

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

# NCHRP Report 388

*A Guidebook for*  
**Forecasting Freight  
Transportation Demand**

**Transportation Research Board  
National Research Council**

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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# Report 388

## *A Guidebook for* **Forecasting Freight Transportation Demand**

**CAMBRIDGE SYSTEMATICS, INC.**  
Washington, D.C.

with

**LEEPER, CAMBRIDGE & CAMPBELL, INC.**  
McLean, VA

and

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and

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**TRANSPORTATION RESEARCH BOARD**  
NATIONAL RESEARCH COUNCIL

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## **NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM**

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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# FOREWORD

*By Staff  
Transportation Research  
Board*

This report provides reference information on freight transportation planning processes, techniques, tools, data, and applications. The report is organized in a Guidebook format to assist planning practitioners and policy analysts to effectively integrate freight planning and demand forecasting into the broader multimodal transportation planning process. Because freight issues are now major concerns to the state DOTs, metropolitan planning organizations (MPOs), port and airport authorities, rail and trucking providers, shippers, and various federal agencies, this Guidebook will provide much needed assistance to a wide range of practitioners. The appendices of the Guidebook contain useful information concerning factors impacting freight demand; freight demand forecasting studies; freight data sources; descriptions of survey procedures; statistical forecasting techniques; transport cost estimation; modal diversion and descriptions of related models; case studies; and public agency information needs. This Guidebook is intended to support a range of planning including strategic and policy planning, statewide or regional systems planning, and more detailed project-level analyses. It will also serve as a basic educational resource into the components of effective freight planning.

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Federal transportation policy as embodied in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has significantly changed transportation planning requirements and expectations at the national, state, metropolitan, and local governmental levels. One major element of that policy having profound implications for decision makers is the requirement for integration of planning and resource commitments for both passenger and freight transportation modes. At the same time, global economic changes are having significant impacts on freight transportation demand. Factors such as worldwide demographics, energy availability, industrial and logistics practices, labor markets, and trade patterns between nations and regions are but a few examples of forces driving demand for freight transportation service and capacity.

There is broad recognition of the need for comprehensive freight policies at the national and state levels and for improved freight planning methods available for statewide, regional, and local application. In order to achieve such policies, the characteristics of freight demand, trends in freight demand, and the relationships between freight transportation demand and capacity need to be understood. There also is a need for integrating the consideration of freight demand into transportation systems and facility planning, financing, operations, and development. Finally, the state of the practice in terms of analytic tools available to effectively forecast freight requirements should be assessed.

Under NCHRP Project 8-30, *Characteristics and Changes in Freight Transportation Demand*, Cambridge Systematics, Inc., in cooperation with Leeper, Cambridge & Campbell, Inc.; Sydec, Inc.; Thomas M. Corsi; and Curtis M. Grimm, formed the

research team to (1) carry out in-depth reconnaissance into current practices, policies, issues, procedures, studies, tools, and data resources in freight demand estimation and planning; (2) develop a preliminary Guidebook to be presented in a workshop session attended by (a) state and local transportation planners, (b) freight planning practitioners, (c) public and private sector practitioners in truck, rail, and water transport, and (d) transportation industry analysts involved in research; and (3) prepare a revised Guidebook based on the results of the workshop and the review by the project panel.

In addition to the Guidebook, this project produced an unpublished final report that describes the entire project, summarizes its conclusions, and suggests further research needs. The project final report is available on a loan basis by request to NCHRP, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, DC 20418.

# CONTENTS

<b>1</b>	<b>CHAPTER 1 Introduction</b>	
	Purpose and Audience for the Guidebook, 1	
	The Need for Greater Attention to Freight Transportation Demand, 1	
	Characteristics of Freight Demand, 1	
	A Comparison with Passenger Demand, 1	
	Modeling Transportation Demand, 2	
	The Current Study, 2	
	Phase I—Reconnaissance, 2	
	Phase II—Develop the Guidebook, 2	
	Phase III—Revise the Guidebook, 3	
	Related Research, 3	
	Organization of the Guidebook, 4	
<b>5</b>	<b>CHAPTER 2 The Freight Transportation System and Public Sector Planning</b>	
	An Overview of the Logistics Process, 5	
	Key Factors Influencing Freight Transportation Demand, 7	
	Direct Influences, 7	
	Indirect Influences, 8	
	Freight Demand and Public Sector Transportation Planning, 10	
	The Need for Freight Demands Forecasts, 10	
	Requirements for Freight Transportation Planning, 11	
<b>12</b>	<b>CHAPTER 3 Demand Forecasting for Existing Facilities</b>	
	Current and Historic Data on Facility Use and Transport Activity, 12	
	Facility Data, 12	
	Published and Proprietary Data, 12	
	Special Surveys, 13	
	Sources of Economic Forecasts, 13	
	Economic Indicator Variables, 14	
	Some Examples, 14	
	Improving the Forecasts, 16	
	Statistical Techniques, 18	
	Regression Analysis, 18	
	Some Basic Issues, 18	
	Univariate Time-Series Techniques, 19	
	The Structural Econometric Time-Series Approach, 20	
	Alternative Futures, 20	
	Sensitivity Analysis, 21	
	Futures Analysis, 22	
<b>23</b>	<b>CHAPTER 4 Demand Forecasting for New Facilities</b>	
	Potential Freight Market, 23	
	Forecasting Changes in the Market, 24	
	Sources of Demand for a New Facility, 24	
	Route Diversion, 24	
	Induced Demand, 26	
	Estimating Demand, 27	
	Surveying Shippers and Carriers, 27	
	Comparisons with Previous New Facilities, 29	
	Evaluating Proximity and Level of Service, 30	
	Analyzing Total Logistics Costs of Individual Shipments, 33	
	Alternative Futures, 34	
<b>36</b>	<b>CHAPTER 5 Policy Analysis</b>	
	Developing a Policy Impact Analysis Framework, 36	
	Developing a Profile of Base-Case Conditions, 37	
	Estimating the Effect of Policies on Costs and Other Service Characteristics, 38	
	Translating Policies into Cost Impacts: A General Framework, 38	
	Cost Estimating Procedures, 39	
	Estimating Policy-Related Changes in Demand, 39	
	Rail/Truck Diversion, 39	
	Barge/Rail Diversion, 40	

<b>41</b>	<b>APPENDIX A</b>	<b>Factors Influencing Freight Demand</b>
<b>60</b>	<b>APPENDIX B</b>	<b>Reviews of Freight Demand Forecasting Studies</b>
<b>70</b>	<b>APPENDIX C</b>	<b>Freight Activity Data Sources</b>
<b>100</b>	<b>APPENDIX D</b>	<b>Freight Transportation Survey Procedures and Methods</b>
<b>106</b>	<b>APPENDIX E</b>	<b>Statistical Forecasting Techniques</b>
<b>119</b>	<b>APPENDIX F</b>	<b>Estimating Transport Costs</b>
<b>130</b>	<b>APPENDIX G</b>	<b>Rail/Truck Modal Diversion</b>
<b>136</b>	<b>APPENDIX H</b>	<b>Three Modal-Diversion Models</b>
<b>139</b>	<b>APPENDIX I</b>	<b>Case Studies</b>
<b>157</b>	<b>APPENDIX J</b>	<b>Informative Needs Perceived by Public Agencies</b>

## CHAPTER 1

# INTRODUCTION

### PURPOSE AND AUDIENCE FOR THE GUIDEBOOK

This Guidebook is intended to be used as a reference document by transportation planners who require forecasts of freight transportation demand for facility planning, corridor planning, or strategic planning, or who wish to gain a greater understanding of influences on private decision making related to freight shipments. Transportation modelers, who may wish to incorporate some of the forecasting techniques presented into their models, also should find this Guidebook useful, as should educators, policy analysts, and corporate planners.

Techniques and supporting information are presented for a variety of analyses involving freight demand. These include analyses to support any type of decision-making situation for which changes in demand for freight transportation are a potentially significant issue. Changes in freight demand might include any of the following:

- Forecasts of increases or decreases in flows over time as a result of economic growth, changes in the economy, or changes in the transport system;
- Diversion of flows to new or expanded facilities;
- Diversion of flows across modes due to regulatory actions, pricing policy, capacity changes, or changes in service level; and
- Analyses of future scenarios.

References are provided to other documents for more detailed information on procedures and data sources.

### The Need for Greater Attention to Freight Transportation Demand

This Guidebook fills a void because very little material is available in existing documents designed to provide guidance for freight transportation planning. The demand for freight transportation planning in the public sector has been growing rapidly, and there is a need for new guidelines due to the planning and monitoring system requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. This legislation instituted entirely new requirements for both comprehensive statewide transportation planning

processes and metropolitan area transportation planning processes to address issues relating to freight and intermodal transportation. Moreover, these planning requirements have become more relevant for decision making because adopted plans and Transportation Improvement Programs (TIPs) now are required to be financially feasible, unlike the financially unconstrained “wish lists” that were routinely adopted without the need for serious choices in many previous planning processes.

These new ISTEA requirements reflect not only an effort to reduce or eliminate shortcomings from previous planning programs, but also a recognition that freight and intermodal transportation are growing rapidly and becoming a more important part of metropolitan, state, national, and world economies. International trade is a rapidly increasing portion of the national economy, and most of this trade involves changes in mode of transportation between the domestic and international legs of shipments. The increasing flows of freight through terminals, their access facilities, and many of the line-haul facilities are creating congestion, time delays, expansion needs, conflicts with passenger movements, and a variety of other challenges to old, single-mode operating systems.

Thus, this Guidebook is not merely a response to new federal mandates, it attempts to respond to planning needs that will be increasingly important in the future.

### CHARACTERISTICS OF FREIGHT DEMAND

#### A Comparison with Passenger Demand

The demand for freight is considerably more complex than passenger demand with respect to the following dimensions:

- **Units of Measure**—It is easy to count passengers. However, freight may be measured in units (e.g., number of automobiles, number of less-than-truckload shipments), by weight (e.g., tons), or by volume (e.g., cubic feet, carloads, container loads).
- **Value of Time**—There are substantial differences between the values placed on time by different passengers, and even between the values placed on waiting time and travel time. The average values also vary by

mode of travel (e.g., bus versus airplane). However, these differences are small compared to those that can exist between the values of time for different freight commodities (e.g., coal and cut flowers).

- **Loading and Unloading**—Passengers generally require a minimum of assistance in getting on and off a vehicle and in making modal connections. Freight requires a variety of different facilities and equipment, and most intermodal facilities are relatively specialized in the types of freight they are designed to handle.
- **Type of Vehicle**—All passenger vehicles contain seats; a very few contain sleeping accommodations. Freight vehicles include both general-purpose containers, vans and boxcars, and special-purpose vehicles designed for carrying refrigerated goods, specific types of liquids, dry bulk, etc.
- **Number of Decision Makers**—The demand for passenger transportation services is determined by a large number of decision makers, each of whom contributes only a small portion of total demand. In contrast, the demand for freight transportation services is determined by a much smaller number of decision makers (shippers, receivers, agents and carriers), some of whom may control significant shares of total demand. Therefore, analyzing freight demand requires a greater understanding of the factors that influence individual decision makers.

## Modeling Transportation Demand

Despite the fact that freight demand is far more complex than passenger demand, most public sector research has been devoted to understanding passenger demand. As a result, a number of useful techniques and models have been developed for forecasting passenger demand, particularly for local movements within individual metropolitan areas.

In the late seventies and early eighties, several ambitious research projects were undertaken to develop comprehensive freight models, generally on a national scale.<sup>1</sup> However, most of these models were found to be unworkably complex and most were abandoned. Perhaps the most successful of these early freight modeling efforts was the one that led to the development of the Association of American Railroads' Intermodal Competition Model (ICM)<sup>2</sup>.

## THE CURRENT STUDY

The current study consisted of the following three phases:

### Phase I—Reconnaissance

In the first phase of this study, we performed the following work:

- Interviewed and surveyed federal, state, and local freight transportation planners and policy analysts to understand their needs and concerns;
- Reviewed current policy issues;
- Reviewed previous freight studies and modeling efforts;
- Identified key characteristics of freight demand, along with the economic, social, political, technological, and environmental factors that influence these characteristics; and
- Evaluated alternative potential products of our research.

The results of the interviews and surveys are summarized in Appendix J.

Some of the findings of the first phase of our study were as follows:

- Most state and local agencies have little experience in forecasting freight demand;
- There are significant differences between the needs of planners and policy analysts;
- Data availability is a critical consideration; and
- Forecasting procedures should be designed to identify a range of possible futures and assess their likelihood, rather than to produce single-point estimates of the future.

One of the most important conclusions of this reconnaissance was that multimodal freight demand is too complex to be adequately addressed in a single comprehensive model. Some demand issues, such as competition between selected modes, can be addressed by relatively specialized models. However, many planning issues, such as evaluating proposals for new freight facilities, require analyses that are too location-specific to be performed entirely with a generic computerized model. Models developed for addressing these issues will not be usable without a substantial supporting effort to obtain location-specific data and to reduce these data to the form required by the model.

Instead of attempting to develop a relatively specialized model, we chose to focus our efforts on collecting and developing a range of procedures that are appropriate for use in freight demand forecasting and on preparing a Guidebook for using these procedures.

### Phase II—Develop the Guidebook

The second phase of this study consisted of developing a preliminary version of this Guidebook.

At the conclusion of this phase, a two-day workshop was conducted at which the contents of the preliminary Guidebook were presented and discussed in some detail. Workshop attendees included: state and local freight planners; public and private sector persons involved in truck, rail, and water transport; and transportation industry analysts from universities and other research institutions. These attendees identified

<sup>1</sup> Reviews of the results of several of these projects are included in Appendix B.

<sup>2</sup> A brief description of the ICM is contained in Appendix H.

a number of aspects of the Guidebook that required clarification or expansion. They also recommended that additional work on the Guidebook be completed quickly, and that the final version of the Guidebook be made available to transportation planners as soon as possible.

### Phase III—Revise the Guidebook

The final phase of our study consisted of identifying those Workshop recommendations that could be implemented in a limited time period, implementing them, and preparing this revised version of the Guidebook. A new Chapter 2 was added, providing additional information on the logistics process and some background information on public sector freight planning. Also, in our separate Final Report to the NCHRP Project Panel, we identified seven areas of research related to our study that NCHRP may wish to consider for future funding. The possible research consists of

- Undertaking a broad program of continuing research designed to expand and improve this Guidebook and to update it as needed;
- Undertaking a more focused program of research designed to develop parameters to be incorporated into the Truck-Rail, Rail-Truck Diversion Model (described in Appendix H) and to calibrate and test this model;
- Performing additional research to develop elasticities and other very simple models for estimating the effects of changes in transport costs on the volume of freight;
- Developing a hypertext or expert system to provide planners with guidance for obtaining and using freight data;
- Preparing a synthesis of ongoing and recent work on freight forecasting and database development;
- Developing software to assist Metropolitan Planning Organizations (MPOs) and State Departments of Transportation in using national data sets such as the Truck Inventory and Use Survey, the Rail Carload Waybill Sample, and the Commodity Flow Survey; and
- Developing a spreadsheet implementation of the comparison and/or proximity/level-of-service (LOS) procedures for estimating demand for a new facility (described in Chapter 4, under Comparisons with Previous New Facilities, and Evaluating Proximity and Level of Service), along with more detailed guidance for obtaining and interpreting the project-specific data required by these procedures.

### RELATED RESEARCH

Users of this Guidebook may be interested in some concurrent research activities now underway. Related NCHRP projects include

- *Measuring the Relationship Between Freight Transportation Services and Industry Productivity* [Project 2-17(4)], which is designed to identify, for specific industry groups:
  - The relative significance of transportation and other logistics costs;
  - The relationships among transportation services, infrastructure, operational conditions, and industry productivity; and
  - The potential impacts of future changes in transportation systems and business practices on these relationships.
 The research also is intended to identify how these relationships can be applied in evaluating public sector transportation investment decisions.
- *Economic Trends and Multimodal Transportation Requirements* (Project 2-20), which is analyzing how national and global economic trends are influencing the transportation requirements of American business.
- *Long-Term Availability of Multimodal Corridor Capacity* (Project 8-31), which is developing a *Multimodal Corridor Analysis Manual* for use in estimating the capacity of the freight and passenger transportation systems. This manual includes a chapter on demand estimation and demand management with a principal focus on the use of elasticity and logit techniques for estimating modal diversion.
- *Innovative Practices for Multimodal Transportation Planning for Freight and Passengers* [Project 8-32(1)], which is preparing a compilation of successful and promising, innovative multimodal planning practices.
- *Multimodal Transportation Planning Data* [Project 8-32(5)], which is developing guidelines on the availability and use of data to support multimodal transportation planning.
- *Development of a Multimodal Framework for Freight Transportation Investment* (Project 20-29), which has focused on rail-highway trade-offs in state rail program activities. A continuation of this project is pending.
- *Methodologies Associated with Freight Planning* (Project 20-5, Topic 25-02), which will provide a synthesis of such methodologies.

Also, the FHWA is sponsoring the development of a Quick Response Freight Manual for use by Metropolitan Planning Organizations and State Departments of Transportation. This Manual will be patterned after NCHRP Report 187, *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide*. It will include the following:

- Procedures and guidelines that can be used to predict the number (and temporal distribution) of truck trips to and from specific sites and to identify the routes these vehicles will use; and

- Development of truck trip tables for inclusion in the assignment of total traffic to a metropolitan area or regional highway network.

## ORGANIZATION OF THE GUIDEBOOK

The second chapter of this Guidebook covers several topics relating to the freight transportation system and public sector transportation planning. The first section of Chapter 2 provides an introduction to the overall logistics process, the second section summarizes some of the key issues relating to freight transportation demand, and the final section contains an introduction to public sector freight planning.

