly acknowledged component, not only of the planning process, but also in programming, budgeting, and system operation. Measures help agencies provide accountability to the public, stay focused on intended results, improve communication with internal and external customers, and improve delivery of services. This is true not only for general transportation, but also for freight-specific policies, programs, and projects.

Table 4.2 shows freight performance measures that might be used to support the policy needs identified in Step 1. General and long-range planning needs and their related performance measures and required forecasting outputs are not shown in Table 4.2 because they include all of the needs and performance measures that are listed. Although the calculation of performance measures will require additional information that will not be available from the forecasting process, such as the administrative, operating, and construction costs associated with a policy, the forecasting outputs are needed to compute the value of these performance measures. Practitioners should consult other documents on the use of performance measures. The intent here is to show which forecasting outputs are required to support the calculation of performance measures. Generally, the performance measure will require detail on the link or system volumes, and the link or system average speeds or times. From these forecasts of demand and performance, practitioners can calculate the performance measurements needed to support the analysis of freight policy alternatives.

Step 3. What Forecasting Models can be Used to Support Decisions?

As shown in Table 2.1, a framework was developed to organize the literature review and to examine how different classes of models have been implemented to support public decision-making. As the figure shows, only certain classes of models have been found useful and applied in support of public decisionmaking. After identifying the freight outputs that are

Table 4.2. Policy needs and corresponding performance measures.

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

required of the forecasting models, it was decided that it was useful to present different categories that should be considered to identify which models will best support the calculation of the performance measures. It is useful to consider the selection of the forecasting process from each of the following groupings: model perspective, model types, and model components.

Model Perspective

Although freight is the movement of cargo in vehicles, it makes a considerable difference in developing models to forecast freight whether those models are being developed from the perspective of the cargo or the perspective of the truck. Figure 4.1 shows a very simple situation of six stops for the movement of four cargo shipments. From the perspective of the cargo, there are four productions (two productions at Stop 0—the base, and one each at Stop 1 and Stop 2) and four attractions (one attraction each at Stops 2, 3, 4, and 5). From the perspective of the truck as a vehicle, there are six productions and six attractions (one each at Stop 0—the base—and Stops 1 through 5). There are five cargo trips as shown by the dotted lines, while there are six truck trips, as shown by the solid lines. Obviously very different models would be required to forecast these movements. This would depend on whether the model was developed to forecast cargo or trucks. This situation for a single truck movement is magnified and compounded when all of the freight shipments within a study area are considered.

Model Types

Although the model categories in Table 2.1 are useful for cataloging model research, an alternate method of classification is presented based on how the models are applied. It is a variation of the methods in Chapter 6 of *NCHRP Report 606: Forecasting Statewide Freight Toolkit*. The model types can best be considered as alternate pathways that follow the steps shown in Figure 4.2.

- **Trend analysis—**This consists only of Step 9a as shown in Figure 4.2. It directly forecasts freight activity using, at most, historical or economic trends.
- **Commodity forecasting—synthetic modeling of commodity flows—**This consists of Steps 4, 5, and 6, which are used to develop modal commodity flow trip tables, and Steps, 7, 9, and 10, which are used to convert that commodity trip table to a suitable format for assignment to modal networks and then to evaluate the flows on those networks.
- **Commodity forecasting—direct acquisitions of commodity flows—**This consists of Step 6a, which directly acquires a commodity flow table instead of following the synthetic process. If the acquired table includes modal flows and these are directly used, this may replace Step 6. If not, Step 6 is required. After the modal commodity table is obtained, Steps 7, 9, and 10 are followed as in the synthetic model.
- **Economic forecasting—**This consists primarily of the feedback loop between networks perforce and economic inputs shown as Step 6b. Depending on the nature of the economic model, it may have commodity trip tables that can replace some or all of Steps 4, 5, and 6. If the zonal structure in the economic model is different than that used in transportation planning, some conversion may be necessary.
- **Nonfreight trucks—synthetic modeling—**This is shown as Step 8. If a multiclass assignment of highways is used in Step 9, this is a required step and will be necessary to determine the correct multiclass highway performance for freight trucks. If not included, freight performance in Steps 9 and 10 will not consider the interaction with what may be the majority of trucks on the road. It also is possible that Step 8 and Steps 4 through 7 are not followed and that