Chapters 3 through 5 provide guidance for freight demand analyses and forecasts in three different contexts, each of which places quite different requirements on the analysis. These chapters describe, in a reasonably step-by-step fashion, a number of procedures that are potentially useful in a variety of demand forecasting contexts. Procedures that are useful in multiple contexts are described once and cross-referenced appropriately. Supporting information for use by several of the procedures is contained in the appendices.

Chapter 3 deals with freight transportation demand forecasting for existing facilities. Such forecasts can be used to evaluate the need for, and the appropriate extent of, potential capacity expansions for an intermodal facility, as well as for addressing traffic-related design issues such as pavement thickness. This type of work tends to focus on forecasting trends, potential changes in past trends, analysis of capacity constraints, and expansion requirements to meet projected demand. Sections of this chapter describe various techniques and sources to use when making these forecasts. One section of Chapter 3 describes techniques for analyzing alternative futures, which is a topic that has potential applicability in each of the other two contexts/chapters.

Chapter 4 addresses demand forecasting for new facilities. This type of work tends to focus on predicting diversion from other routes and other modes of transportation, and on ana-

lyzing changes in flows through networks. The procedures discussed in Chapter 3 can be used for forecasting growth in overall transport activity, but different procedures (presented in Chapter 4) are needed for estimating the extent to which future flows will be diverted to use the new facilities.

Chapter 5 deals with policy analysis. Different policy issues tend to require different procedures. Therefore, this chapter emphasizes a structured approach to defining, analyzing, and evaluating issues in a systematic manner to ensure that all critical factors are given appropriate attention. Although the evaluation processes are likely to vary widely depending on the policy options being analyzed, changes in freight demand almost always are important considerations in the evaluation process because many significant impacts (e.g., revenues and environmental impacts) are directly affected by changes in demand.

The appendices contain additional information on a variety of areas:

- Appendix A contains an extensive discussion of key factors that influence freight demand;
  - Appendix B includes reviews of several previous freight demand forecasting and modeling studies;
  - Appendix C contains descriptions of approximately 50 freight databases of interest to users of this Guidebook;
  - Appendix D discusses survey procedures;
  - Appendix E addresses statistical forecasting techniques;
  - Appendix F presents procedures and data for estimating transport costs;
  - Appendix G reviews available information on rail/truck modal diversion and presents some simple procedures for developing order-of-magnitude diversion estimates;
  - Appendix H reviews three rail/truck diversion models of current interest;
  - Appendix I contains two Case Studies of the use of some of the procedures in Chapters 4 and 5; and
  - Appendix J summarizes the results of our Phase I interviews and surveys of public agencies.
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## CHAPTER 2

# THE FREIGHT TRANSPORTATION SYSTEM AND PUBLIC SECTOR PLANNING

This chapter covers three topics relating to freight transportation demand and public sector transportation planning. The first section of the chapter provides a general description of the entire logistics process, of which transportation is one component. The second section presents brief descriptions of a number of factors that influence freight demand. The final section discusses the relationship between freight demand and public sector transportation facility planning, corridor planning, and strategic planning.

### OVERVIEW OF THE LOGISTICS PROCESS

The logistics process consists of all functions relating to the handling and movement of a product from its point of production to its point of consumption by another firm or its sale to an individual. Outbound logistics, formerly known as physical distribution, refers to the portion of this process that is of concern to the producer and extends as far as delivery to the customer. Inbound logistics refers to the portion of the process that is of concern to the firm consuming the product and includes ordering the product, transporting it to the plant gate, and any handling and movement within the plant. Significant roles in the logistics process also may be played by transportation firms, wholesalers, and third-party logistics firms that specialize in providing logistics management services on a contract basis.

The movement of a product from the point of production to the point of consumption actually consists of a number of separate movements between various locations, at the production and consumption sites, and at warehouses and other intermediate storage facilities. Variables describing the physical components of this process include the number and location of the storage sites, the storage time at each site, transport modes used between sites, and shipment sizes. Associated costs include the costs of building and operating storage facilities, inventory costs, shelf-life costs, transport costs, loading and unloading costs, loss and damage, order costs, and “stockout” costs resulting from late deliveries.

The goal of logistics management is to minimize the overall costs of the entire logistics system. A number of trade-offs must be considered as part of the decision-making process. For example, reducing order size and the size of individual shipments reduces inventory costs, but it also increases trans-

port costs and order costs. Similarly, the use of centralized warehouses reduces inventory costs by reducing the number of warehouses that must be stocked, but it increases transport costs. The probability of running out of stock can be reduced by increasing inventory or by only using carriers with good records for on-time delivery. “Just-in-time” (JIT) inventory systems minimize inventory costs for a consuming firm, but they may increase the inventory costs of suppliers and place significant constraints on carriers.

Successful companies evaluate performance and base management decisions not only on financial and cost measures, but also on customer satisfaction and logistics performance measures. By streamlining the logistics process, companies can reduce cycle time and improve productivity, thereby increasing the level of customer satisfaction and improving competitiveness. To achieve this, both shippers and carriers must

- **Know and Understand What Customers Require—**This demands a proactive rather than reactive approach and improved communication throughout the logistics chain from supplier to customer, as well as between shippers and carriers.
- **Recognize the Importance of Networks When Making Site Decisions—**Of the many factors companies consider when making location decisions, access to transportation networks is an increasingly important consideration.
- **Respond to Demographic and Market Shifts—**A company’s success increasingly depends on anticipating and positioning itself to take advantage of emerging markets and shifting trade patterns. The challenge lies in determining how to secure and allocate resources to meet market demands and in identifying partners to exploit markets.
- **Develop and Maintain Information Systems Capabilities—**With increasing demands for swift and reliable service comes an increasing need for effective information systems capabilities.

Technology makes it possible to have fully integrated systems for meeting needs ranging from operations (i.e., cost control, shipment tracking, service performance, shipper links) to marketing and decision support tools. Through elec-

tronic data interchange, shipment information is entered by a shipper or agent and then passed through to carriers, triggering functions such as equipment availability and interchange, insurance requirements, cargo release, and other information that is added to the initial shipment record until delivery, billing, and payment are completed. Customers have access to information on a real-time basis for monitoring the status of their shipments. These systems can be tailored to meet customer order, production, and system requirements.

There are many third-party logistics service providers and logistics products in the market today that perform a full range of functions, including:

- Pre-shipment planning;
- Shipping document preparation;
- Insurance requirements;
- Mode/carrier selection and planning;
- Equipment availability, scheduling, and interchange;
- Order tracking and shipment tracing;
- Fleet routing;
- Cross-dock distribution;
- Warehouse management;
- Rate management;
- Advanced shipment notification;
- Cargo release;
- Freight bill auditing and claims;
- Billing and payment;
- Carrier performance evaluation; and
- Vendor-managed inventory systems.

Although many of these logistics tools and services have been available for years, implementation has been slowed by a number of factors, not the least of which has been the time required to learn how, and in what combination, to use the available tools and services. In addition, companies must learn how to organize and analyze the tremendous amount of data and information available as a result of the technology.

It is clear that technological advances and regulatory change, along with emergence of the "global marketplace," have dramatically influenced and increased the importance of the logistics process both domestically and internationally. Consequently, more effective integration of the various components of the distribution chain is required to facilitate the transactions necessary to move goods worldwide from origin to destination.

Shippers and manufacturers have a growing need to find more efficient ways to move raw materials, parts, and finished goods throughout the world, and are faced with increased information requirements for managing worldwide manufacturing, distribution, and logistics. They require a logistics process that can help them manage changing demand and inventories during various stages of production and distribution on a global scale.

For carriers, there is an increasing awareness of the importance of establishing worldwide standards in transportation,

ranging from documentation and information technology to equipment, handling, infrastructure, and safety standards. Carriers require a system that provides information for equipment control, pickup and delivery schedules, loading and stowage, labor scheduling, and pricing based on changing demand along various routes.

Ports, airports, terminals, and warehouses, as well as other ancillary services and facilities are vital links in the logistics chain. Over the past two decades, significant technological advances have been introduced at these facilities to make throughput more efficient, thereby increasing the speed, reliability, capacity, and productivity of the overall transportation and distribution process. There has been an increasing trend toward establishing load centers (or hubs) and feeder points (both inland and coastal) to and from which expedited carrier service is provided. There has also been a decline in the number of terminals, as well as expansion and increased mechanization of the remaining terminals. Traditional hinterlands and monopoly positions have declined in importance as a result of increases in the amount of discretionary freight that can move by any number of routes and combinations of modes.

In regions that appear to offer certain locational advantages with respect to transportation, both public and private sector interests have undertaken ambitious and often risky development projects. These range from major capital improvement projects, such as intermodal container transfer facilities, inland ports and terminals, air cargo industrial parks, to aggressive public/private marketing initiatives and coastal/inland alliances, such as the Columbus Inland Port Program.

The logistics process feeds a network of modes and services, which in combination are competitive and provide opportunities and acceptable profit margins for all participants. It involves cooperative ventures among historical competitors, including investment in research and new technology; and closer alliances between suppliers and buyers of transportation services, including the ability to identify special customer needs and problems and to respond with customized services. The logistics process will continue to evolve as shippers increasingly rely on logistics managers to determine how daily input and output requirements can be managed.

The continuing evolution of the logistics process and the increasing volume of freight movements have significant implications for planners and decision makers in both the public and private sectors. An efficient and reliable transportation network is vital to the logistics process and to the national economy. Infrastructure and other capital improvements to accommodate technological advances, service changes, and increased freight and passenger volumes have attracted and will continue to attract considerable investment. The public and private sectors must cooperate and communicate with each other to ensure access to the data and

information necessary to make planning and policy decisions that affect the logistics process.

## KEY FACTORS INFLUENCING FREIGHT TRANSPORTATION DEMAND

A variety of factors influence freight transportation demand, some directly and others indirectly as a result of changes in transport costs and rates and in the services offered. The following is an overview of some factors that affect freight demand today or may do so in the future. Appendix A of the Guidebook provides a more detailed discussion of these factors and, where appropriate, includes measures for each factor, sources of data for each measure, and comments on the usefulness of the data sources.<sup>1</sup> Current information about many of the factors discussed here can be obtained from publications, such as *Traffic World*, that follow the transportation industry.

### Direct Influences

Among those factors that directly influence freight transportation are the following:

- **The Influence of the Economy**—The demand for transportation services is derived from the level of economic activity. Trends or changes in the national or regional economy affect manufacturing and distribution processes. As a derived demand, the most basic influence on total freight demand is the volume of goods produced and consumed. Expansion in a national or regional economy results in increases in overall freight demand, while contractions in the economy result in reductions in freight demand.

Freight demand is closely related to the goods production component of gross domestic product (GDP). While real GDP of goods is a reasonable overall measure of the economy's influence on freight demand, it measures goods production in dollars rather than in weight or volume. Production of low value (dollars per ton) bulk commodities, such as agricultural products and coal, generate a larger share of freight demand than their total value would indicate. In addition, commodity value and perishability often influence mode choice, with lower value commodities generally moving on slower, less costly modes and higher value or perishable commodities moving via faster, more expensive modes. It is important, therefore, to distinguish between commodities when incorporating production forecasts into forecasts of freight demand.

- **Industrial Location Patterns**—Industrial location patterns are critical to determining transport demand as measured in ton-miles or other units that reflect length of haul. The influence of spatial distribution can best be measured through its actual effect on demand: as average length of haul by commodity or total ton-miles transported. The spatial distribution of economic activity also influences mode choice, with many commodities likely to be shipped by one mode when distances are short and by another when distances are longer.
- **Globalization of Business**—As noted earlier, many companies today manage worldwide production and distribution systems, and national economies are increasingly being integrated into a global economy. As production facilities are shifted to locations around the globe where products can be produced more economically, the demand for world trade will continue to increase. The patterns of domestic and foreign production and distribution vary significantly by industry and product type, and they affect transportation requirements in the United States. Increasing imports from South Asia eventually may warrant containership service directly from India, a service that would operate through the Suez Canal to the East Coast of the United States. These containers would then be transported inland from the East Coast, instead of from the West Coast as currently is the case.

The changing patterns of world trade influence both transport flows and mode choice. Most worldwide freight flows are intermodal; this highlights the need for standardization of equipment, handling, and safety procedures.

- **International Trade Agreements**—Global production and distribution are also affected by international trade agreements, quotas, and tariff restrictions. The dynamics of the global marketplace have driven the formation of numerous large regional trading blocs including the European Union (EU), the ASEAN Free Trade Area (AFTA), and the North American Free Trade Agreement (NAFTA). Further integration of economies of individual countries into regional economic and trading blocs is likely to occur.

The essence of NAFTA is to lower total costs for North American businesses exporting goods within the North American market. The tariff elimination schedule will allow all trade between Canada and the United States to be duty-free by 1998. For most U.S.-Mexico and Canada-Mexico trade, tariffs will be phased out by the year 2003. The agreement contains a stipulation designed to prohibit importers from other countries from taking advantage of the tariff elimination by simply passing through one of the NAFTA countries.

The implications of NAFTA have been significant for freight transportation interests, particularly in the border regions. NAFTA provisions radically change cross-

<sup>1</sup> Several of the factors discussed here and in Appendix A are being studied in more detail in a recently initiated NCHRP study, *Economic Trends and Multimodal Transportation Requirements* (Project 2-20), being performed by Louis Berger International, Inc.

border transportation systems (particularly between the United States and Mexico), which were complicated by regulations that increased costs. The passage of NAFTA also spawned the implementation of the Customs Modernization and Informed Compliance Act (or MOD Act), which gave Customs the authority to expand its automated entry system. Over time, it allows Customs to eliminate old systems and adopt practices that will save both taxpayers and the trade community time and money. As tariff rates decline and cargo flows increase, improvements to the border infrastructure and the border crossing processes will continue.

At the end of 1994, Congress approved legislation that implemented an agreement known as the Uruguay Round of trade negotiations under the auspices of the General Agreement on Tariffs and Trade (GATT) negotiated by the United States and other countries. The agreement requires all GATT members to reduce tariffs in stages. This reduction will benefit U.S. exporters, particularly those doing business with high tariff countries.

Also at the end of 1994, the United States and 33 other countries in the Western Hemisphere committed themselves to achieving a free trade agreement by 2005. Analysis of the implications of such a trade pact will continue. While it is likely to increase opportunities for all countries in the pact, it also could dilute or diminish the bond among the three NAFTA countries.

- **Just-in-Time Inventory Practices**—JIT systems focus on keeping inventories at minimum levels by coordinating input deliveries with production schedules. Adoption of a JIT system often results in increasing the frequency with which inbound shipments are scheduled, decreasing the lead times and sizes of these shipments, and increasing the importance of receiving these shipments on time. Firms that adopt JIT systems often reduce the number of suppliers and transport companies with which they deal, and select suppliers that are close enough to be able to deliver shipments within short lead times.

The effects on freight demand are to increase the number of individual shipments, decrease their length of haul, and increase the importance of on-time delivery. There may be some shifts to modes that are faster or better able to handle smaller shipment sizes. Within modes, the shift is likely to be to carriers capable of providing highly reliable service.

- **Carrier-Shipper Alliances**—There have been dramatic changes in the institutional relationships among transportation providers and users. Shippers demand faster, reliable, door-to-door “seamless” transportation services, often without stating a mode preference. Such services can be made available through a single vendor who can arrange, manage, and monitor the movement. Increasingly, shippers are entering into partnerships with, and often providing in-plant space for, person-

nel of logistics companies, which, in turn, often are subsidiaries of carriers.

- **Centralized Warehousing**—As transportation systems have become more efficient and more reliable, there has been more consolidation of warehousing and distribution. This has resulted in part from the fact that manufacturing firms are increasing their use of third-party logistics providers who specialize in optimizing the distribution process. The results are increases in the demand for transportation and in associated costs and reductions in inventory costs.
- **Packaging Materials**—The use of lightweight materials as protective packaging for many manufactured products has resulted in a reduction in the average density of shipments. The increase in low-density shipments has created a demand for larger truck trailers and shipping containers.
- **Recycling**—Increased use of recycled materials affects origin/destination patterns, lengths of haul, and modal use of several commodities. Recycling plants frequently are located near the markets they serve, which also provide them with materials for recycling.

### Indirect Influences

Among the factors that have an indirect impact on freight demand by influencing costs and service are the following:

- **Economic Regulation and Deregulation**—Deregulation within the transportation industry was driven by the desire to encourage greater price and service competition and to increase opportunities to develop multimodal and intermodal relationships among and within the various modes. The trend toward regulatory change began with the Transportation Act of 1940, but was most evident in the deregulatory actions taken in the 1970s and 1980s. These actions include the Airline Deregulation Act of 1978 (which was preceded by deregulation of the all-cargo air services industry in 1977), the Motor Carrier Act of 1980, the Staggers Rail Act of 1980, and the Shipping Act of 1984. All of these actions paved the way for the growth in intermodalism, the formation of multimodal transportation companies and alliances, and the evolution of logistics management.
- **International Transportation Agreements**—Bilateral and multilateral international transportation agreements often involve complex negotiations as the nations involved seek to protect their interests and to create opportunities for trade and economic growth. Where carrier entry or participation is restricted in a particular market, rates tend to be higher. Each mode operates under a unique set of international arrangements. International air service agreements define the service routes, and they control the number of carriers from each coun-

try, as well as the type of aircraft, that can serve those routes. Although international water transport is largely free from route restrictions, carrier conferences influence rates and services in major markets, and cargo preferences may limit carrier participation in some trade. International motor carrier operations in North America are likely to become more efficient and competitive as a result of NAFTA, under which various prohibitions on U.S., Mexican, and Canadian carriers will be phased out and safety standards will be harmonized. In recent years, U.S. and Canadian rail carriers have become more integrated, affecting service, rates, and rail competition.

- **Intermodal Operating Agreements**—Transportation carriers have become increasingly multimodal, looking for the most effective ways to integrate and market their capacity and to combine the services of rail, truck, water, and air modes. Traditional competitors, both within and across modes, are recognizing the need to build cooperative relationships. This is occurring not just in the United States, but also internationally. As a result of intermodal operating agreements and joint ventures, carriers are able to offer a broader range of services and to tailor service packages for individual shippers.
- **Single-Source Delivery of International LTL Shipments**—Since the early 1980s, less-than-truckload (LTL) carriers have established separate units, referred to as non-vessel operating common carriers (NVOCCs), to arrange for the international transport of LTL shipments. The LTL firm handles the domestic transport of the shipment; the containership operator, from whom the NVOCC has purchased space, provides the ocean transport of containers filled with LTL shipments; and the overseas land transport is provided by an agent or trucking company with whom the U.S. carrier has an operating agreement.
- **Fuel Prices**—For all modes of transportation, fuel is a large and volatile cost component. An increase in fuel prices is likely to result in greater rate increases for faster modes (e.g., air) and for premium services provided by a given mode (e.g., high-speed rail container and trailer carriage). Accordingly, some shift of demand may occur. When evaluating the effect of fuel price changes on modal demand, it is necessary to consider fuel requirements for competing services rather than modal averages.
- **Publicly Provided Infrastructure**—Carriers (except for rail) rely heavily on publicly financed and maintained infrastructure. The Federal Aviation Administration is responsible for airport runways and related airside infrastructure, as well as the air traffic control system. The U.S. Army Corps of Engineers is responsible for channel and harbor maintenance and for the operation of locks and dams. The U.S. Coast Guard provides

navigation aids and operates Vessel Traffic Services at selected ports. The Federal Highway Administration implements the federal aid highway program, which funds the National Highway System and other highways on the basis of a matching formula; and most major highways are constructed and maintained by state highway agencies.

- **User Charges and Other Taxes**—User charges are the principal means of financing publicly provided infrastructure. Government efforts to recover the costs of building and maintaining transportation infrastructure will continue to affect the competitive position of the modes involved. For the water mode, harbor maintenance fees fund approximately 40 percent of construction and maintenance costs for coastal harbors, and a variety of user charges (wharfage, dockage, equipment rental fees, gate fees, franchise fees) finance port operations. For the air mode, federal spending on airports and airways is supported by taxes on domestic and international airline passenger tickets, air cargo waybills, and fuel taxes (all of which are deposited in the Airport and Airway Trust Fund), with construction and operation of individual airports also financed through revenue bonds, facility leases, landing fees, and slot fees. Federal highway programs are supported by the Highway Trust Fund, which receives fuel taxes, an annual heavy vehicle use tax, and excise taxes. Most states also have highway or transportation trust funds, some with constitutional restrictions on how those funds are used.

In addition to user charges, transportation companies pay business, sales, and property taxes. Most of the revenue from these taxes is used for general operations of federal, state, and local governments, though some is available for transportation applications. Considerable discussion and debate continues relating to the use of fuel taxes for nontransportation purposes.

- **Government Subsidization of Carriers**—Government subsidization of carriers reduces transport costs and affects competition between classes of carriers, between modes, and between operators of carriers registered in different countries. Among domestic carriers, the rail industry has been concerned about subsidization of the motor carrier and barge industries. With the exception of public subsidies for operations on otherwise unprofitable branch lines, railroads currently do not receive any government subsidies (although they were the beneficiaries of historic subsidies, including granting of right-of-way and in some cases adjoining lands). Barges, on the other hand, provide service on waterways operated and maintained by the U.S. Army Corps of Engineers and pay a relatively small portion of the cost of constructing, operating, and maintaining the waterway infrastructure. Similarly, trucks operate on public roads, and the issue of whether heavy trucks pay their

fair share of federal highway taxes continues to be controversial.

Operating subsidies to U.S.-flag vessel operators are likely to end in the near future. This could mean the demise of the U.S. merchant marine, as vessel operators reflag. Some argue that air carriers do not pay an appropriate share of costs associated with the air traffic control system, but the financial condition of the airline industry makes any substantial near-term increase in user charges unlikely.

- **Environmental Policies and Restrictions**—Environmental policies and restrictions affect all modes of transportation. The restrictions placed on the water mode and ports include the Clean Water Act, the Oil Pollution Act, dredge disposal controls, and speed and draft restrictions. Motor carriers are most affected by emissions controls and clean fuel requirements. Air carriers, particularly the all-cargo carriers that operate older aircraft and that operate primarily at night, are most affected by noise restrictions. These environmental policies and restrictions significantly add to the cost of freight transportation. In addition to the effects of environmental policies on modal costs, environmental policies that affect decisions on the locations of industrial sites and the locations at which raw materials are produced also affect freight demand.
- **Safety Policies and Restrictions**—Safety regulations generally increase carrier capital and operating costs while reducing accident-related costs, but their overall impact on freight demand is relatively minor. Safety regulations influence carrier behavior only when the perceived costs exceed the perceived benefits to the carrier.
- **Effects of Changes in Truck Size and Weight Limits**—Changes in truck size and weight limits can have a significant impact on the cost of goods movement by truck. Truck size and weight limits control the amount of payload that can be carried on a truck. For high-density freight, the maximum payload usually is controlled by weight limits; for low-density freight, the maximum payload usually is controlled by the cubic capacity of the truck (i.e., length, width, and height limits). Because increases in truck size and weight limits increase the payload per trip, fewer truck trips are required to carry the same amount of freight. Longer and heavier trucks generally cost more to operate on a per-vehicle-mile basis; however, these increases only partially offset any cost savings associated with making fewer trips.

Changes in truck size and weight limits may result in shifts of freight to or from other modes, particularly rail. Without the diversion of additional freight from rail, increases in truck size and weight limits would be expected to reduce truck traffic volumes. The extent to which volume reductions would be offset by the diver-

sion of freight to trucks is an important issue in the debate over the effects of changes in limits.

- **Congestion**—In many urban areas, increasing highway traffic congestion and incident-related congestion are reducing the efficiency of freight transportation and the reliability of just-in-time shipping. In port areas, there is a need to coordinate vessel loading and unloading with rail and truck schedules and with peak/nonpeak traffic flows. At both ports and airports, the customs clearance process may cause congestion.
- **Technological Advances**—A number of significant technological advances in equipment and information systems over the past three decades have had a profound impact on freight transportation. The most notable equipment advances include containerization, double-stack technology, automation and robotics, handling and interchange systems, automated terminals, and conveyance design. Advances in information systems include electronic data interchange (EDI), automated equipment identification (AEI), applications of Intelligent Transportation Systems (ITS) to commercial vehicle operations, global positioning systems, and cargo/container routing and tracking systems. Many of the technologies that enable significant increases in productivity are readily available, while others require significant financial investment before achieving wide application. It should be noted that existing regulatory, market, and institutional obstacles must be overcome before some of these advances can be implemented.

## FREIGHT DEMAND AND PUBLIC SECTOR TRANSPORTATION PLANNING

### The Need for Freight Demand Forecasts

Forecasts of freight transportation demand are required for planning transportation facilities, for corridor planning, and for strategic planning for entire transportation systems.

For *facility planning*, forecasts are needed to determine the appropriate capacity of new facilities that may be built and of existing facilities that are being considered for expansion. In the case of an intermodal facility, such as a seaport terminal or an airport, forecasts are needed to determine the volume of freight that the facility must be capable of handling, the number and size of the vessels or aircraft that are likely to use the facility, and the requirements for truck and rail access to the facility. Also, if a system of user charges is to be established to cover the costs of building and operating the facility, forecasts are needed to determine the level at which these charges should be set to recover the costs.

For *corridor planning*, freight demand forecasts are needed to determine the adequacy of the existing facilities and services in the corridor and the potential need for expanding these facilities and services. For *strategic planning*, forecasts of freight demand are needed to evaluate the

overall viability of alternative strategies and the demand for individual components of those strategies.

Chapter 3 presents procedures for forecasting the demand for existing transportation facilities, and Chapter 4 presents procedures for the more complex task of forecasting the demand for new facilities. The facilities considered in these two chapters may be intermodal facilities or they may be single-mode facilities, such as a road, serving an entire corridor. The procedures presented in these two chapters also can be used to develop forecasts for an entire corridor or for a system of transportation facilities.

### **Requirements for Freight Transportation Planning**

The Intermodal Surface Transportation Efficiency Act (ISTEA) contains specific requirements for freight transportation planning by metropolitan planning organizations (MPOs) and state departments of transportation (DOTs). Under Section 1025 of ISTEA, states are required to have a continuous planning process and transportation improvement program that recognizes "access to major traffic generators such as ports, airports, intermodal transportation facilities, and major freight distribution routes" and "to coordinate this effort with metropolitan areas." Issues relating to landside access and congestion are among the most critical challenges facing planning agencies, and major infrastructure projects are planned or underway throughout the country. Among the most notable is the Alameda Corridor project, designed to dramatically improve rail and highway access to the Ports of Los Angeles and Long Beach. The \$1.8 billion project, expected to be completed by the year 2000, will consolidate 90 miles of branch lines into a single 20-mile rail corridor in which goods can be shipped at high speed to a central deconsolidation terminal from which they then can be routed throughout the United States.

Under Section 1024 of ISTEA, MPOs are responsible for 20-year metropolitan capital investment plans encompassing both freight and passengers. Recognizing this need, freight interests have made an effort to communicate with MPOs, which are tasked with addressing local freight industry requirements.

A realistic and objective assessment of the current freight transportation situation is vital to the planning process at both the state and metropolitan levels. This includes examining

past, current, and projected future freight movements, as well as market forecasts, demographics, and shipper identification. Among the questions such an assessment can help answer are the following:

- Are carrier services, terminal facilities, and other services adequate to meet demand? If not, where are improvements needed?
- Could existing freight flows be handled more efficiently? What is the outlook for expanding existing and developing additional freight flows and value-added services?
- What are the constraints to achieving a more efficient and cost-effective freight transportation network (e.g., land use constraints, environmental issues, regulatory environment, competitive factors, etc.)?
- Is progress being made in improving intermodal connections?
- How would freight transportation improvements or expansion enhance regional economic and industrial development efforts?
- What resources are available in the short term and in the long term?
- How can public agencies and the private sector coordinate efforts to realize future opportunities?

The integration of freight planning into the overall planning process in general, and into the transportation planning process in particular, requires the ability to assess the following:

- The freight commodity flows and their associated industrial and economic activity;
- The freight transportation network serving a region;
- The institutional relationships within and between the public and private sectors, and within and among different modes of transportation;
- The data and information needed to identify markets and to develop tools for formulating and assessing planning and development options; and
- The roles and organizational structures within the relevant agency.

This Guidebook focuses on only the first of these issues: forecasting freight demand.

## CHAPTER 3

# DEMAND FORECASTING FOR EXISTING FACILITIES

A significant issue faced by public sector transportation planners is determining the appropriate capabilities for various modal and intermodal facilities. Ideally, these facilities should be able to accommodate the projected demand for them, plus an appropriate amount of spare capacity. The basic information required by these planners is the expected demand for use of these facilities.

This chapter presents an introduction to forecasting freight demand for existing transportation facilities; the more complex subject of forecasting freight demand for new transportation facilities is addressed in the next chapter. Additional information relating to the procedures described in this chapter is presented in Appendices C–E.

Sources of information on historic and current transport activity and facility use are presented in the first section of this chapter; sources of economic forecasts are discussed in the second section. The third section presents a simple procedure for combining an economic forecast with historic data on transport activity to produce a forecast of transport demand; several options for improving the quality of these forecasts also are described. The fourth section discusses several regression and extrapolation procedures that can produce forecasts of transport demand from time-series data. The final section presents the identification and evaluation of alternative futures that should be considered by planners determining a course of action.

### CURRENT AND HISTORIC DATA ON FACILITY USE AND TRANSPORT ACTIVITY

The most readily available information about demand for an existing facility is information about past and/or current use of the facility—that is, about past and/or current demand for the facility under certain price and service conditions. If there are no unusual supply constraints, and demand has not been affected significantly by unusual economic conditions, then this demand information can be used as the basis for forecasting demand under similar “normal” conditions. The procedures presented in this chapter use data on (or estimates of) past or current use or transport activity as the basis for generating forecasts of demand.

There are three types of sources of data on facility use and related transport activity:

- Data compiled by the facility operator;
- Data collected and published by federal agencies and other public and private entities that monitor or analyze

transport activity on a regional, state, national, or international level; and

- Data collected as part of a special survey designed to supplement data available from other sources.

These data sources are discussed in the following subsections.

### Facility Data

Facilities that impose user charges for the use of their services invariably collect usage data that are related to the fees collected. They also may collect additional data, either for their own planning purposes or because the data are required by a governmental agency. Data directly related to user fee collections (e.g., facility use by vehicles, vessels, containers, etc.) are likely to be quite accurate. However, these data are likely to lack detail on actual freight volumes, commodities, origins, and destinations, and, in some cases, whether freight is even being carried; even when such detail is collected, the data may be of lower quality. Special surveys may be necessary if more detailed data are desired for forecasting or planning purposes.

### Published and Proprietary Data

Appendix C contains information on approximately 35 compilations of data that are available from public or private sector sources in printed or electronic form. These sources vary with respect to: their level of detail; the modes, commodities, and types of movements covered; whether they incorporate information on all movements of a given type or on just a sample of such movements; and, in the case of sample data, the size and structure of the sample. Some of the more significant of these sources follow.

- **The ICC Carload Waybill Sample Public Use File**—This contains tons, carloads, trailers, containers, revenue, commodity, and BEA region<sup>1</sup> origin and destination for a sample of rail shipments.
- **Waterborne Commerce and Vessel Statistics**—This contains annual data on tons by commodity, harbor,

<sup>1</sup> The Bureau of Economic Analysis (BEA) has divided the United States into 183 economic areas (or regions), each of which contains one or more cities and the surrounding hinterland.



waterway segment, direction, and type of movement (internal, coastwise, export, or import) for all movements using domestic waterways.

- **U.S. Air Freight Origin Traffic Statistics**—This contains estimates developed by the Colography Group of annual weight, value and number of air freight shipments for 73 industries by “market area” of origin.
- **The 1993 Commodity Flow Survey**—This is expected to contain estimates of tons and value of shipments by commodity, mode, and origin and destination state or NTAR;<sup>2</sup> eight modes will be distinguished (including private truck, for-hire truck, and air/surface parcel transport).
- **Transearch Database**—This contains estimates of tons by commodity and origin and destination state or BEA region for air, truck, rail, and water movements.

### Special Surveys

Data from the above mentioned sources may be supplemented by information collected from special surveys conducted (partly or primarily) to contribute to the forecasting process. The type of survey to be used for this purpose depends on whether or not the firms using the facility in question are known.

When the set of firms using a facility is known (e.g., from information maintained by the facility operator), a survey can be conducted of all or a sample of these firms. Such a survey can be designed to collect data on the annual volume of use by shipment characteristics of interest (e.g., shipment size, commodities, origins and destinations, etc.), as well as information on expected near-term changes in these volumes, use of competing facilities, and factors affecting the choice of facilities. When designing such a survey, it is important to limit the amount of information requested so that respondents do not find the survey to be burdensome.

When the set of firms using a facility is unknown or only partially known, an unbiased sample of firms using the facility cannot be constructed. Instead, a survey generally is designed to collect information on a sample of movements by interviewing employees who are moving shipments to or from an intermodal facility or who are transporting shipments over a facility serving a single mode (e.g., a road). This approach is commonly used for obtaining information on truck transport, the mode for which the least amount of published data is available. For example, the North American Truck Survey (NATS), described in Appendix C, was performed by interviewing truck drivers at truck stops, and a special survey conducted on behalf of the state of Washington<sup>3</sup> was performed by interviewing truck drivers at weigh stations.

Movement-oriented surveys generally are limited to collecting data on a single movement.<sup>4</sup> The data collected may correspond to the annual shipment data collected from a firm (e.g., shipment size, commodity, vehicle type, origin and destination, etc.), although truck drivers and other carrier employees interviewed for a survey may have somewhat less complete information about these shipments than does carrier management. Also, because the data from such surveys are limited to individual shipments, a much larger sample is required to obtain a reliable indication of the overall use of a facility.

Information on facility use obtained from movement-oriented surveys is most accurate when the facility is geographically confined (e.g., it is an intermodal facility or a relatively short road segment) and the survey is conducted at the facility. For geographically dispersed facilities (such as roads), the sampling procedure may miss surveying certain types of movement, such as short hauls that do not pass any survey locations, or overweight trucks that use bypasses to avoid weigh stations. Surveys conducted at truck stops are likely to pick up very few short movements because drivers on short trips are less likely to stop at truck stops. Also, if multiple survey locations are used, movements on routes that pass more than one survey location are more likely to be sampled than movements on routes that pass only one such location; however, this is a type of sampling bias for which corrections can be readily developed.

Additional information on the design and use of special surveys is presented in Appendix D.

### SOURCES OF ECONOMIC FORECASTS

The most important determinants of transport demand are the volume of goods that are produced and consumed, and the locations of production and consumption. Consequently, forecasts of production and consumption, or of overall economic output, are important sources of information for developing freight demand forecasts.

Because economic forecasts have many applications aside from their use in forecasting transport demand, such forecasts often are available from several sources. Accordingly, most forecasts of demand for freight transport are based to some extent on forecasts of changes in the economy. Potential sources of these forecasts are described below.

Several states fund research groups that monitor the state's economy and produce forecasts of economic change. For example, the Center for the Continuing Study of the California Economy develops 20-year forecasts of the value of California products by two-digit Standard Industrial Classification (SIC) code. Similarly, the Texas Comptroller of Public Accounts develops 20-year forecasts of population for 10 substate regions and 20-year forecasts of output and employment by one-digit SIC code and substate region, and a private firm produces 20-year forecasts of output and employment in Texas by three-digit SIC code.