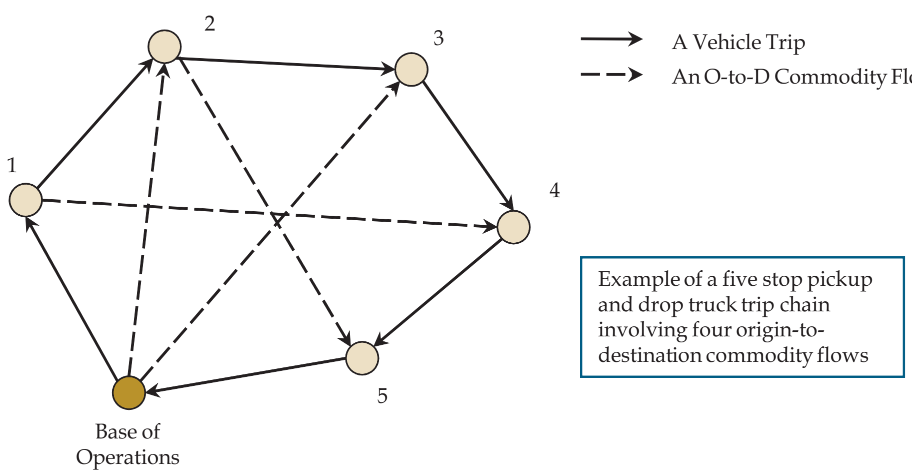

Figure 4.1. Illustrative Freight Shipments Cargo and Truck Perspectives.

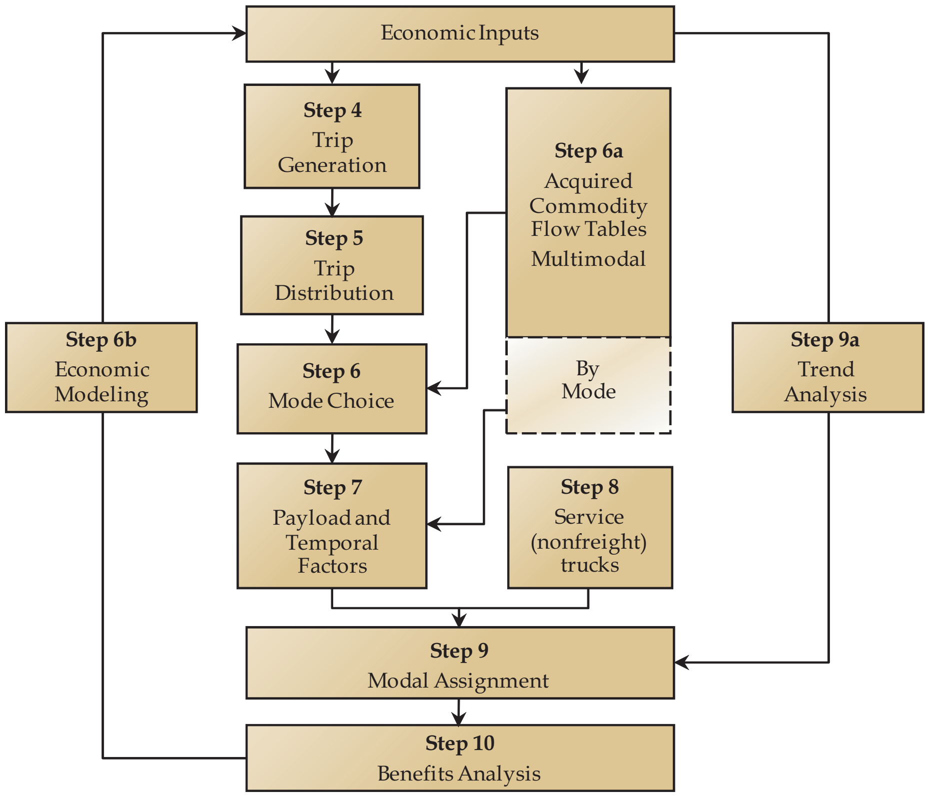

Figure 4.2. Model methods.

commodity freight trucks are included with all trucks in Step 8. If this is the case, the performance of freight trucks cannot be separated from the performance of all trucks.

Model Flow Components

This dimension is intended to capture how the flow variables are defined in the model steps. The same flow components need not be in each step. In fact, Step 7 (which is where factors are used to convert from annual tons as flow units in Steps 4 to 6 to daily truck) is excluded to account for this. However, the flow units can be disaggregated based on the need for those units to fulfill specification and calibration reasons, model validation requirements, or benefits analyses requirements.