<sup>2</sup> The National Transportation Analysis Regions (NTARs) are a set of 89 regions, obtained by aggregating the 183 BEA economic areas into larger units.

<sup>3</sup> William R. Gillis, Kenneth L. Casavant, and Charles Howard, Jr., “Survey Methodology for Collecting Freight Truck Origin and Destination Data,” The Gillis Group, Pitzville, Washington, July 1994. Additional information about the conduct of this survey is contained in Appendix D.

<sup>4</sup> Note that the NATS survey collects data on both the truck's current movement, whether empty or loaded, and its preceding loaded movement.

Long-term economic forecasts also are available from two federal agencies. At 2-year intervals, the Bureau of Labor Statistics (BLS) publishes low, medium, and high 12- to 15-year forecasts of several economic variables, including real domestic output, real exports and imports, and employment, for each of 226 sectors generally corresponding to groups of three-digit SIC industries.<sup>5</sup> Also, at 5-year intervals, the BEA develops 50-year regional projections of population and personal income as well as employment and earnings by industry sector.<sup>6</sup> The BEA forecasts are published by state for 57 industries, and by metropolitan statistical area and BEA economic area for 14 industry groups.

In addition to the state and federal agencies, short-term and long-term economic forecasts also are available from several private sources. The private firms use government and industry data to develop their own models and analyses. Two of the better-known private sources are DRI/McGraw-Hill (DRI) and the WEFA Group.

DRI provides national, regional, state, Metropolitan Statistical Area (MSA), and county-level macroeconomic forecasts on a contract or subscription basis. Variables forecast include gross domestic product (GDP), employment, imports, exports, and interest rates. DRI also produces short-term (2- to 3-year) and long-term (20- to 25-year) industrial input and output forecasts for 250 industries (two-, three-, or four-digit SIC codes). Industrial inputs include employment, energy, and materials used in production. These input/output forecasts are updated semiannually. Price and wage indices also are forecast for 650 different industries.

WEFA produces quarterly short-term (2- to 3-year) and long-term (10- and 25-year), and annual long-term (25-year), U.S. macroeconomic forecasts. Variables forecast include GDP, employment, price indices, financial indicators, and foreign exchange rates. WEFA also produces short-term (3-year) output forecasts for 537 industries (at the four-digit SIC level) on a quarterly basis, and long-term (10-year) input and output forecasts for 480 industries semiannually.

## ECONOMIC INDICATOR VARIABLES

A highly useful and relatively simple procedure for deriving forecasts of transport demand from economic forecasts is to assume that demand for the transport of various commodity groups is directly related to variations in corresponding economic *indicator variables*. The most desirable indicator variables are those that measure goods output or demand in physical units (tons, cubic feet, etc.), but forecasts of such variables frequently are not available. More commonly available indicator variables are constant-dollar measures of output or demand; employment; or, for certain commodity groups, population, or real personal income.

The indicator variables can be used either to derive *annual growth rates* or to derive *growth factors* representing the ratios of forecast-year values to base-year values. The procedure requires data on or estimates of transport activity or facility use, by commodity group, for a reasonably “normal” base year, as well as forecasts of growth in the corresponding indicator variables. The basic version of this procedure follows:

1. Divide base-year transport activity or facility use by commodity group.
2. Associate each commodity group with an economic indicator variable that is related to the production of or demand for that commodity group and for which forecasts are available from some exogenous source. (For example, the transport of food products might be associated with production of food products.)
3. For each indicator variable, obtain either a *growth factor* by dividing its forecast-year value by its base-year value, or obtain a forecast *annual growth rate* (e.g., by determining the average annual growth rate implied by the variable’s base-year value and its value in any forecast year).
4. For each commodity group, estimate forecast-year demand either by multiplying base-year activity by the corresponding growth factor or by applying the indicator variable’s annual growth rate to base-year activity.
5. Aggregate the forecasts across commodity groups to produce forecasts of total transport demand and forecasts of transport demand for any set of commodity groups of interest.

## Some Examples

### *The Vessel Traffic Services Study*

One example of the use of economic indicator variables is a set of forecasts of waterway freight traffic and freight-vessel traffic developed for the Volpe National Transportation Systems Center (VNTSC) and for the U.S. Coast Guard.<sup>7</sup> Traffic forecasts were required for study zones surrounding 24 major ports to estimate the value of Vessel Traffic Service (VTS) systems being considered to enhance the safety of vessels traveling to and from these ports.

For the VTS study, base-year data on freight and vessel traffic were obtained, primarily from the U.S. Army Corps of Engineers (COE) commodity and vessel traffic files for 1987. For all but one of the study zones of interest, this file provided estimates of import, export, and domestic freight traffic, in tons, by commodity and direction, for several waterway segments, for each of 159 commodity groups. Movements of four of these commodity groups were dropped

<sup>5</sup> The most recent BLS forecasts are contained in U.S. Department of Labor, Bureau of Labor Statistics, *American Work Force 1992-2005*, Bulletin 2452, April 1994.

<sup>6</sup> See U.S. Department of Commerce, Bureau of Economic Analysis, *BEA Regional Projections to 2040*, Three Volumes, U.S. Government Printing Office, October 1990.

<sup>7</sup> Herbert Weinblatt, *Commodity and Vessel Traffic Forecasts*, Task Report, prepared by Jack Faucett Associates for the Volpe National Transportation Systems Center, Cambridge, Massachusetts, March 1991.

from consideration because forecasts were not needed. On the other hand, a separate commodity code was created for liquefied natural gas (LNG), a commodity of particular concern for the VTS study. Information from the LNG import terminals was used to separate base-year LNG movements from other movements of "petroleum coal products, not elsewhere classified." For the Santa Barbara Channel, the one study zone for which COE data were not available, base-year estimates of freight traffic by commodity were derived from VNTSC estimates of vessel traffic through the channel and from commodity data for Los Angeles/Long Beach.

Forecasts of commodity traffic for four forecast years (1995, 2000, 2005, and 2010) were developed using annual forecasts for the 1986–2000 time period developed by the BLS in 1988.<sup>8</sup> The forecasts used were the moderate growth forecasts of real domestic output, exports, and imports, by industrial sector. For these purposes, a correspondence was developed between 127 of the BLS's 226 sectors and the 155 commodity groups for which forecasts were required. (The BLS sectors used were the 126 goods-producing sectors plus the scrap sector.)

For each commodity group, the average annual growth rates in real output, real exports, and real imports of the corresponding BLS sector or sectors were determined. These growth rates then were applied to the base-year estimates for each commodity group of domestic movements, exports, and imports, respectively, to produce forecasts for each forecast year of interest.

For three commodity groups of special interest to the study, the above forecasts were modified on the basis of additional data; and for a fourth commodity group, a separate forecast was developed.

- Forecasts of coastwise shipments of petroleum products for several ports were modified to reflect BEA employment forecasts<sup>9</sup> for oil and gas extraction in Alaska and for petroleum refining in Texas and Louisiana.
- Forecasts of crude oil imports entering three Texas port areas were adjusted to reflect the effect of a planned offshore petroleum terminal, using information from persons involved in the planning effort.
- Relatively conjectural forecasts of LNG imports were developed from data on 1990 LNG imports at two terminals, and from information about capacity at these two terminals as well as a third that was expected to resume operation at the time of the study. The forecasts for imports of all other petroleum products were reduced to be consistent with the forecasts of LNG imports.

### *The California Freight Energy Demand Model*

The California Freight Energy Demand (CALFED) Model was developed for the California Energy Commission in

1983.<sup>10</sup> This model is used by the commission and by the California Air Resources Board for forecasting truck and rail freight activity and energy consumption. These agencies expect to update and expand the model within the next few years.

The CALFED Model develops forecasts of truck and rail freight traffic for 11 commodity groups for five regions of the state, as well as additional forecasts of overall truck (freight and non-freight) activity by vehicle type and region. Forecasts of truck and rail freight activity are developed by applying growth factors to base-year estimates of activity by commodity, region, and vehicle type or railroad-car type.

Table 1 lists the 11 commodity groups distinguished by the model and the corresponding economic indicators used for deriving the growth factors. California forecasts of all indicators shown in the exhibit are produced regularly by the Center for the Continuing Study of the California Economy (CCSCE). The CALFED Model uses forecasts expressed in physical units, where available, and forecasts of value of output or employment in most other cases; population forecasts are used for deriving growth factors to be applied to household-goods transport.

The model uses exponential interpolation and extrapolation to derive forecasts for years in which CCSCE forecasts are not available.

For example, total production of food products in California in 1982 was 13.58 million metric tons (tonnes) and, at the time the model was developed, the CCSCE projected that production in 1987 would be 14.54 tonnes. These two figures imply an average annual growth rate of 1.38 percent in the production of food products over the period from 1982 to 1987. Accordingly, annual ton-miles of food products transported by rail and truck were forecast to grow by 1.38 percent in each year between 1982 and 1987. Using the CCSCE forecasts for 1992, 1997, and 2002, a somewhat higher annual growth rate (1.68 percent) was derived from the 1987–1992 period, and somewhat lower rates (1.33 percent and 1.08 percent) for the following 1992–1997 and 1997–2002 periods.

Separate CCSCE forecasts were available for each commodity group identified in Table 1 except for Groups 1 and 2, fruits and vegetables, and other agricultural products. In the absence of forecasts for these two commodity groups, the growth rates obtained for food products (Group 5) were used for Groups 1 and 2.

The following is a somewhat simplified description of the development of base-year (1977) estimates of truck and rail traffic:

- Base-year estimates of truck transport of manufactured goods were developed using 1977 Commodity Trans-

<sup>8</sup> U.S. Department of Labor, Bureau of Labor Statistics, *Projections 2000*, U.S. Government Printing Office, Washington, D.C., March 1988.

<sup>9</sup> U.S. Department of Commerce, Bureau of Economic Analysis, *BEA Regional Projections to 2040*, U.S. Government Printing Office, Washington, D.C., June 1990.

<sup>10</sup> Herbert Weinblatt, *California Freight Energy Demand Model*, prepared by Jack Faucett Associates for the California Energy Commission, Sacramento, California, June 1983.

**TABLE 1 Economic indicators used by the CALFED Model**

Commodity Groups	Economic Indicators
1. Fruits and Vegetables	Food Products (tonnes)
2. Other Agricultural	Food Products (tonnes)
3. Construction and Mining	Employment in construction
4. Timber and Lumber	Lumber, plywood, etc. (board feet)
5. Food Products	Food products (tonnes)
6. Paper Products	Paper products (tonnes)
7. Chemicals	Chemicals (1972 dollars)
8. Primary Metals	Primary metals and transport equipment (1972 dollars)
9. Machinery	Machinery (1972 dollars)
10. Other Manufacturing	Cement and glass (tonnes); output of SIC codes 22, 23, 25, 27, 30, 31, 34, 38, and 39 (1972 dollars)
11. Household Goods	Population

portation Survey data<sup>11</sup> on movements among eight BEA economic areas in California and between these areas and 165 economic areas in the rest of the country. Estimates of ton-miles in each of the model's five sub-state regions were derived using likely mileages within each of these regions for movements between each of the origin and destination (O/D) areas. For interstate movements, separate mileages were assigned to each of several entry/exit routes (shown in Table 2); every O/D pair was associated with one of these routes. Traffic moving through California originating and terminating in other states or other countries was assumed to be negligible.

Base-year estimates of truck ton-miles of nonmanufactured commodities were derived from 1977 Truck Inventory and Use Survey data on the VMT of heavy vehicles serving the corresponding sectors, and estimates of effective average payload by commodity group. In the case of agricultural products, additional data from other sources supported the development of these estimates.<sup>12</sup>

<sup>11</sup> U.S. Bureau of the Census, 1977 Commodity Transportation Survey, special computer tabulations prepared for the Transportation Systems Center, Cambridge, Massachusetts. (This Census survey was last conducted in 1977 and has since been replaced by the Commodity Flow Survey discussed in the section entitled Published and Proprietary Data, above, and in Appendix C.)

<sup>12</sup> Jack Faucett Associates, *The Multiregional Input-Output Accounts, 1977: Interregional Commodity Flows*, Volume VI, prepared for the U.S. Department of Health and Human Services, August 1982; U.S. Department of Agriculture, *Agricultural Statistics, 1980*, U.S. Government Printing Office, 1980; and U.S. Department of Agriculture, *Fresh Fruit and Vegetable Shipments*, Calendar Year 1978, FVUS-7, Washington, D.C., July 1979.

- Base-year estimates of rail ton-miles by commodity group and California region were derived from 1977 railroad waybill data<sup>13</sup> using a variant of the procedure used for truck transport of manufactured goods.

### Improving the Forecasts

The basic economic indicator procedure (as presented above) assumes that for any transport facility, the percentage change in demand for transport of each commodity group will be identical to the percentage change in the corresponding indicator variable. However, because of changes over time in the value of output per ton, output per employee, transportation requirements per ton, and competition from other facilities and modes, the percentage changes in the indicator variables and the commodity group transport demand are unlikely to be the same. To the extent that the likely effects of these changes are understood and can be estimated at reasonable cost, the basic procedure should be modified to reflect these effects.

Additional discussion of factors influencing these effects is contained in Appendix A.

### Value per Ton

For most commodity groups, the relationship between the value of output (measured in constant dollars) and volume shipped (measured in pounds, tons, cubic feet, etc.) may change over time. These changes may be due to a change in the mix of commodities being produced within a given commodity group (e.g., more aluminum and less steel) or a change in the average real value per ton of major products within the group. As a consequence of these changes, the value per ton may either increase or decrease. For example, computers represent a product category in which the value per ton, or per pound, has decreased appreciably due to the shift to personal computers from mainframes.

When forecasting transport demand for several different commodity groups, adjusting for expected changes in value per ton for all commodity groups will be relatively expensive and may have little effect on the overall transport demand forecast. If there are one or two commodity groups of particular interest, some consideration should be given to determining how the real value per ton for these groups has been changing and how it is likely to change over the forecast period. Information about past trends and potential future changes usually can be obtained from industry associations or informed observers. Government publications (e.g., *Agricultural Statistics* or the *Census of Manufacturers*) are other potential sources of historic price data for specific products.

<sup>13</sup> U.S. Department of Transportation, Federal Railroad Administration, 1977 Waybill File, Washington, D.C.

TABLE 2 Average mileage in California for interstate truck movements

BEA Economic Area	Entry/Exit Route	Mileage by Freight Model Region				
		(1) San Francisco	(2) Los Angeles	(3) San Diego	(4) Sacramento	(5) Rest of State
164. San Diego	I-5		138	60	71	520
	I-15		276	63		98
	I-8			70		
165. Los Angeles	I-5		68		71	581
	I-80		68		208	332
	I-40		244			5
	I-10		242			5
166. Fresno	I-5				71	403
	I-80				182	208
	I-15		150			159
	I-40		198			159
	I-10		256			151
167. Stockton	I-5				71	268
	I-80				198	73
	I-15		150			297
	I-40		198			297
	I-10		256			289
168. Sacramento	I-5				36	235
	I-80				146	55
	I-15		150		32	330
	I-40		198		32	330
	I-10		256		32	322
169. Redding	I-5					117
	I-80					196
	I-15		150		71	445
	I-40		198		71	445
	I-10		256		71	437
170. Eureka	I-5					164
	I-80					356
	I-15	129	150			450
	I-40	129	198			450
	I-10	129	256			442
171. San Francisco		80			28	235
		74			199	42
		55	150			313
		55	198			313
		55	255			296

### Output per Employee

Real output is related more closely to transport demand than is employment, so employment is a less desirable indicator variable than real output. However, because long-term forecasts of employment are more available than forecasts of output, employment forecasts must be used for some purposes.

As a result of improvements in labor productivity, the real dollar value of output per employee increases over time, and physical output (in tons or cubic feet) tends to increase as

well. Forecasts of the overall increase in real dollar-valued output per employee for goods-producing industries (i.e., agriculture, mining, construction, and manufacturing) can be obtained from DRI/McGraw-Hill. To avoid a downward bias in the forecasts of transport demand, forecasts of the percentage change in employment should be converted to forecasts of the percentage change in (real dollar-valued) output. This is achieved by multiplying the estimated percentage change in employment by the estimated compound growth in labor productivity over the forecast period.

### *Transportation Requirements per Ton of Output*

Decreases in the real cost of transportation over time have resulted in a general tendency for industry to increase its consumption of transport services as a substitute for more expensive factors of production. Consequently, shipment sizes have been decreasing while both lengths of haul and standards of service have been increasing. This has generated a demand for premium quality services (e.g., just-in-time delivery) provided by traditional modes, as well as diversion to more expensive modes that offer faster, more reliable service.

Statistical analyses, using procedures such as those presented below in Statistical Techniques, should provide useful data for forecasting the extent to which these trends are likely to increase the overall demand for freight transport. However, analyses of the secular shift toward higher quality modes are unlikely to produce reliable results because of the difficulty in controlling for temporal changes in modal service quality.

### *Competitive Factors*

As appropriate, forecasts of demand for a facility or mode should be adjusted to reflect expected changes in the degree of competition from other facilities or modes. These changes may result from the following factors:

- Expected changes in relative costs;
- The elimination of base-year supply constraints at the facility in question or at competing facilities;
- The development of future supply constraints at the facility in question or at competing facilities;
- The development of new competing facilities; or
- Changes in the routing decisions of major carriers (e.g., intermodal container carriers).

The forecasting problems posed by base-year supply constraints often may be avoided by choosing a base year in which no significant supply constraints existed. When this is impractical, the effects of the supply constraints may be eliminated by using a combination of historic data and subjective judgment to adjust the estimates of facility use in the base year. Annual growth rates or growth factors then may be applied to the adjusted estimates of base-year demand to produce the forecast demand.

## **STATISTICAL TECHNIQUES**

### **Regression Analysis**

Regression analysis, an alternative to the use of economic indicator variables, has a strong theoretical underpinning. Regression analysis involves identifying one or more inde-

pendent variables—the explanatory variables—which are believed to affect the value of the dependent variable (the variable to be explained), and then calculating an estimate of the relationship between the independent and dependent variables. For our purposes, the dependent variable usually would be some measure of freight activity (e.g., ton-miles) and the independent variables usually would include one or more measures of economic activity. Forecasts must be available for all independent variables. These forecasts may be obtained from exogenous sources or from other regression equations (provided that the system of equations is not circular); alternatively, they may be developed by the forecaster using other appropriate techniques.

For forecasting purposes, regressions normally use historic *time-series* data<sup>14</sup> obtained for both the dependent and independent variables. Regression techniques are applied to the historic data to estimate a relationship between the independent variables and the dependent variable; this relationship is applied to forecasts of the independent variables for future time periods to generate forecasts of the dependent variable for the corresponding time periods.

Software for estimating the coefficients of the independent variables is widely available, easy to use, and, once the data are assembled, very inexpensive to run. Software ranging from spreadsheets to advanced statistical packages such as SAS, SPSS, and TSP provide regression capabilities. The researcher enters data for the independent and dependent variables and invokes the proper command to produce the parameter estimates. The packages also present the researcher with some statistical measures, discussed below, which can be used to assess the appropriateness of the model.

Appendix E contains an introduction to regression analysis along with references to several textbooks. Some of the basic requirements for using regression techniques for forecasting transport demand are discussed below.

### **Some Basic Issues**

The use of time-series regression analysis requires the availability of historic time-series data for the dependent variable, and for all independent variables (or proxies for these variables) that have a significant influence on the value of the dependent variable. A frequently used proxy variable is “time,” which can be used to represent any influences (e.g., value per ton or output per employee) that tend to increase or decrease uniformly over the historic time period and are expected to have a similar effect over the forecast period. However, when using time as a proxy, steps must be taken to ensure that it does not capture historic trends (e.g., modal diversion) that may not be expected to persist into the future.

<sup>14</sup> An alternative to time-series regression is cross-sectional regression, which uses observations of the dependent and independent variables across a set of similar entities (e.g., states, industries, or firms).

A related issue is the use of transport activity as the dependent variable. As observed above in the section Current and Historic Data on Facility Use and Transport Activity, transport activity actually represents transport demand under certain price and service conditions. If these conditions remained reasonably constant over the historic period and are expected to remain constant over the forecast period, they need not be represented explicitly in the regression. However, any price and service conditions that have varied significantly (or are expected to vary) should be represented by the independent variables or otherwise be given special treatment.

Of particular concern when using transport activity as the dependent variable is the effect of any supply constraints at the facility of interest or at a competing facility. Although such constraints have no effect on transport demand, they may have a significant (albeit temporary) effect on transport activity. If such constraints only affect transport activity in a single historic time period (e.g., a single year), it is appropriate to exclude data for that period from the regression. If activity is affected in several time periods, it may be preferable to represent the effect of the constraint in the regression, possibly by using a *dummy* variable (i.e., a variable that has a value of 1 in time periods when the effect is present and a value of 0 in other time periods).

### Univariate Time-Series Techniques

Unlike regression analysis, which is based on a presumed theoretical relationship between dependent and independent variables, univariate time-series methods<sup>15</sup> are not based on economic theory or interaction. The basic time-series methods are sophisticated extrapolation tools that allow the past behavior of a variable to be characterized and projected into the future. Because time-series models do not explain behavior, they do not provide a basis for estimating the impact of changing policy variables.

Time-series models require less data than regression models. Historic data are required only for the variable being forecast. The models implicitly presume the following:

- The effects of all of the variable's significant influences (e.g., growth and cyclical variation in economic activity, changes in competition from competing facilities/modes) can be adequately captured by an analysis of the historic changes in the variable itself; and
- During the forecast period, these influences will not change in character (e.g., the character of the business cycle will not change and overall economic growth will not significantly accelerate or decelerate).

The requirement that the influences on the variable to be forecast not change makes these techniques more appropri-

ate for short-term forecasting than for developing the long-term forecasts usually required for facility planning. Also, it should be noted that, like all other techniques presented in this chapter, the use of historic data on transport *activity* to represent transport *demand* presumes that the activity data do not reflect the effects of any significant supply constraints.

Time-series analysis assumes that the data series to be forecast has been generated by a random process with a structure that can be defined and modeled.<sup>16</sup> Indeed, time-series models describe the random nature of the process that generates the data series under investigation in a way that will be useful to planners for forecasting purposes. Furthermore, time-series models generate confidence intervals for predictions; this confidence band widens as the length of the prediction period increases. Planners find the range estimates to be more realistic than the simple point estimates provided by extrapolation techniques.

Time-series models require that the variable to be forecast be "stationary," a situation in which its random or stochastic properties do not vary with respect to time. In other words, the forecast variable's mean value, its variance, and its covariance with other observations of the variable must be independent of time. This is a major limitation of time-series models, since it means that they cannot be used to forecast variables that exhibit any type of trend. However, they can be used to develop such forecasts indirectly by substituting a "detrended" variable for the variable of interest.

A common procedure for developing a detrended variable is through differencing—i.e., by creating a time series consisting of the difference between each data point and its predecessor. If the resulting time series is stationary, time-series forecasting techniques can be applied to it, and forecasts of the variable of interest can be derived from its base-year value and from forecasts of the change in its value during each subsequent time period.

Brief discussions of three univariate time-series techniques are presented below. Additional discussion of time-series methods is presented in Appendix E.

### ARIMA

The most common nonregression time-series model is the Auto-Regressive Integrated Moving Average model, known as ARIMA. ARIMA tools are widely available in statistical software packages and spreadsheets.

An ARIMA model requires the analyst to specify three parameters,  $p$ ,  $d$ , and  $q$ :

$p$  is the order of the autoregressive dimension of the model, i.e., the number of lagged values of the dependent variable;

<sup>15</sup> The seminal work on time series methods is G.E.P. Box and G.M. Jenkins, *Time Series Analysis: Forecasting and Control*, Holden Day, San Francisco, 1970 (revised edition, 1976).

<sup>16</sup> This discussion is drawn from Robert S. Pindyck and Daniel L. Rubinfeld, *Econometric Models and Economic Forecasts*, McGraw-Hill, Inc., 1981, pp. 493–500.

- $d$  is the number of times the dependent variable,  $Y$ , is differenced to achieve the stationary form  $Y^*$ ;  
 $q$  is the number of lagged values of the error term that represents the moving average component of the model.

To develop and use an ARIMA model, an analyst follows three steps:

- Model identification, in which the values of  $p$ ,  $d$ , and  $q$  are determined;
- Estimation of other model parameters; and
- Verification that the model is satisfactory.

Of these steps, model identification is most critical and most challenging. The analyst must interpret several statistics, including a *correlogram*,<sup>17</sup> to determine which model specification is best for the data series in question. ARIMA models often are considered to be a “partial art form” because they leave much room for interpretation.

### Exponential Smoothing

Exponential smoothing involves removing the random fluctuations in a data series to establish its underlying pattern, and then using that pattern to develop forecasts. Forecasts developed through smoothing are most appropriate for a short time horizon in which the underlying trends of the past are expected to continue to be the primary determinant of the variable’s value.

### Curve Fitting

Curve fitting estimates how well a time series “fits” or can be described by a standard mathematical function (“curve”). Some of these functional forms, such as a straight line, are very simple, while others are more complex, such as a logistic curve. Most software packages provide a variety of functional forms to use for evaluating the data series and allow the analyst to project the curve beyond the estimation period. Forecasts developed in this way also are most appropriate for short-term use.

### Structural Econometric Time-Series Approach

One limitation of the ARIMA model and other time-series methods is that their analyses lack any explanatory power. There is no underlying theoretical relationship specified between the dependent variable and those factors that might affect its value, as there is in a regression model. The depen-

dent variable itself contains all information needed to estimate its own future values. That specification is unsatisfying to analysts who are interested in estimating how changes in other variables affect the dependent variable.

It may be difficult or impossible to explain the movement of a time series by relating it to an economic variable. First, the researcher may be unsuccessful in finding an explanatory variable that is related to the time series in a systematic way. Alternatively, no data may be available for the explanatory variables that the researcher believes have an effect on the time series. Furthermore, a structural model relating economic explanatory variables to the time series may have standard errors so large that the model’s coefficients are statistically insignificant, and the standard forecast errors produced by the model may be too large for the results to be useful. In cases where the structural model approach proves unsatisfactory, the time-series model represents a useful alternative.<sup>18</sup>

Econometricians who were dissatisfied with the lack of a theoretical basis for time-series methods eventually developed a synthesis that combines the structural and time-series models. An approach known as the structural econometric time-series approach (SEMTSA) was one of the results of this effort. As Peter Kennedy explains:

SEMTSA is based on the observation that dynamic structural equation econometric models are special cases of multivariate time-series (Box-Jenkins) processes in which *a priori* restrictions suggested by economic theory have been imposed on the parameters. Furthermore, if the exogenous variables in the econometric model can be viewed as being generated by a multiple time-series (ARIMA) process, then each of the individual endogenous variables in the econometric model can be expressed as a univariate Box-Jenkins ARIMA process.<sup>19</sup>

SEMTSA develops a traditional, theoretically grounded, structural model; derives the properties of corresponding ARIMA equations; and uses time-series methods to estimate the ARIMA equations. The results are checked for consistency with the structural model. If inconsistencies are noted, the proposed structural model is reexamined to identify its probable flaws. This approach makes it possible to model the underlying relationships between the dependent variable and the factors influencing it. At the same time, SEMTSA takes advantage of the ability of the time-series approach to identify and model the random processes at work in the dependent variable through a process that accounts for patterns in the past movements of the variable and that uses that information to predict future movements of the variable.<sup>20</sup>

### ALTERNATIVE FUTURES

The two preceding sections have presented procedures for producing a single forecast of freight demand. The goal of

<sup>17</sup> A *correlogram* is a plot of the autocorrelation coefficient,  $r_k$ . Its pattern can often reveal the particular form of the ARIMA model to an experienced analyst. For a good discussion of correlogram patterns and the specifications they suggest, see Peter Kennedy, *A Guide to Econometrics*, Third Edition, MIT Press, Cambridge, Massachusetts, 1984, pp. 260–261.

<sup>18</sup> Pindyck and Rubinfeld, *op. cit.*, pp. 470–471.

<sup>19</sup> Kennedy, *op. cit.*, p. 249.

<sup>20</sup> Pindyck and Rubinfeld, *op. cit.*, pp. 470–471.



these procedures is to produce as good a forecast as is practical with available resources. However, planners are cautioned that the forecast is likely not to be completely accurate—either because some of the assumptions (e.g., those relating to economic growth) prove to be inaccurate, or because of deficiencies in the procedure itself.

Because it is impossible to guarantee that any forecast is perfectly accurate, effective planning requires that planning decisions account for possible inaccuracies in the forecast. The consequences of these possible inaccuracies will influence how the planners may wish to use the forecast. For example, for some capacity expansion projects, the cost of not being able to accommodate demand may be much greater than the cost of overexpansion. In such cases, planners may wish to develop a “high likely” forecast of demand to use as the basis of expansion plans. On the other hand, for bond-financed projects, the greater concern might be whether capacity utilization will be high enough to generate sufficient revenue for paying off the bonds. For these projects, the focus may be on identifying the lowest level of future demand that is likely to occur.

The conventional approach to analyzing the effects of alternative futures is to subject a forecast to some form of *sensitivity analysis*. This approach is discussed in the first subsection below, but with an emphasis on forecasting those alternative futures that are of greatest concern.

A different approach to sensitivity analysis involves *starting* by identifying the alternative futures of concern and *then* identifying the conditions under which these futures could occur. This alternative, which we shall call *futures analysis*, is discussed in the second subsection.

### Sensitivity Analysis

The development of any forecast requires that a number of explicit or implicit assumptions be made. Some of the assumptions that may be incorporated into forecasts of demand for a transportation facility relate to the following:

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

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

One approach to conducting a thorough sensitivity analysis is to generate two reasonable alternatives for each explicit and implicit assumption in the analysis: one that would increase the forecast of demand, and one that would decrease it. A high forecast of demand can then be generated by using the alternative assumptions that would tend to increase the forecast (or at least all those that are logically compatible with each other); and a low forecast can be generated by using the alternatives that would tend to decrease the forecast. These high and low forecasts should provide planners with appropriate information about the possible future range of transport demand. Planning decisions then can incorporate any changes in transport demand within this forecast range.

A somewhat more systematic type of sensitivity analysis consists of making small changes in the analytic assumptions, one at a time, and determining the effect of each change on forecast demand. The resulting sensitivity estimates help to identify the assumptions to which the forecast is most sensitive. These assumptions can then be reviewed and, if appropriate, improved. Also, a subjective determination can be made about the degree of confidence one has in the accuracy of the assumptions. Assumptions that are not deemed to be highly accurate can be varied and the implications of such variation can be determined—either by repeating the forecasting process using appropriate sets of alternative assumptions; or by making the simplifying (and not necessarily accurate) assumption that the effect of changing each of the analytic assumptions is linear and by deriving alternative forecasts from the original forecast and the previously estimated sensitivities.

The second type of sensitivity analysis can provide more insight into the relationships between the various analytic assumptions and the forecasts produced, but this approach requires a greater expenditure of resources. Furthermore, the most important sensitivity results—high and low forecasts of demand—can be generated using either approach, although these forecasts will be affected by the alternative analytic assumptions used to generate them and

the care with which the high and low forecasts are then generated.

### **Futures Analysis**

The preceding subsection discussed the use of alternative assumptions about the future and the possible use of ones about economic relationships as the basis for generating alternative forecasts of transport demand. In futures analysis, this process is essentially reversed. More specifically, futures analysis may be viewed as consisting of two steps. First, identify those alternative futures (e.g., levels of future demand) that would warrant a different planning decision than the one indicated by the original forecasts. Then, for each such alternative future, identify the circumstances under which it might occur.

For some capacity expansion projects, there may be concern about the potential inability to meet future demand without further capacity expansion that could be accomplished most efficiently as part of the current project. For such projects, the second step of the futures analysis would include a determination of the conditions under which future demand might exceed planned capacity. Some of the possible contributing causes to be considered would include

- Higher-than-expected economic growth;
- Higher-than-expected growth in the mode(s) served (due to changes in transport requirements of shippers or in cost and service characteristics of competing modes);
- Higher-than-expected growth in transport demand in the region served by the facility (due to unusual

growth in production and/or consumption in the region); and

- A temporary or permanent loss of capacity at a competing facility.

If there appears to be a significant probability that future demand would indeed exceed planned capacity, further analysis then would be performed to obtain a better understanding of this probability and the expected costs and benefits of expanding the planned expansion.

For bond-financed projects, in particular, an alternative future of concern would be one in which demand for the facility would not generate sufficient revenue for operating the facility and paying off the bonds. We assume that the total cost of financing the facility is reasonably well known and that the cost of operating the facility (as a function of use) is understood. Then, for a given user-fee schedule, the minimum level of use that will pay the financing and operating costs of the facility can be estimated.

The second step of a futures analysis for this type of project would include a determination of the conditions under which future use would fall short of the required minimum level. Possible contributing causes would include lower-than-expected growth in the overall economy, in the mode(s) served, or in the region served, as well as an unanticipated increase in competition from other facilities (including potential new facilities). If it is determined that use may not be adequate under the assumed user-fee schedule, other user-fee schedules should be considered, incorporating appropriate adjustments in usage forecasts to reflect the effects of the alternative fees.

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## CHAPTER 4

# DEMAND FORECASTING FOR NEW FACILITIES

Transportation planners frequently must estimate how much a proposed new transportation facility or project will be used. The estimated future use of a new facility is a critical consideration in deciding whether or not to go ahead with the project.

Overestimates and underestimates may be equally costly. Overestimates result in the construction of projects or facilities that will be underutilized and that may not generate enough revenue to cover project costs. Underestimates result in the failure to build needed facilities, thereby causing congestion and delays at existing inadequate or outmoded facilities, increasing transport costs, and placing the area served by the facility at a competitive disadvantage.

This chapter addresses the issue of forecasting demand when the contemplated facility or project is new—i.e., situations in which planners do not have the benefit of a past record of facility use on which to base a projection of future use. While the previous chapter focused on the issue of projecting future use of existing facilities, this chapter deals with the projected use of new facilities. Included in this discussion are such projects as: a new freight airport; a new highway (e.g., an intercounty connector highway, a bypass route, an outer beltway, etc.); a new intermodal facility; or development of a new doublestack rail line.

Planners projecting the demand for new facilities must define the available universe of freight flows from which the new facility could draw business, and must decide how this universe of freight is likely to grow in the future. The first section of this chapter discusses the identification of the universe of freight flows that might use a new facility, and the second section discusses forecasting changes in these flows.

Once the universe of relevant freight flows is established and projections for that universe are developed, the focus shifts to assessing how much of the current and future freight traffic would use the new facility. For most new facilities, most or all of the freight using the new facility will be shifted to the facility as a result of *route diversion*, i.e., the freight will continue to be transported via the same combination of modes used prior to the opening of the new facility, but the route used will change to make use of the new facility. In some cases, a modest portion of the freight using the facility will be diverted from another mode; and in some relatively unusual cases, such as a new waterway or a new rail line through an area without rail service, modal diversion will be

the most significant source of freight using the facility. Also, a small amount of freight using the new facility may represent new freight movements stimulated by the establishment of the facility. The third section of this chapter discusses these sources of demand for a new facility in some detail, and the fourth section presents four procedures for estimating this demand.