- Behavioral, calibration, and specification classifications are developed during model specification and calibration. They are intended to develop forecasting methods and equations for flows with similar behavior. The freight OD flow tables, either produced synthetically or acquired, generally will have separate tables by commodity. This is because commodities are expected to behave in similar fashion in trip generation to changes in activity drivers, such as employment; in trip distribution to changes in accessibility such as interzonal composite costs; and in mode choice to changes in costs by mode regardless of location. For service or nonfreight trucks, this may mean difference by land use categories, since truck trips to, from, and between land uses should behave in a similar manner.
- Validations are classifications that are developed to assist in model validation. These may not be flows that can be expected to behave similarly, but reflect flows that are consistent with observable characteristics. Thus, while not all single-unit trucks or combination tractor-trailer trucks might be expected to behave in the same manner, this classification may be used in the model because it develops volumes that assist in model validation against observed truck classification counts.
- Benefits are classifications developed during benefit calculations and may reflect classifications that are useful in benefit/impact analysis. While flow in these classifications will not necessarily behave similarly nor be consistent with observable validation flows, they may be useful classifications in the benefits/impacts calculation. An example would be the use of gross vehicle weight (GVW) for trucks. This may be useful in that different emission rates have been established for different gross vehicle weights, despite the fact that vehicles that have the same GVW are not expected to behave similarly, and that GVW is not a readily observable characteristic of truck flow on specific highway links.

Table 4.3. Tonnage production equations for selected commodities (2002, ktons).

SCTG	NAICS	Description	Coefficient	*T-Stat*	R2
Cereal Grains (2)	311	Food Manufacturing	0.407	5.11	0.48
		Farm Acres (in Thousands)	0.441	4.20	
Other Agriculture Products (3)	311	Food Manufacturing	0.188	10.43	0.65
		Farm Acres (In Thousands)	0.051	2.14	
Meat/Seafood (5)	311	Food Manufacturing	0.053	25.94	0.86
Milled Grain Products (6)	311	Food Manufacturing	0.053	13.64	0.62
Logs (25)	113	Forestry and Logging	0.323	4.02	0.70
	115	Support Activities for Agriculture and Forestry	0.843	3.91	
	321	Wood Product Manufacturing	0.465	6.48	
Wood Products (26)	321	Wood Product Manufacturing	0.625	18.37	0.75
Newsprint/Paper (27)	113	Forestry and Logging	0.887	13.59	0.73
	323	Printing and Related Activities	0.086	7.38	
Paper Articles (28)	322	Paper Manufacturing	0.101	10.76	0.81
	323	Printing and Related Activities	0.038	4.82	
Base Metals (32)	331	Primary Metal Manufacturing	0.424	8.69	0.75
	333	Machinery Manufacturing	0.085	3.24	
Articles of Base Metals (33)	332	Fabricated Metal Product Manufacturing	0.115	14.51	0.65
Machinery (34)	332	Fabricated Metal Product Manufacturing	0.085	2.92	0.63
	333	Machinery Manufacturing	0.081	2.01	
Electronic and Electrical (35)	333	Machinery Manufacturing	0.02	3.00	
	334	Computer and Electronic Product Manufacturing	0.012	4.35	0.70
	335	Electrical Equipment, Appliance, and Component Manufacturing	0.029	2.44	

Source: Cambridge Systematics, *Development of a Computerized Method to Subdivide the FAF2 Regional Commodity OD Data to County-Level OD Data*, FHWA, January 2009, unpublished.

Step 4. How Much Freight? Trip Generation: Productions and Attractions by Commodity in Tons

This step is necessary for those models that estimate commodity freight tables synthetically. The volume of commodity flows that begin in a zone, called productions, and an end in a zone, called attractions, must be determined for each zone. Since mode choice is a later step, at this point, the freight flow must be expressed in units that are common to all modes. Commonly, this is tons, although other multimodal units (e.g., value) can be used. To calculate the productions and attractions for each zone, the economic drivers of freight must be available. These drivers will be some indication of the size (e.g., as indicated by employment) of the different industries that produce or attract (consume) freight. Since shipments of commodities can be expected to be associated with different industries, equations relating the freight productions and attractions will be developed for those commodities that are expected to respond similarly to certain industries. Public agencies generally develop equations for their own study area from a commodity flow survey for their area. Some general equations have been developed for an FHWA project to disaggregate FAF2 data from regions to counties.[12] A sample of these equations is shown in Table 4.3. However, any average equations should be used with caution, since the economies of each state and region are so different that average equations developed for average economic conditions can not be expected to apply.

Additionally, equations for freight productions and attractions can not be expected to apply to all zones. In passenger forecasting, there are zones that generate significant trips (e.g., airports) not related to employment as an indicator of activity. These zones are treated as special generators where the number of productions and attractions are directly specified in any model forecasts. In freight forecasting, this same treatment as special generators is required for ports, rail terminals, and

[12] Cambridge Systematics, *Development of a Computerized Method to Subdivide the FAF2 Regional Commodity OD Data to County-Level OD Data*, FHWA, January 2009, unpublished report.

other locations that might be significant producers or attractors of freight for commodities, but for where there is no significant employment in these zones in the industries associated with those commodities.

Step 5. Where Does the Freight Go? Trip Distribution: Trip Table Os and Ds

This step is necessary for those models that estimate commodity freight tables synthetically. The distribution of productions from, and attractions to, zones, as calculated in Step 4, must be distributed between all of the zones. Although this distribution may be based on an existing table of freight flows, through a Fratar process, the most common means of synthetically distributing trips between zones is through the use of a gravity model. In the gravity model for freight, as in other transportation applications, the mathematical equations used are applied separately for flows with similar behavior (e.g., commodities). The productions and attractions by commodity are distributed in the gravity model based on the accessibility between the zones, as measured by the impedance between zones. For freight models, the impedance variable for the large geographies considered by freight is most often found to be distance. By examining the commodity flow survey data, it is possible to determine those parameters, such as the average trip length by commodity, which are used to vary the accessibility in response to changes in the impedance variable. The match of the trip length distribution for one commodity in the Florida freight model of the observed commodity flow and the estimated flow in a gravity model is shown in Figure 4.3. It is possible that impedance variables other than distance and other distributions may better match observed data. Practitioners are urged to consult freight references such as the QRFM to explore this topic in detail.

Step 6. What Mode Does Freight Use? Mode Choice: Trip Table Os and Ds by Mode

This step is necessary for those models that estimate commodity freight tables synthetically. The multimodal tonnages moving between zones must be allocated to the various modes that are used to transport freight. The choice of mode used by freight is a complicated process. As discussed in Section 3.5, the choice will be based on many considerations, including the characteristics of the mode, goods, production zone, and attraction zone. When insufficient detail exists to properly model this choice, either because the format and parameters of the choice equations or the data on the characteristics are not known for the base or forecast year, the future choice of mode is assumed to be the same as the existing choice of mode. When this model of forecasting mode choice is used, as it is in many freight models and in FHWA's FAF, it is assumed that the factors effecting mode choice are captured in the existing observed mode choice by commodity. Thus, when the mode share is forecast to change over time, it reflects changes in the volume and mix of commodities carried. For example, in Table 4.4, which is from the FAF2 state profile of California, the freight mode share by truck is forecast to change from 73 percent in 2002 to 77 percent in 2035. However, this is because the forecast of the commodity mix for California is different from the mix in the base year. A basic assumption in the FAF2 is that for each commodity in the FAF2, the mode share in 2035 is the same as it was in 2002.

If the mode share is available for an existing year, that table of mode shares by commodity can still be examined to find OD pairs that perform worse than other OD pairs at the same distance. The mode shares for these markets can be adjusted in a qualitative process to reflect policy changes—for example those that might be expected to bring their mode share to aver-

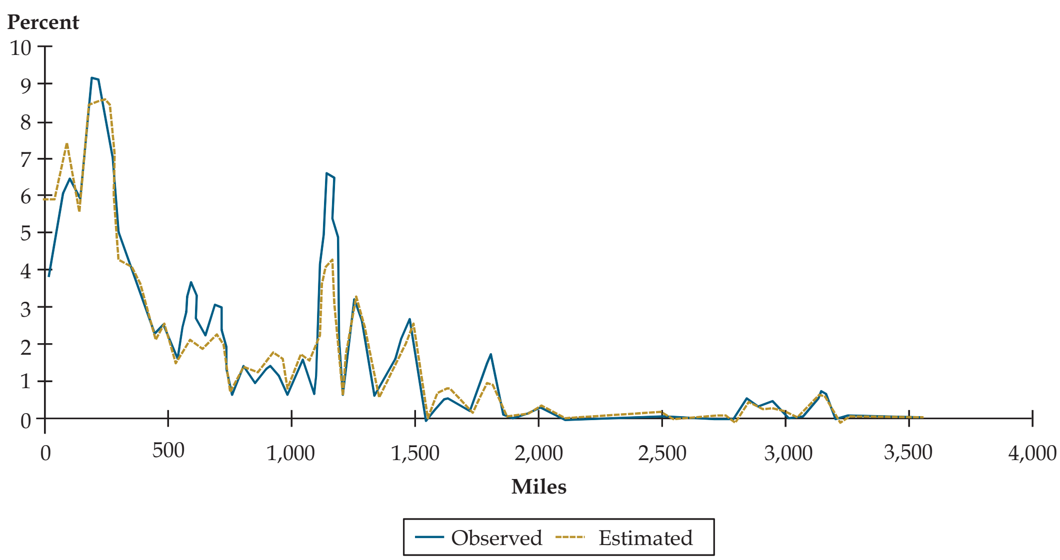

Figure 4.3. Florida freight gravity model results (food products).