The fifth section of this chapter provides a brief discussion of the analysis of alternative futures (which is discussed in more detail in Chapter 3 under Alternative Futures.). Additional information on data sources, cost estimation, and mode diversion is contained in Appendices C, F, G, and H, and a case study describing the analysis of the demand for a new freight airport in North Carolina is presented in Appendix I.

In summary, the following four steps describe demand forecasting for new facilities:

1. Identify the potential freight market,
2. Forecast changes in the market,
3. Estimate the new facility's market share, and
4. Evaluate the effects of alternative futures.

## POTENTIAL FREIGHT MARKET

Most of the use of most new facilities would be drawn from a reasonably identifiable set of existing facilities with which the new facility would compete. In the case of a new road, the competing facilities consist of existing roads to which the new road would provide a reasonable alternative. These alternatives may be nearby (e.g., alternatives to a new route through a metropolitan area generally consist of the existing routes traversing the area in the same general direction), or they may be more distant (as in the case of a possible new Interstate-quality highway designed to serve traffic currently using I-40 or I-70).

In the case of a new intermodal facility, the competing facilities consist of most or all of the facilities that have service areas that overlap the natural hinterland of the new facility. In the case of some facility types (e.g., container ports), the hinterlands can be quite extensive, and the set of competing facilities might be relatively dispersed geographically.

The first step in estimating the use of a new facility is to identify those competing facilities from which most of the facility's traffic is expected to be drawn and to identify the

types of traffic of interest (e.g., selected commodity groups, containerized or bulk traffic, etc.). For each of the competing facilities, data on the current volume of these types of traffic should be obtained. (Published sources of such data are discussed in Chapter 3, under Current and Historic Data on Facility Use and Transport Activity, and in Appendix C.)

In making these identifications, consideration should be given to the question of how broadly the sets of competing facilities and types of traffic of interest should be defined. An overly broad definition will result in an unnecessary increase in the amount of data required and, more importantly, in the amount of subsequent analysis required to determine the portion of total identified traffic that is likely to be diverted. In general, for analytical purposes, omitting facilities and traffic types that are expected to be only minor contributors to the new facility is desirable. It must be recognized, however, that this will result in a slight downward bias in estimated diversion.

### FORECASTING CHANGES IN THE MARKET

The second step in estimating use of a new facility consists of estimating expected changes in the volume of traffic identified in Step 1 that are likely to occur over the forecast period. These forecasts are obtained using either economic indicator variables (as described in Chapter 3 under Economic Indicator Variables) or statistical procedures (such as those discussed in Chapter 3 under Statistical Techniques and Appendix E). Once an initial forecast is obtained, it should be improved using sensitivity analysis or futures analysis, as discussed in Chapter 3 under Alternative Futures.

### SOURCES OF DEMAND FOR A NEW FACILITY

The use of a new transportation facility may come from several sources:

- Diversion of traffic from a competing facility without any change in modes used (i.e., route diversion);
- Diversion of traffic from another mode (i.e., modal diversion);
- Increased production by existing shippers in the area served by the facility; and
- Establishment of new shippers in the area.

Of these four sources, *route diversion* normally will be the principal source of demand for the new facility. *Modal diversion* may be a significant source of demand when a facility introduces a new mode into an area, but most new facilities will result in very little true modal diversion (although there may be some reduction in access hauls to intermodal terminals).

The last two sources, which represent *induced demand*, also are likely to be quite minor sources of demand for a new

transportation facility. However, because they are sources of particular importance to the area's economy, they frequently are viewed as an important reason for building the facility.

The first subsection below contains an extended discussion of route diversion, and the second contains briefer discussions of the two forms of induced demand. Procedures for estimating all four sources of demand for a new facility follow under Estimating Demand.

### Route Diversion

An individual freight movement is packaged and loaded on transportation equipment at the point of origin and discharged at the final destination, often with one or more intermediate transfers between modes, equipment types, or carriers. Routing may be narrowly defined as an itinerary made up of modal linkages (highways, rail lines, ocean and air routes) and origin, destination, and intermediate transshipment points (ports, airports, truck terminals, rail yards, intermodal hubs). A more general definition could incorporate the type of carrier, equipment, and level of service (e.g., overnight large package routing via an integrated air carrier).

The factors that determine cargo routing patterns include:

- Transportation infrastructure;
- Cost, quality, and reliability of service;
- Specialized facility and service requirements;
- Decision-making process and control; and
- Competitive environment.

Route diversion analysis requires the identification of competing routings for various markets and submarkets. The routing of a freight shipment between points A and B will be determined primarily by the available modal linkages, with the range of options varying with type of shipment and number of compatible modes. A truck shipper may be able to choose among many different carriers and highway routings between two points, while a rail shipper may be captive to a single line with track to the shipment's origin and/or destination. Similarly, an air cargo shipper may be restricted to certain international airports due to limited air service to particular markets.

The capacity and quality of the transportation infrastructure are major factors driving the cost and service characteristics of competing routes. For similar service options, transit time and transport cost often are the determining factors in routing decisions, with transit time affecting both the quality of service and operating costs for the carrier. The trade-off between cost and service often is differentiated in the routing options, such as the choice between a local terminal with limited services versus a regional hub with comprehensive but congested services. Again, the analysis of route diversion, in most cases, must consider the relative cost and time factors for the entire routing, not just the portion involving a comparison with a similar facility.

Routing decisions may be constrained by special requirements for handling, storage, or processing. For example, certain agricultural imports must be quarantined at U.S. government-authorized facilities, which are available only at certain ports and airports. Similarly, an overweight intermodal container may be restricted to routings that avoid roads on which overweight truck operation is not permitted. Market projections for new facilities should include only those commodities and markets that are compatible with available facilities and services.

Given the underlying economics and technical constraints, routing decisions ultimately determine the potential for route diversion. The routing of an individual shipment may be determined by the shipper, the consignee, the carriers involved, or third-party operators (e.g., freight forwarders), with multiple decision makers often involved. A small package shipper that tenders freight to an integrated carrier may neither know nor care about the true routing. On the other hand, a large barge shipper may operate private truck and barge fleets and have full control of door-to-door routing, including the ability to build new facilities. In estimating route diversion, it is critical to understand who makes the routing decisions, and how the decisions are made.

Route-choice criteria can vary by shipment or type of shipment. Factors influencing route choice may include cost, transit time, service frequency, reliability, cargo security, and cargo-tracking capabilities. The selection of a particular facility may be direct or indirect. For example, an air exporter might choose an international carrier on the basis of its authorized gateway airports, or might instruct its forwarder to use a particular airport based on cargo security. On the other hand, the shipper may select a “generic” service without regard to the particular routing. The rise of mini-bridge container routings in the ocean liner industry (e.g., Japan to U.S. East Coast via transcontinental rail service) was partially the result of shippers’ general indifference to port selection for intermodal routings.

Routing patterns also may depend on who controls the transportation, the shipper or the receiver. Typically, this is determined in the terms of sale. In international transactions, routing patterns often are dictated by relationships between shippers and receivers with national transportation companies. For example, Japanese importers and exporters traditionally have controlled the transportation to the U.S. inland in both directions, resulting in a market advantage to affiliated Japanese ocean carriers.

Shippers often leave routing decisions to carriers, or to forwarders, brokers, or other third parties that select the carrier or carriers. Transportation providers will seek to optimize their own internal systems rather than individual movements, typically leading to patterns different from those based on individual shippers’ decisions. In particular, carriers may have large fixed investments in certain routings that restrict the ability to shift service patterns. A new facility seeking to attract traffic can either entice a carrier to serve the facil-

ity, or encourage shippers either to select a carrier using the facility or to direct their carrier to serve the facility.

A multimodal example may illustrate route diversion to new facilities. Assume that a parts manufacturer currently is exporting containerized products to a buyer in central England using the following routing:

- Truck from factory to rail yard in Chicago;
- Rail to East Coast port;
- Loaded on outbound container vessel in North Atlantic port rotation;
- Discharged at U.K. container port; and
- Truck to final destination.

The routes involved in this shipment include

- Roads between origin and rail yard;
- Rail line to East Coast port for selected railroad;
- Load and discharge port plus intermediate calls for liner service; and
- Roads and highways between U.K. port and final destination.

The potential “diversions” for this shipment include

- Alternative truck route to rail yard;
- Alternative truck route direct to U.S. port;
- Alternative rail routing to same U.S. port;
- Alternative rail routing to different U.S. port;
- Alternative ocean routing to same U.K. port;
- Alternative ocean routing to different U.K. port; and
- Alternative truck route to final destination.

The “new facility” options include

- **New Highway to Rail Yard (in the United States or in the United Kingdom)**—Route diversion would depend mostly on the comparative cost and time factors relative to existing routings. Unless the new highway directly parallels the existing route, the analysis would require comparing total costs and time, including access from origins and destinations.
- **New Rail Facility for Current Railroad**—Route diversion would be determined mostly by the railroad, which could dictate the use of a new facility, assuming no difference in cost or service to the shipper or to other transportation providers with decision-making power.
- **New Rail Facility for Competing Railroad**—Route diversion would be based on improved costs or services over the existing facility. If the new railroad serves a competing U.S. port, the improved service also may shift port traffic.
- **New U.S. or Foreign Port Terminal**—A new port terminal can divert traffic from existing terminals in the same port or from competing ports. As previously

observed, the new facility could entice a carrier to serve both facilities or to replace the existing call with a call at the new facility. A new carrier also could initiate competing services. New traffic would include traffic from a new carrier serving the facility captured from existing ports and carriers, and traffic from an existing carrier split or entirely diverted from the existing port.

The techniques required to estimate route diversion to new facilities include

- A detailed estimate of carriers' or shippers' flows;
- Comparative analysis of cost and service for routings with the new facility compared to current routings; and
- Projection of the sensitivity of current flows to diversion using cost elasticities if available or, more likely, using comparable market situations.

Detailed cargo-flow data generally are not available, and flow projections must be based on single-point traffic statistics (e.g., port and airport statistics), which then can be associated with specific commodity, service, or carrier markets. "Shippers" often must be defined in general geographical and commodity categories for which routing distributions are developed (e.g., a certain percentage of Midwest corn exporters ships via Port A). As previously noted, the required scope for the market definitions will depend on whether the competitive environment is localized or generalized. For example, the market for the fifth container terminal in a large ocean port may be based on projected patterns through that port alone, while projecting the market for a new type of facility might require a national analysis.

Having specified the baseline routing conditions, a comparison of relative costs and services can be used to "calibrate" the existing traffic patterns. Noneconomic factors also should be considered. Unless the market is dominated by a few commodities or shipment types, this often requires developing prototype movements, which are used to represent the spectrum of flows. A useful simplifying assumption is to incorporate all service and time differences into a total cost that can be used to compare routings. For example, an estimated inventory cost often is used as a measure of the service benefits from improved transit times or as a measure of the cost penalty for congestion-related delay.

### Induced Demand

As previously noted, induced demand may result from increased production by existing shippers in the area or the establishment of new shippers in the area. These two sources of induced demand are discussed briefly in the following sections.

#### *Existing Shippers*

In concept, any reduction in transport costs reduces the costs of existing firms in the area and increases their ability

to compete with firms from other areas. In practice, except for producers of low-value commodities (e.g., grain), the transport cost savings obtained by any single shipper as a result of a new facility are likely to represent substantially less than 1 percent of the delivered price of the shipper's product. The effect on total production, and therefore on use of the new facility, is likely to be small, and may not be worth estimating separately.

If analytic estimates of this effect are desired, they can be developed for a particular product by estimating the annual volume of inbound and outbound movements associated with the product and estimating the transport-related cost savings expected for these movements (using procedures presented in Appendix F). Expressing these savings as a percentage of the value of the product delivered annually (and ignoring any economies of scale<sup>1</sup>) produces an estimate of the maximum percentage reduction in the product price that can result from the reduction in transport costs. For manufactured products, in the absence of specific information on the price elasticity of demand, unit elasticity can be assumed; i.e., a 1 percent reduction in price can be assumed to produce a 1 percent increase in shipments.

Demand for agricultural and mining products may be much more elastic, but the supply of these commodities usually is quite inelastic. Accordingly, a reduction in transport costs for these products is unlikely to have any significant effect on their shipment volume (although such a reduction may have a substantial positive effect on the profitability of local producers of these commodities).

#### *New Shippers*

A major reason for considering the development of a new transportation facility may be the hope that it would result in new shippers moving into the area. Although a new transportation facility may increase the attractiveness of the area to potential new shippers, actual location decisions will depend both on the resulting transport costs and quality of service, as well as on a variety of other locational factors.

A new road or intermodal facility may increase the attractiveness of the area served to new firms by improving accessibility to markets and decreasing transport costs. In theory, this effect could be greatest when the new facility makes it practical to use a form of transport that was not previously available. For example, a new airport in an area that has no airports could enable a firm that requires air service to consider locating in the area. On the other hand, if service at the airport is relatively limited, as is likely in the case of a new airport, such a firm might not find the air service adequate for its needs.

If information is available on the expected inbound and outbound transportation requirements of a particular firm

<sup>1</sup> If economies of scale exist, an increase in production may result in some further reduction in costs. However, for manufactured goods, the small increases in production that are probable are unlikely to produce any significant economies of scale.

that is considering moving into the area, the procedures of Appendix F could be used to estimate the value of a prospective new transportation facility to that firm. However, the firm's decision to locate in the area depends on several other factors, including overall accessibility to suppliers and markets; available industrial sites; labor costs; taxes; and, perhaps, financial inducements. The complexity of industrial location decisions makes it difficult for outside observers to make reliable predictions as to whether or not a firm actually will locate in a particular area, and the relatively small impact of new transportation facilities on total costs limits the likely effect of such new facilities on these decisions. Accordingly, in the absence of solid commitments by new firms to locate in the area, transportation planners probably should assume that such firms are unlikely to generate significant use of a new transportation facility.

## ESTIMATING DEMAND

Procedures for estimating the demand for a new transportation facility include the following:

- Surveying shippers and carriers to determine their likely use of the new facility;
- Developing estimates from forecasts of the overall market (discussed above, under The Potential Freight Market and Forecasting Changes in the Market) and information about the degree of market penetration by similar facilities that have been developed in the past;
- Allocating the overall market among competing facilities on the basis of proximity and expected level of service; and
- Performing a detailed analysis and comparison of total logistics costs (TLC) for shipments when transported via their current routings and when transported via the new facility.

### Surveying Shippers and Carriers

A survey is likely to be attractive to many planning agencies. A survey is capable of developing estimates of demand that are based primarily on information provided by the parties whose decisions will determine the extent to which a new facility actually will be used. Nonetheless, the survey approach may be somewhat more complex than it appears, and use of this approach to obtain reasonable estimates of actual demand requires a good deal of care.

The steps required in performing a survey are as follows:

1. Determine the universe of potential users of the new facility;
2. Select a sample of firms to survey;
3. Prepare the survey questions;
4. Conduct the survey; and
5. Expand the survey results to estimate total use of the new facility.

### 1. Determine Universe of Potential Facility Users

The first step in conducting a survey involves determining the universe of firms whose decisions will determine use of the new facility. For a new intermodal facility, the universe includes any air, water, or rail carriers that may decide to serve the facility; trucking companies usually should be excluded from the universe, since their use of the facility is likely to be determined entirely by the decisions of others. For a new road, the universe should include both private and for-hire truck operators that may use the road.

In addition, the universe of relevant firms includes all firms that ship into or out of the area served (or, more properly, the subset of these firms that actually control the routing decisions of these shipments). To control the size of this portion of the universe, it may be desirable to include only firms with facilities actually located in the area and to structure the questions so as to learn about both the shipments and receipts at these facilities.

### 2. Select Sample for Surveying

The second step consists of determining which firms in the universe to survey. If the universe is small (relative to study resources), it may be practical to survey all firms in the universe. More likely, it will be possible to survey only a sample of shippers and receivers (although it usually will be desirable to survey all carriers).

If a sample is to be selected, it generally is desirable to stratify the universe of shippers and receivers on the basis of industry, firm size, and/or location and to vary the sampling rates by stratum. For a new airport, high sampling rates may be desirable for shippers that are large, located relatively close to the airport, or ship and receive high-value goods that are relatively likely to go by air, with lower sampling rates used for other strata. Strata consisting solely of firms that are likely to make little or no use of the facility may be deleted from the survey, with use by firms in these strata treated as being negligible.

For each stratum, a reasonably unbiased sample of firms should be selected; e.g., by enumerating all firms and selecting every  $n$ th firm. If the universe is large, it may not be practical to identify all small firms individually. However, for any individual stratum, some care should be taken to make sure that the percentage of firms sampled does not drop off as firm size (or shipment volume) declines or distance from the facility increases.

### 3. Prepare Survey Questions

The third step is to prepare the survey questions. These should include questions relating to: total volume of shipments originating and/or terminating in the area; the percentage likely to be shipped via the new facility; any effect the new facility is likely to have on shipment volume

(induced demand); and identification of the decision maker (shipper, receiver, or carrier) that would actually determine whether the facility is used. A question on the extent to which likely use depends on the level of carrier service should also be considered. Responses from those who are not decision makers generally should be excluded from the analysis; however, responses from shippers and receivers that are not decision makers should be used as proxies when the actual decision maker is an out-of-area receiver or shipper.

The survey material should include appropriate information about the new facility, and shippers should be provided with a description of the level of carrier service expected at the facility.

Requested information may include the following items:

- Company name and address;
- Type of facilities operated in study area (manufacturing, warehousing, etc.);
- Major commodities shipped and received;
- Total volume of shipments and receipts;
- Expected use of the new facility (volume by commodity);
- Effect of the new facility on routings of these shipments (e.g., Commodity A will be moved by truck from Plant B to the new facility instead of to Intermodal Facility C);
- Expected effect of the new facility on operations in the area; and
- Name and telephone number of the survey respondent.