Table 4.4. FAF freight shipments from California by weight (2002 and 2035, millions of tons).

	2002 From State		2035 From State	
	Number	Percent	Number	Percent
Total	127.4	100	476.9	100
Truck	92.8	73	366.0	77
Rail	11.7	9	35.4	7
Water	1.2	1	2.2	<1
Air, air and truck	0.4	<1	2.6	<1
Truck and rail	4.0	3	14.3	3
Other intermodal	5.0	4	29.5	6
Pipeline and unknown	12.4	10	26.7	6

Source: FHWA, FAF2 California State Profile.

age conditions. This accepted forecasting technique for mode choice is often referred to as Market Segmentation.

In some cases, it is desirable to develop estimates of mode choice for markets in which the modal information is limited (e.g., because the mode was never offered). In this case, adjusting the mode share to match observed averages would not apply. For this case and for any case where estimates prepared by a qualitative process are needed, a mode choice model may be developed. This is not a trivial undertaking and will likely require a survey to identify the significant variables in the mode-choice decisions, as well as the coefficients and other parameters that should be applied to these variables. Section 3.5 describes a process where the FAF2 commodity flow was used as an RP survey to determine these variables and their parameters. Section 3.5 did find that, consistent with the choice decisions reveled by the FAF2, that modal distance, which presumably serves as a surrogate for modal cost and time, is the most significant explanatory variable in mode choice.

Step 6a. Direct Acquisition of Commodity OD Tables: Alternate Ways to Get Freight OD Tables

The equations required in Steps 4, 5, and 6 to develop a synthetic freight trip table by mode most likely will be developed from a commodity flow survey. Typically, those freight surveys, unlike household surveys used in passenger planning, already have been expanded to represent all geographies over an extended time period, most often a year. Although these commodity flow surveys may not be formatted like the trip tables used in freight forecasting, it requires little effort to reformat these surveys into tables. When a commodity flow survey has been acquired and developing the trip generation, trip distribution, and mode-choice equations from that survey, as well as the forecast data required to use these models, is costly, a decision to use that commodity flow directly in the modeling process may be quite reasonable.

This step uses an acquired commodity flow survey as a trip table. Generally, this survey will dictate the behavioral classifications used in the model (e.g., the commodities and/or modes in the survey will be used in the forecasting model). Additional processing of the acquired table may be necessary to convert from the geographies used in the survey to the zones used in transportation modeling.

Step 6b. Economic/Land Use Model: Alternate Ways to Get Freight OD Table by Mode

The process described produces a trip table where the economic/land use activities that give rise to freight are exogenously supplied to the freight model. However, the freight demand may be considered as part of a complex iterative economic/land use decision. This step may consist of the repetition of earlier steps, which allows the forecast of economic activities to be varied in a feedback loop, after the performance of the system is calculated in Step 10.

More complex economic models may explicitly include a trip generation step (freight produced by zones), a trip distribution step (freight moving between zones), and a mode-choice step (freight moving between zones), including mode used. Any or all of these steps may replace the synthetic steps described in Steps 4 through 6. The economic model may not use the same geographies as the transportation process, therefore, it may be necessary to disaggregate flows of the geographies in the economic model to zones compatible with network assignment. Unless the economic model includes other nonfreight flows that impact freight performance, there may be a need to examine the outputs of the economic model with outputs of assignment (e.g., to see if the speeds and times are consistent), and iterate as necessary.

Step 7. How Many Freight Trucks? Payload and Temporal Factors: Trip Table Os and Ds by Mode by Vehicle

This step converts commodity flow trip tables to a format that is consistent with the assignment process to be used in Step 9. Commodity flows tables, whether acquired or produced synthetically, are most often in tons per year. Most transportation assignment processes assign vehicles per day. Thus, it is necessary to convert the flow in tons to flow in vehicles (e.g., trucks), and to convert from flow per year to flow per day. The development of factors to convert tons to vehicles for trucks may be based on local observations or surveys, or may make due with national surveys such as the Vehicle Inventory and Usage Survey. The payload factors, tons per truck, must match the behavioral commodity classification system used by the model. Table 4.5 shows a table of payload factors that is used by Tennessee DOT (TnDOT) in freight forecasting.

In addition to commodity as shown in Table 4.6, other considerations may be important in developing payload factors. These considerations include the length of the haul, the empty mileage, the class of the vehicles, etc.

A second conversion is necessary to the commodity flows to correct for the time period to daily. While other practitioners have used conversion factors from 250 to 365 days per year, as discussed in Section 3.2, dividing annual flows by 310 days might be the appropriate adjustment for an average weekday. If the average weekday in the forecasting model should be for midweek truck flows, it may be appropriate to divide annual flows by 295 days.

In addition to adjustments to average weekdays, commodity flow forecast adjustments for seasonal variations may be required. As discussed in Section 3.4, while local commodity flows may vary due to local facilities and conditions, national averages indicate little need to adjust average commodity flows for seasonal variations.

For some applications, it may be necessary to adjust commodity truck flows to hourly volumes. Again based on the research reported in Section 3.4, the hourly flows for trucks should be considered to be 6 percent of daily flow for each of the hours from 11:00 A.M. to 7:00 P.M.

Step 8. What Service and Other Trucks Must be Considered with Freight? Nonfreight Vehicle OD Tables

This step supplies a table of all other truck activities, which are in addition to the truck table forecast to carry freight. The trucks that provide services, move construction materials and equipment, and are used in maintenance activities, as well as the local movement of goods that is not included in commodity flow tables interact with commodity trucks on the highway system. In order to properly determine the performance of the freight trucks, it is necessary to have tables for all vehicles sharing the highway system with freight trucks, including those trucks that do not carry freight.

Freight may move over national distances, and the model area used in forecasting freight flows may not be the same as the model area needed to address nonfreight, service, trucks that have primarily a local area of operation. For that reason models may choose to handle the nonfreight truck table differently than the freight truck table. The forecast of nonfreight trucks will most often be through a synthetic process of trip generation and trip distribution, similar to the steps for freight

Table 4.5. TnDOT freight model truck payload after adjustment.

Commodity	Pounds per Truck	Tons per Truck
Agriculture	48,500	24
Chemicals	48,500	24
Construction and mining	50,500	25
Food and kindred products	48,500	24
Household goods and other manufactures	38,500	19
Machinery	36,500	18
Mixed misc. shipments, warehouse and rail intermodal drayage, secondary traffic	36,500	18
Paper products	46,500	23
Primary metal	51,500	26
Timber and lumber	53,000	27

Source: PBS&J, Tennessee Long-Range Transportation Plan Freight Model, 2005.

Table 4.6. Comparison of trip rates by truck type and land use.

Truck Type	14,000–28,000 Lbs		8,000–28,000 Lbs	14,000–28,000 Lbs	2–4 Axles, 6+ Tire, Single–Unit, 16,000–52,000 Lbs	
Land Use	NWRG Survey (Production)	NWRG Survey (Attraction)	NCHRP 298 (MAG)	NCHRP 298 (SCAG)	PSRC Truck Model (Production)	PSRC Truck Model (Attraction)
Households	0.011	0.011	0.069	0.0087	0.0163	0.0283
Ag/Mining/Construction	0.040	0.044	0.106	0.0836	0.0404	0.2081
Mining					0.0404	10.8831
Construction					0.0453	0.0644
Retail	0.032	0.035	0.132	0.0962	0.0744	0.0090
Government						
Education/Government	0.037	0.038	0.006	0.0022	0.0135	0.0118
Finance/Insurance/Real Estate	0.008	0.008	0.021	–	0.0197	0.0276
Manufacturing						
Products	0.050	0.050	0.100	0.0575	0.0390	0.0396
Equipments					0.0390	0.0396
Transportation/Utility	0.168	0.170	0.106	0.4570	0.0944	0.0733
Wholesale	0.192	0.190	0.106	0.0650	0.1159	0.0258
Other	–	–	0.106	0.0141	–	–

Source: Cambridge Systematics, *SCAG Heavy-Duty Truck Model Update*, Southern California Council of Governments, April 2008.

described in Steps 4 and 5 above. The trip generation rates and the trip distribution factors should be developed through the use of commercial vehicle surveys. One example of trip rates for nonfreight trucks is shown in Table 4.6. This table, develop for the Southern California Association of Governments (SCAG), shows rates from other models in order to provide context for the SCAD model development. The development of a nonfreight truck trip table may be an adaptation of an existing total truck table. If this is the case care must be taken to avoid double counting the trucks that carry freight. It will be necessary to adjust the total truck trip rates and distributions to account for the freight trucks that are being handled separately.