The survey should be designed for clarity and to minimize the time and effort required by the respondents. Any major survey should be pretested on a small sample of respondents to identify wording that can be improved and areas where respondent burden can be reduced. An interview survey form used in a recent study of demand for a possible rail/truck intermodal facility is reproduced in Appendix D.

#### 4. Conduct the Survey

The fourth step consists of the actual conduct of the survey. Although several options exist, a telephone/mail/telephone follow-up procedure usually produces a high response rate with a relatively moderate expenditure of resources. This procedure starts with an initial set of telephone calls to determine that each firm actually is a potential user of the new facility, to identify the most appropriate respondent within the firm, and to enlist that person's cooperation in responding to the survey. In the case of large firms, routing decisions may be handled at a headquarters office rather than at individual facilities in the study area. If a firm is not a potential user of the facility, no further questions need be asked, but the firm should be retained in the survey sample as representative of a number of firms in the same stratum that are not expected to use the facility.

The survey forms then are mailed to the participating firms and the firms are given two or three weeks to respond by mail. Additional telephone calls should be made to each firm that does not respond to encourage a response and possibly to obtain an oral response. The appropriateness of telephone responses depends on the specific questions asked and whether or not respondents are expected to review their records or perform any analysis before responding.

If telephone responses are allowed, firms that do not respond can be presumed to be relatively uninterested in the new facility and so can be presumed to make little or no use of it. Even if written responses are required, nonrespondents are likely to make less use of the new facility than respondents.

#### 5. Estimate New Facility Use

The final step in the process is expanding the survey results to produce an estimate of total use of the new facility by all potential users. A substantial amount of care is required in this step to avoid double-counting the responses.

For each stratum, total estimated usage by surveyed firms can be divided by the number of firms sampled (including nonrespondents and firms that indicated that they would not use the facility) to obtain an estimate of usage per firm. If only written responses are used, some upward adjustment of this ratio is appropriate to allow for usage by nonrespondents. The result is multiplied by the number of firms in the stratum to produce an estimate of total usage in the stratum. The use of this estimate presumes that the total number of firms in the stratum is known or has been reliably estimated and that the sample selected for the stratum was not biased toward higher volume shippers (e.g., by picking the most visible members of the stratum). Finally, the estimates of total usage by stratum are added across strata to produce an overall estimate of use of the new facility.

In adding the estimates, some care will be required to determine that the shipper and carrier surveys produce complementary estimates of facility use; i.e., that the former survey provides an estimate of usage for shipments whose routings are determined by the shipper while the latter survey provides a corresponding estimate for shipments routed by the carrier. A careful review of survey responses will be necessary to avoid such double-counting.

Another, but usually less important, source of potential double-counting occurs in the case of shipments that both originate and terminate in the study area. If both shippers and receivers of such shipments claim responsibility for routing decisions, double-counting will result.

The resulting estimate of new facility use will represent usage due to route diversion, mode diversion, and increased shipments to or from firms currently in the area. Shipments to or from firms that may be induced to move into the area by the new facility will not be explicitly represented in this estimate, but this effect is likely to be small.



A more significant issue is the extent to which use is overestimated as a result of exaggerated usage forecasts by respondents expecting to benefit from the new facility. Such exaggeration may take the form of carriers stating an unwarranted expectation of moving operations to the new facility and shippers overestimating expected increases in traffic volume (a natural occurrence even when there is no incentive to exaggerate). Satisfactory procedures do not exist for identifying such exaggeration and minimizing its effects on estimated use of the new facility. The lack of such procedures limits the reliability of estimates produced by the survey approach.

### Comparisons with Previous New Facilities

The comparison approach is a relatively attractive option, particularly in the early stages of the planning process. This procedure consists of the following:

1. Identifying similar facilities that have been developed recently;
2. Obtaining market share data for these facilities;
3. Adjusting these market shares so that they are applicable to the proposed new facility; and
4. Applying the adjusted market shares to forecast demand in the study area to produce a range of estimates of forecast usage of the new facility.

The comparison approach presumes that at least some new transportation facilities of the type under consideration have been developed in the recent past. If not, this approach cannot be used and, perhaps more importantly, careful consideration should be given to identifying and understanding the reasons why no such facilities have been developed.

#### 1. Identify Recently Developed Facilities

The first step in the comparison process involves identifying other new transportation facilities of the types being considered that have been developed in the recent past (probably over the past 10 to 20 years), and selecting those facilities that are most similar to the facility being considered. Factors to be considered in evaluating the similarity of facilities include facility capacity, geographic size of the relevant market area, geographic density of freight generated in the area (measured in weight or volume units per square mile), types of freight originating and terminating in the area, and characteristics of the existing facilities with which the new facilities must compete. Since it is unlikely that there will be good matches for all these factors, a fairly generous standard of "similarity" should be used and, if possible, several similar "comparison" facilities should be identified.

#### 2. Obtain Market Share Data

The second step in this process involves obtaining information about the shares of the relevant markets captured by

the comparison facilities and the number of years required to attain that market share. This step entails the collection and interpretation of data and information from the operators of the comparison facilities. A useful adjunct to this activity would be to conduct more extensive discussions with the facility operators to gain additional insight into the facility planning and development processes.

At the conclusion of the second step, a very preliminary range of estimates of demand for the new facility should be developed by applying the market shares captured by each of the comparison facilities to the projected overall market in the area served by the new facility (see *Forecasting Changes in the Market*, above). These preliminary estimates may be useful in determining the level of effort to be expended on the remainder of the analysis and even whether any additional analysis is warranted.

#### 3. Adjust Market Share Data

The third step involves a careful review of the differences between the market shares obtained by each of the comparison facilities and the market share likely to be obtained by the new facility. For each comparison facility, differences to be considered in this step include the following:

- **The Market Areas Served by the Two Facilities**—Do both market areas extend into the natural hinterlands of competing facilities to an equal extent; or is one market area limited to areas close to the new facility or to the comparison facility, while the other includes a substantial amount of area in which shipments generated are relatively unlikely to use the new facility or the comparison facility?
- **Commodity Mix**—Are the mixes of commodities shipped into and out of the two areas reasonably similar, or does one area have a commodity mix weighted more heavily toward commodities that are likely to be shipped via the facility in question than does the other area?
- **Service by Scheduled Carriers**—Are both facilities expected to receive the same level of service (quality and frequency) by scheduled air, water, or rail carriers, or is one likely to receive better service?
- **Competition from Existing Facilities**—Are both the new facility and the comparison facility subject to the same degree of competition from other facilities with respect to proximity, facility capabilities and constraints (storage capacity, channel depth, runway lengths, etc.), level of service of scheduled carriers, and so forth?

For each comparison facility, each of the differences relative to the proposed new facility should be analyzed. This analysis should be used as the basis for adjusting the comparison facility's market share to produce a market share that better represents the likely market share of the proposed new facility.

#### 4. Produce Range of Usage Estimates for the New Facility

The result of the third step is a set of adjusted market shares, with one value derived from the original market share of each of the comparison facilities. The extent of the adjustments that were made and the degree of judgment required for these adjustments will affect the relative reliability of each of the adjusted market shares. Any outliers that are considered to be relatively unreliable should be dropped, and the remaining values should be used to define a range of likely market shares for the proposed new facility. Applying this range of market shares to the projected overall market produces a revised range of estimates of demand for the new facility.

As described above, the analysis explicitly reflects the effects of route diversion and any mode diversion. It does not produce separate estimates of induced demand, nor is the projected overall market adjusted for any increase resulting from induced demand. However, because induced demand is included in data on use of the comparison facilities, it is implicitly included in the market shares developed in Steps 2 and 3. Because induced demand is likely to be quite small in comparison to the overall market (which includes freight that continues to be shipped via competing facilities), the exclusion of induced demand from the projected overall market is likely to have only a small effect on the resulting estimates of demand for the new facility; a correction for this omission probably is not warranted.

Some operators of comparison facilities may have data that purport to represent the extent of induced demand attributable to the development of their facilities (which, presumably, could be used to infer induced demand at a similar new facility). However, substantial care should be exercised in accepting such data at face value—such data frequently attribute all traffic growth to the advent of the facility in question without attempting to exclude the effects of normal growth in the area's economy that would have occurred even if the facility were not developed.

#### Evaluating Proximity and Level of Service

Another relatively attractive option for estimating the demand for a new intermodal facility is to allocate the market between the new facility and competing local facilities based on the relative proximity and the relative levels of service (LOS) expected to be provided at the various facilities. This procedure may be viewed as a variant of a gravity-model approach. One variant of this procedure is used in a case study presented in Section 1 of Appendix I. This procedure consists of the following:

2. For each subarea, assigning a proximity score for each of the facilities;
3. Developing a set of LOS scores for the new facility and for all competing facilities that serve the study area;
4. Combining the LOS and proximity scores;
5. For each subarea, allocating the Step 1 freight volumes across facilities; and
6. Adding the estimates of freight volume allocated to the new facility across all subareas to produce an overall estimate of usage.

##### 1. Divide Study Area into Subareas

The first step in this procedure involves dividing the market area to be served by the new facility into subareas (e.g., counties or county aggregates) and forecasting the annual volume of the freight of interest originating or terminating in each of the subareas. Potential sources of base-year estimates include data from the Colography Group and Reebie Associates (see Appendix C). (An example presented below describes the use of Colography Group data for analyzing demand for a new airport.) The base-year volume estimates may be used to distribute forecasts of the total volume of freight of interest across subareas; or, alternatively, forecasts of freight by subarea may be developed directly from the base-year estimates.

##### 2. Assign Proximity Scores

In the second step of this proximity/LOS procedure, proximity scores are assigned to each subarea/facility pair. Each score should be based on the road distance from the facility to the approximate centroid of economic activity in the subarea (e.g., using highway mileage tables for household goods carriers). As an option, the distances may be adjusted to reflect transport costs, transit times, and transit-time reliability. A proximity score of 10.0 should be assigned whenever road distance or the adjusted road-distance-value is less than 50 mi; longer distances should produce lower scores.

Two suggested functions for converting distances to proximity scores are shown in Figure 1. The stepwise function<sup>2</sup> presumes a sharp break in the attractiveness function at 300 mi, while the continuous function assumes a more gradual decline in attractiveness with distance. (The continuous function is obtained by using a score of 10 for distances less than 100 miles, and by dividing 1,000 by the distance in miles for longer distances.)

1. Dividing the study area into subareas and forecasting the annual freight volume of interest originating or terminating in each subarea;

<sup>2</sup> The stepwise function was used in a study described in Section 1 of Appendix I. (Transportation Management Group, Inc., Leeper, Cambridge & Campbell, Inc., and COMSIS Corporation, *North Carolina Air Cargo System Plan and a Global Air Cargo Industrial Complex*, February 1992.) In the North Carolina study, the proximity and LOS scores were added (instead of being multiplied, as suggested in Step 4).

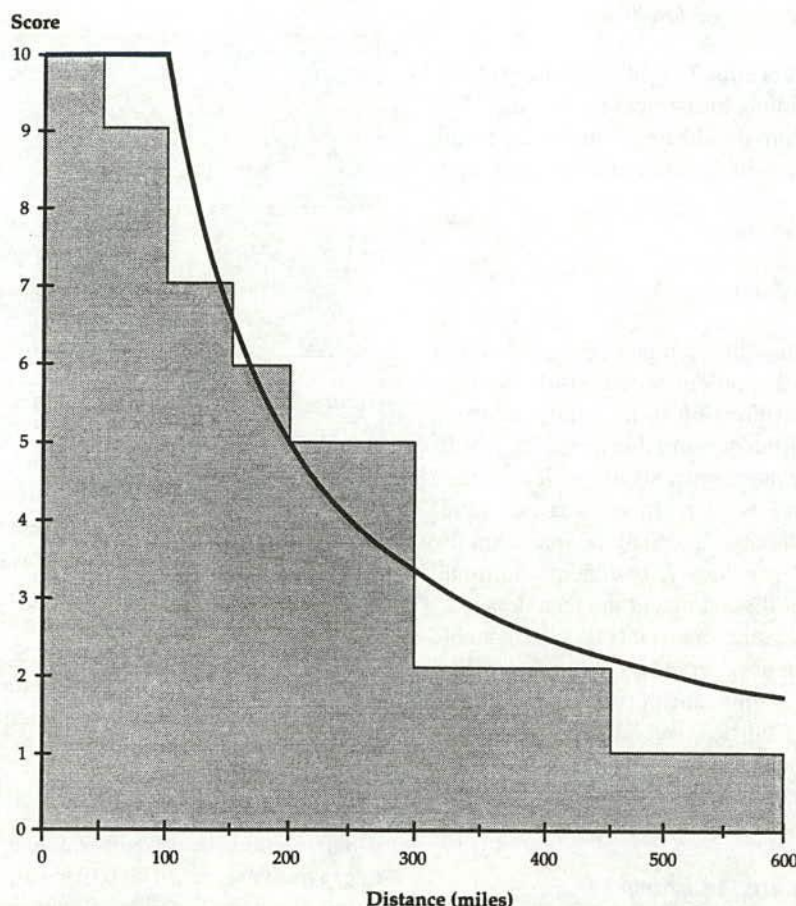


Figure 1. Suggested proximity-score functions.

### 3. Develop LOS Scores

The third step involves the development of forecasts of the relative levels of service expected at the new facility and at each of the existing facilities servicing the study area. An LOS score of 10.0 should be assigned to the facility with the highest level of service. Each of the other facilities should be compared to this facility in terms of

- Number of destinations or markets accessible via scheduled air, water, or rail service from the facility (preferably weighted by the size of the destination market);
- Frequency of service to markets accessible via both facilities; and
- Any differences in carrier costs per unit of cargo for serving the two facilities (e.g., due to the higher cost per unit of cargo for using smaller vessels to serve low-volume markets or to access ports with limited channel depth).

These comparisons then should be used to assign LOS scores to each of the other facilities, with a LOS of 5.0 being assigned to a facility whose LOS, based on the above crite-

ria, is half as good as that of the facility with the highest LOS. In many analyses, it may be desirable to assign separate sets of LOS scores for different types of traffic (e.g., domestic versus international or short haul versus long haul) and, in Step 1, to develop freight forecasts that are similarly disaggregated.

For the existing facilities, the LOS scores should be derived using information about current service available at the facility and any expected changes during the forecast period. For the new facility, it will be necessary to develop reasonable forecasts of the level of service that would be provided. It is important that these forecasts be reasonable because overestimating the level of service to be provided by the carriers will result in overestimating freight demand.

### 4. Combine LOS and Proximity Scores

The fourth step involves computing an overall score for each of the facilities being considered. One option is to obtain this score as the product of the LOS and proximity scores.



### 5. Allocate Freight Volumes Across Facilities

The fifth step involves allocating freight originating or terminating in each subarea among the competing facilities. For each subarea, this allocation should be proportional to the Step 4 scores (perhaps after eliminating facilities with very low scores).

### 6. Produce Overall Usage Estimate

The results of the fifth step then can be aggregated across all subareas of the study area to produce forecasts of the share of freight originating or terminating in the study area that would use each of the facilities serving this area. The resulting forecast of new facility use represents usage due to route diversion, the primary source of usage. In some cases, a modest upward adjustment to this forecast may be made, on the basis of factors discussed previously, to reflect additional usage resulting from modal diversion and induced demand.

As described above, the study area will be a reasonable approximation to the entire area served by the new facility. However, it may exclude significant portions of the areas served by the competing facilities. Accordingly, the usage forecasts produced for those facilities will represent only a portion of their actual usage.

#### The LOS/Proximity Procedure: An Example

Consider a region consisting of five of the airport market areas (A, B, C, D, and E) distinguished in Colography's *U.S. Air Freight Origin Statistics*,<sup>3</sup> and assume that the region is served by two airports. Further assume that the development of a third airport is being considered. Such an example is shown schematically in Figure 2.

The first step in the procedure is to forecast air cargo traffic originating and terminating in each market area for an appropriate forecast year. Colography data are used to obtain base-year air cargo traffic originating in each of the market areas for 73 manufacturing industries and for a 74th "all other" industry. Base-year air cargo terminating in the region is obtained from data on cargo received at the two existing airports and distributed across market areas in the same way as the originating traffic is distributed.

Forecasts are developed using one of the procedures presented in Chapter 3 (e.g., using economic indicator variables). The first column of Table 3 shows an assumed forecast of total air cargo traffic originating and terminating in each market area. Total forecast-year traffic for all five regions is assumed to be 380,000 units. To simplify the example, we have chosen not to distinguish between originating and terminating traffic, although such a distinction

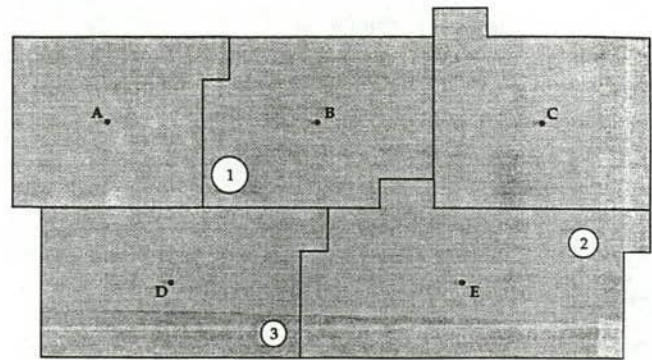


Figure 2. Study region for proximity/LOS example.

usually would be made when developing an actual freight demand forecast. Also, any current or future use of the three airports by traffic that does not originate or terminate in the study region has been ignored.

The second step of the procedure involves assigning a proximity score to each market area/airport pair. For each market area, the approximate centroid of air cargo generation (or, more simply, of manufacturing activity) is located, and the road distances to each of the three airports is obtained. These distances are shown in the last three columns of Table 3.

The second part of Step 2 converts the Figure 2 distances to proximity scores. The scoring system used in this example is the stepwise function shown in Figure 1. The resulting proximity scores are shown in Table 4.

The third step consists of assigning LOS scores to each facility. A score of 10 is assigned to the facility that is expected to have the best service in the forecast year, assumed to be Airport 1, and proportionately lower scores are assigned to the other facilities. This scoring is necessarily subjective, combining easily quantified measures (number of flights per week, number of destinations served, etc.) with more qualitative ones (relative importance of the destinations served, schedule characteristics, etc.). The scores should reflect attractiveness to the "typical" shipper, recognizing that different shippers are likely to be interested in different destinations and may have other unique service

TABLE 3 Distances and traffic volumes for proximity/LOS example

Market Area	Annual Traffic	Distance to Airport (Miles)		
		1	2	3
A	70,000	140	465	240
B	100,000	100	265	225
C	90,000	315	115	365
D	70,000	125	390	70
E	50,000	265	110	230
	380,000			

<sup>3</sup> The Colography Group, *U.S. Air Freight Origin Statistics*, Marietta, Georgia, annual. A one-page description of this data source is contained in Appendix C.

**TABLE 4 Overall scores for proximity/LOS example**

Market Area	Airport			Total
	1	2	3	
A	70	6	25	101
B	90	30	25	145
C	20	42	10	72
D	70	12	45	127
E	50	42	25	117

requirements. In the example, Airport 2 is assumed to warrant a LOS score of 6.0; and forecast service at the new airport, Airport 3, is assumed to warrant a score of 5.0.

In Step 4, overall scores are computed for each market area/airport pair by multiplying the proximity scores by the LOS scores. The resulting overall scores are shown in Table 4. Also, for each market area, the last column of this exhibit shows the sum of the three separate market area/airport scores.

In the fifth step, the Step 1 forecast freight volumes for each market area are allocated across airports on the basis of the overall market area/airport scores. The fraction of Area A air cargo shipped via Airport 1 is obtained by dividing 70 (from Table 4, Column 1) by 101; and the forecast volume of such freight is obtained by multiplying this fraction by 70,000 units. The results of this step are shown in Table 5.

The final step consists of obtaining forecasts of the total volume of air cargo shipped via each of the three airports by adding the volumes originating and terminating in each of the five market areas. These forecasts are shown at the bottom of Table 5.

#### *Additional Discussion*

The proximity/LOS procedure can be modified to consider a more extended study area that includes most or all of the area served by all the facilities under consideration. If this is done, then, with one additional step, usage forecasts can be

**TABLE 5 Proximity/LOS sample—forecasts of annual traffic**

Market Area	Airport		
	1	2	3
A	48,515	4,158	17,327
B	62,069	20,690	17,241
C	25,000	52,500	12,500
D	38,583	6,614	24,803
E	<u>21,368</u>	<u>17,949</u>	<u>10,684</u>
Total	195,535	101,911	82,555

produced for all the facilities studied. The extra step involves adjustments for a small amount of freight “leaking” into or out of the study area; i.e., out-of-area freight that is shipped via one of the facilities studied, and study-area freight shipped via a competing facility that is not studied. In the case study presented in Appendix I, this modified procedure was used—the study area was taken to be the entire state of North Carolina plus selected counties in adjoining states, and freight forecasts were developed for each of the state’s three major airports both with and without the addition of a proposed new all-cargo airport.

Another advantage of an extended study area, as suggested in the preceding paragraph, is that it permits the allocation system to be calibrated using data from a recent year. The calibration process involves performing Steps 1 through 5 using data for the base year and comparing the resulting allocation of freight among the existing facilities to the known freight volumes in that year. The judgmentally derived scoring system used in Steps 2 through 4 then is reviewed and modified to improve the match between the allocations produced by the procedure and actual freight volumes. This optional calibration step (used in the Appendix I case study) reduces the role of judgment and should improve the quality of the forecasts produced. However, judgment will still play a critical role in forecasting the level of service to be provided at the new facility.

Once the analysis has been completed, a review should be conducted to determine whether the Step 6 forecast of use of the new facility justifies the level of service assumed in Step 3. This review may make use of information about service provided at existing facilities with similar levels of usage. If the assumed level of service is higher than justified, it is unlikely to materialize, and actual usage would be lower than the forecast indicates. In this situation, two analytic alternatives exist.

The first alternative involves repeating Steps 3 through 6 using a lower LOS for the new facility. Because a lower LOS will produce a lower usage forecast, some experimentation may be necessary to determine the extent to which the LOS must be reduced to obtain an assumed LOS that is justified by the forecast use of the facility.

The second alternative is simply to accept, without further experimentation, the provisional conclusion that demand for the new facility is likely to be insufficient to attract the kind of service that would be necessary to make the facility viable.

#### **Analyzing Total Logistics Costs of Individual Shipments**

The fourth procedure is the most disaggregate and the most difficult to implement. This procedure consists of the following:

1. Selecting a representative sample of shipments originating or terminating in the study area;

2. Estimating the total logistics costs for each of these shipments if shipped via its current route and if shipped via the new facility;
3. Determining the likelihood that the shipment would be diverted to go via the new facility; and
4. Expanding the Step 3 results obtained for the sample of shipments to represent the universe of shipments originating or terminating in the study area.

### *1. Select a Sample of Shipments*

The first step consists of selecting a sample of shipments originating or terminating in the study area. This sample usually is stratified by commodity, and may be stratified by other variables as well (e.g., by current modes used, by whether the shipment originates or terminates in the area, by subarea of origin or destination, etc.). An important consideration in constructing the sample is that it include a reasonable number of shipments representing each of the strata that are likely to contribute any significant amount of use to the new facility.

### *2. Estimate Total Logistics Costs*

The second, and most difficult, step involves estimating the TLC for each shipment if transported via the new facility and if transported via its current route. A slightly simpler alternative is to focus on estimating the differences between these two TLC values. When only route diversion is involved, the principal potential contributors to this difference are:

- a. Transport cost differences resulting from differences in the length of haul required by any one mode;
- b. Transport cost differences resulting from differences in the efficiency with which the two facilities can be served (e.g., as a result of differences in vessel sizes); and
- c. Differences in transit times and transit time reliability resulting from differences in scheduled service at the two facilities.

Estimates of transport cost differences resulting from differences in the length of haul or service efficiency can be developed using estimates of length of haul along with transport cost information presented and referenced in Appendix F. Estimates of differences related to scheduled service at the two facilities require forecasts of differences in the level of service offered by carriers serving the two facilities as well as commodity-specific information about inventory costs and stock-out costs. For many shipments, the relative values of the two estimates of TLC will be significantly affected by the quality of service forecast for the new facility. The difficulty of developing a reliable forecast of quality of service, com-

bined with the effort required to perform the rest of the Step 2 analysis, generally makes this procedure less attractive than the others.

### *3. Estimate Potential Diversion to New Facility*

The third step consists of estimating the likelihood that the shipment would be diverted to make use of the new facility. The simplest alternative for this step is to assume that the alternative with the lower estimated TLC will be selected. A more complex and somewhat more reliable alternative is to use a logit formulation<sup>4</sup> to assign shipment shares to the two alternatives, allowing for the effects of random errors in the TLC estimates and in the shippers' perception of TLC, and allowing for the effects of random imperfections in carrier pricing.

### *4. Develop Total Usage Forecast*

The final step consists of expanding the estimates of use of the new facility by shipments in the sample to represent a total usage forecast for the facility. This step simply entails dividing the results for each stratum by the sampling rate (expressed as a fraction) and summing across all strata. The result represents use of the facility as a consequence of route diversion and (if considered in Step 2) modal diversion.

As in the case of the preceding procedure, it is recommended that the Step 4 estimates of facility use be evaluated to determine whether they are consistent with the level-of-service assumptions made for the new facility. If estimated facility use appears to be inadequate to justify the assumed level of service, the analysis should be repeated, assuming a lower level of service at the new facility.

## **ALTERNATIVE FUTURES**

As the preceding discussion indicates, the private sector decisions that determine demand for a transportation facility are more difficult to forecast in the case of a new facility than in the case of an existing or replacement facility. Consequently, a careful evaluation of the effect of alternative futures on the need for and likely success of a facility is even more important in the case of a new facility than in the case of an existing facility.

Procedures for performing such an evaluation are presented in Chapter 3 under Alternative Futures. These procedures apply to new facilities as well as to existing facilities. However, in the case of a new facility, there are certain alternatives that must be given careful attention. The most

<sup>4</sup> E.g., see Thomas A. Domencich and Daniel McFadden, *Urban Travel Demand: A Behavioral Analysis*, American Elsevier Publishing Company, New York, NY, 1975.

important of these alternatives is the possibility that one or more carriers or other expected major users of the facility will make substantially less use of the facility than anticipated. The circumstances under which such reduced use may occur should be carefully evaluated, and the sponsors of a new facility should determine in advance how they would deal with such a possibility.

If a survey procedure is used, the best method of performing the alternative futures analysis requires some careful consideration. Ideally, this analysis would be incorporated directly into the survey (e.g., by adding questions relating to the effect of alternative levels of service on usage), but any such additional questions must be handled with care to avoid overburdening respondents and reducing their level of cooperation.

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## CHAPTER 5

# POLICY ANALYSIS

The objective of this chapter is to provide planners with methods for analyzing the impact of government policies on freight demand. Chapter 5 takes a broader view than Chapters 3 and 4, which address the estimation of demand for specific facilities. Chapter 5 discusses techniques that are not limited to a particular facility, but instead are used to estimate the impacts of public policies on freight demand for an entire geographical area, such as a metropolitan area, a state, a region, or the nation. The policy may be targeted at the transportation industry, such as a fuel tax increase, or it may be a general policy with transportation implications such as a change in trade policy. The policy may be a federal, state, or even a local policy. Even if the policy is issued at the federal or state level, its local impact may be of interest to a metropolitan planning organization.

Policy impact analysis may be approached systematically. This chapter develops a four-step approach for assessing the transportation demand impact of government policies:

- Develop a policy impact analysis framework;
- Develop a profile of base-case conditions;
- Estimate how the policies under consideration will affect costs and other service characteristics; and
- Predict the effects of the policies on demand, either aggregate or by mode or submode.

## DEVELOPING A POLICY IMPACT ANALYSIS FRAMEWORK

Establishing an overall framework for the policy impact analysis should be done at the outset of a project. The framework will drive the rest of the analysis, from data collection to the quantification of a policy's impact. It also will help to ensure the accuracy of the results, as well as the efficiency with which those results are derived.

The following questions are among those that should be considered in developing the framework:

- **How may the policies under consideration affect demand?**

The general attributes of a policy should be examined to determine how the policy may affect specific modes. In general, policies may be categorized in three groups:

1. Policies that directly affect the costs of service for a particular mode, such as a tax increase on diesel fuel;
2. Policies that indirectly affect modal costs, such as truck size and weight regulations; and
3. Policies that directly affect freight demand, such as trade agreements.

Certain policies may have direct impacts on the costs of service for particular modes. For example, an increase in the tax on diesel fuel will have a direct, quantifiable impact on truck and rail costs. These increased costs must be evaluated with respect to their impact on the demand for each mode. The initial assessment of the link between the policy and the mode will dictate how the overall analysis should proceed.

Other policies will have a more indirect impact on modal costs. Truck size and weight regulations will have a direct impact on the types of equipment that motor carriers may use. In turn, equipment types will affect the cost of transporting goods via truck; unit costs of transportation tend to decrease with the use of larger equipment. Again, a careful structuring of the process will shape the specific analytic approach required to link the policy to modal costs and, subsequently, to demand for each mode.

Rather than affecting modal costs, some policies have a direct impact on modal demand. These policies include international trade agreements, such as the North American Free Trade Agreement (NAFTA) and the General Agreement on Tariffs and Trade (GATT), that stimulate trade, which, in turn, increases the demand for transportation. Another example is the policy requiring a certain percentage of domestic content manufactured and sold in the United States; this policy may reduce demand for the freight transportation associated with motor vehicle parts produced in foreign countries.

Although the structuring of the analytic process for the policies mentioned thus far has been straightforward, some policies are more difficult to frame. For example, government policies dealing with truck safety are intended to decrease the frequency of accidents, but also may increase operating costs for the motor carrier industry. The cost of monitoring and implementing the safety program may or may not be more than offset by reduced accidents. The analytic framework must be broad enough to consider both of these issues.



- **What types of shipments will be affected?**

Identifying the shipment types that may be affected by the policies under consideration is a key step in structuring the framework. The characteristics that determine how a shipment is affected include commodity, origin, destination, weight, value, size, frequency, mode, equipment type, and routing. For example, commodity density is a key characteristic in determining which shipments will be affected by changes in truck weight limits. Truck weight regulations effectively limit the practical maximum payload for high-density commodities but not for low-density commodities. Therefore, a change in truck weight limits would not affect most low-density shipments.

- **What are the potentially significant impacts of demand changes due to the policies under consideration, and what procedures will be used to estimate these impacts?**

Demand estimation usually is a means to evaluate policy impacts, rather than an end in itself. Policy impacts may include costs to shippers and receivers, the financial viability of key industries, pavement costs, energy consumption, and emissions. The need to estimate certain impacts may impose special demands on the analysis. For example, pavement costs are affected not only by traffic volumes, but also by vehicle axle weights. If pavement costs are an issue, it may be necessary to structure the demand analysis to include an estimate of the policy's impact on travel by trucks with different numbers of axles and different operating weights. Similarly, if emissions are an issue, it may be necessary to estimate demand separately for transportation submodes that have significantly different emission rates per ton-mile or per vehicle-mile.

- **For what time periods are demand estimates needed?**

The effects of policies on demand may vary considerably over time. Usually, these effects occur as a result of changes in costs to shippers, carriers, or receivers. Because equipment, shipping patterns, and other characteristics do not always respond immediately to cost changes, the effects of policies on demand may evolve over time. Most commonly, policy analysis encompasses a period that allows the effects of long-run changes to occur. In some cases, however, the short-run effects can be important. Over the long run, policies that would greatly increase the price (or reduce the availability) of fuel most likely will result in the use of more fuel-efficient vehicles. In the short run, however, these policies may be disruptive.

- **What data or forecasts are available for developing a profile of base-case conditions?**

Estimating the effects of policies on freight demand requires that the base-case demand flows be developed for the specific geographic areas (i.e., states, regions, etc.) under investigation. The greater the level of detail that is available regarding existing freight flows, the more detailed the impact assessment will be. Ideally, freight flow data will include information on specific commodities and modes. Information on rates and services for each mode is desirable as well. It is important to be creative and persistent in the pursuit of data. Often, compromises must be made and data with known deficiencies must be accepted in order to proceed with the analysis. Also, if the available data are out of date, projections must be made to bring the database up to the current time period.

- **What other resources, such as time or personnel, are available for the policy impact assessment process?**

The policy analysis process may involve considerable trial and error. Ad hoc revisions may be made to proposed policies so that problems uncovered during the analysis may be addressed. This places a premium on demand analysis procedures that can be applied quickly and easily. In addition, many public agencies and private groups, with very different perspectives, may participate in the policy development and analysis process. It is highly desirable for all of the participants to understand the source of demand estimates and, if they choose, to reproduce these estimates. Demand estimates produced by "black box" methodologies will have little credibility, particularly when the results contain anomalies that cannot be easily explained.

## **DEVELOPING A PROFILE OF BASE-CASE CONDITIONS**

The profile of base-case conditions serves as the platform from which the impacts of policies on demand are projected. The following are the steps involved in constructing this platform:

- **Identify the Shipment Types That May Be Significantly Affected by the Policy**—As noted in the preceding section, the key characteristics to be considered in determining whether a shipment will be affected include commodity, origin, destination, weight, value, size, frequency, mode, equipment type, and routing. Appendix A provides an extensive discussion of factors influencing freight demand, including those that influence demand directly as well as those that influence demand indirectly through their effects on costs and other service characteristics.
- **Compile Information on Current Demand for These Shipments**—Data on current demand may be obtained from published sources or from special surveys. Appendix C discusses published sources of demand data.

Appendix D provides an overview of freight transportation survey procedures and methods that may be used in conducting special surveys.

- **Project Current Demand Forward to the Analysis Period**—The next step in developing a profile of base-case conditions is to project the estimates of current demand forward to the analysis time period. Chapter 3 provides an extensive discussion of procedures to be used for this purpose. If the analysis period is not too far in the future and demand is not expected to change significantly due to exogenous forces, then it is possible to skip this step and to use current demand as the platform for estimating policy impacts.

### ESTIMATING THE EFFECT OF POLICIES ON COSTS AND OTHER SERVICE CHARACTERISTICS

Estimating a policy's impact on freight demand usually requires an assessment of the policy's impact on modal costs. This section provides a general framework for this assessment.

#### Translating Policies into Cost Impacts: A General Framework

The initial step in the process is to analyze how a proposed policy will affect the costs of providing transportation service by one or more modes or modal combinations. For some policies, this step is straightforward. For example, changes in policies affecting measurable portions of carrier costs, such as fuel taxes or registration fees, can be translated directly into changes in modal costs.

However, the difference between short-run and long-run impacts complicates the analysis of even straightforward policies such as increases in fuel taxes. In the long run, carriers may change the composition of their vehicle fleets to become more fuel efficient or less affected by the tax; for example, if the tax is on diesel fuel but not on natural gas, all of a carrier's new vehicle purchases may be powered by natural gas. Although such strategies will mitigate the impacts of the original policy, they generally are longer run adjustments, and, in some cases, may not be feasible with existing technology. Consequently, the straightforward cost impact may require adjustments to reflect these long-run cost impacts.

The assessment of other policies can be more complicated, as seen in the following examples:

- **A Policy Increasing Truck Size and