Step 9. What Facilities Do Freight Vehicles Use? Assignment of Modal Vehicles to Networks

This step assigns the freight trip tables, expressed in modal vehicles, to the modal networks. Although public agencies traditionally forecast assignment to the highway system, they less often forecast assignment to other modal networks. That does not mean that Steps 4, 5, and 6 or the alternate processes described above are not worthwhile. Unless freight is addressed multimodally, the trip table of freight trucks could consider all of the multimodal decisions made in moving freight. The difficulty in making assignments to modal networks is twofold. First the information about the other modal networks may be limited. The connections, availability, and capacity of the links forming the other modal networks may not be readily available, particularly in a format that can be used in assignment. When the modal networks are available in a format that can be used in assignment models (e.g., all nodal connectivity issues have been addressed and zonal connectors have been added), the whole issue about how these routing decisions are made must be decided. The routing decisions of freight over the railroad, air, and water networks reflects business decisions that are in no way similar to the multiclass user equilibrium assignment routines used by highways. For the TnDOT and the Association of American Railroads (AAR), rail assignments have been prepared that assign rail trip tables using shortest distance assignments that do not consider operational or capacity diversions.

When truck freight assignments are made to the highway system, it must be recognized that freight trucks are not the only vehicles, much less the only trucks, using the road. The performance of freight trucks on the highway network should consider the assignment of the freight truck table, together with the nonfreight trucks discussed in Step 8, as well as all other vehicles, such as autos that use the highway. These multiclass user equilibrium highway assignments already are customarily being prepared by transportation practitioners in support of public decisionmaking. For freight planning, it is also necessary to track the assignment of freight trucks in order to report on their specific volumes and the paths that they use.

Step 9a. What Facilities Do Freight Vehicles Use? Direct Estimation

This step bypasses all of the forecasting steps described above. It uses the time series models, which consider historical freight flows separately or with other economic factors, to develop freight forecasts. Because those steps are skipped, changes in freight trip generation unrelated to the facility being examined can not be considered, nor can issues of redistribution of freight, modal diversion of freight, or route diversion of freight, which would be explicitly considered by the other steps discussed previously.

However, there are instances where a freight model does not include the freight facility for which forecasts are desired. The decision being considered may not be unique enough to warrant the development of a freight model. Impacts of the freight project on other conditions, for example, on the economy or the environmental, may be simple or small enough to be ignored. If this is the situation, the forecasts are limited to a single freight facility, the other impacts are not considered, and the impacts of the project can be considered simply—a trend forecast may be sufficient as a freight forecast.

Step 10. How Do Freight Vehicles Perform on the Network? Estimation of Benefits

Public decisions are not easily made using the outputs of transportation forecasting models. Public decisions are based on how the scenarios examined produce benefits for the users, business, and society. The benefits, cost, and impacts of transportation projects need to be evaluated not only against other transportation projects, but against other public investments and policy decisions. To make these comparisons, it is customary to process the outputs of transportation models—the volumes and performance of vehicles on modal networks—into other more generic impacts such as direct and indirect costs, emissions of green house gases and other pollutants, and economic development.

This step considers the use of models to calculate the benefits and impacts of freight transportation projects, policies, and programs. Most benefits evaluations recognize that transportation activities, including freight, can impact the system in multiple ways. For example, Moving Cooler,[13] calculates emission impacts from transportation as being related to changes in demand, operation, vehicle technology, and fuel. The freight forecasting steps described above can not consider vehicle

[13] Cambridge Systematics, Inc., *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions,* Urban Land Institute, July 2009.

technology or fuel, nor would freight policies be expected to change these elements. However, the steps described above directly consider the changes in demand and operations, as measured by speeds and times.

Benefits and impacts are calculated based on using the demand and operational performance associated with freight projects, programs, and policies. The outputs of these evaluations may be monetized, may be in environmental emissions, or in other units that may allow for useful comparisons. The benefits models may be simple spreadsheet formulations or complicated evaluation packages such as FHWA's IDAS or STEAM software programs. The interaction with the freight forecasts is to process the outputs of freight forecasting into a format that can be used as inputs into these evaluation models. This may require geographic or temporal aggregations of the outputs for the freight forecasting process. The output of this step is typically used in proving the values for the performance measures that were previously described in Step 2.

4.2 New Methods to Generate Freight Demand and Performance

Although the freight forecasting process described in the steps above can adequately support most existing public decisions, it is not clear that they will always be able to provide this support as the decisions under consideration change. New methods of monitoring, regulating, and charging for vehicle operations may require different models. For passenger activities, this has led to the development of activity-based modeling, where trips are not considered in isolation but are considered as a chain of trips supporting those activities. A variety of research is underway to study how freight and truck activities would function as activity/chaining models. In order to support these activities for truck and freight models, additional research is needed to determine the number of trips in a chain, the length of trips in the chain, and the degree to which the next stop is governed by the characteristics of the current stop.

Section 3.3 described research that was conducted using inexpensive GPS data to determine this information. The records of trucks subscribing to GPS services were examined and processed in several metropolitan areas. Values were produced that can be used in truck chaining models. Truck GPS subscription records can be expected to become more commonly available. Ways to disclose more detailed information about the type of truck without disclosing proprietary information are likely to be developed. This may preclude the need for expensive and time-consuming survey efforts and may make truck freight chaining models more widely available.

In addition to truck activity chaining in freight, the partnership between public and private freight interests is likely to require improved models for the total logistics process. These models are necessary for the public and private decisionmakers to have adequate information to determine the value of public–private partnerships.

Similarly, some network and facility design models supporting freight, which are primarily used to support private investment decisions, may need to be available in public forms if decisions on the value of public–private partnerships to develop these facilities are to be considered.

The outreach to public decisionmakers identified the lack of data as a serious gap in preparing freight forecasts. Improvements in freight data collection were not a focus of this project because this is being pursued by TRB and U.S. DOT as well as other agencies in many on-going research projects. However, the data that currently are available may be better utilized to prepare the necessary freight-related data. The research topics investigated in Section 3 were specifically chosen to exploit existing public, available—or in the case of subscription GPS—low-cost data. That research has shown that, in addition to new and improved data collection activities, efforts to better use existing data could help fill freight data gaps.

CHAPTER 5

Conclusions and Recommendations

The literature review found that there is a considerable body of research associated with developing new methods for analyzing the transportation issues associated with freight. Those methods are suitable for addressing a variety of topics of concern to public decisionmakers. Those models can be classified according to a framework and that classification can be applied to those models used by both the public and private sectors. The most well-developed applications in support of public–sector decisions were time series and commodity-based models, with a growing interest in, and application of, network and microsimulation models. A survey of staff supporting public–sector decisionmakers found a general satisfaction with the types of models that are available, but a general concern about the availability and quality of data that can support public decisionmaking for freight policies, programs, and projects. The research topics pursued focus on the use of publicly available or low-cost data that can support the improvement of the models used in freight forecasting and analysis.

- Research into the use of low-cost GPS data for trucks, as available, from subscribers to commercial monitoring services, found that these data can be easily processed to improve the understanding of where trucks stop, and to identify the connections between those truck stops. Both the interchange of trips between land uses and the average characteristics by trip were found to be similar among four observed metropolitan areas.
- Research in the use of publicly available truck classification data together with publicly available commodity flow data, as assigned to a highway network, found that flows by different commodities were fairly similar both seasonally within a year and temporally within a day. This seasonal finding was compared with economic trade data from the economic census of manufacturers. The comparison showed that economic activity by commodity/industry, which would be expected to result in freight flows, was also generally uniform throughout the year.
- Research in the use of publicly available commodity flow data found it to be suitable for use as an RP survey to develop mode-choice parameters. Sufficient data were available from a variety of sources that could provide information about possible decision variables affecting mode choice. The analysis showed that distance was the primary determinant of mode choice for most commodities, and that other decision variables were only significant when used in a function together with distance. The inability to develop better models of freight mode choice suggests that those modal decisions are due to localized logistics and business decisions that might not be easy to forecast. The inability to define better mode-choice functions suggests that methods that pivot from observed mode shares might be more appropriate.

The literature review, survey, and research led to the development of a proposed guidebook for freight forecasting. The proposed 10-step process should provide suitable guidance for transportation planners to include freight flows, and flows of commercial trucks serving purposes other than carrying freight, into their forecasting process.

Section 3.2 of this report discusses topics that, although not chosen for additional research in this project, were identified as areas that might fill critical gaps in the freight forecasting processes. Additionally, the research topics that were addressed suggested the following additional avenues for research:

- The GPS research topic suggests that the utilization of commercial subscription GPS data, especially as these data are improved through the addition of more explanatory variables such as engine status or vehicle type, is especially promising.
- The seasonal and temporal flow research topic suggests that additional emphasis on obtaining complete continuous truck classification count data for entire years, and the utilization of that data to develop suitable factors, is warranted.
- The research in the use of commodity flow databases as an RP survey topic suggests that the utilization of flow data for historical years, as well as potential decision variables for these same years, could lead to promising insights about how mode-choice decisions are made.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation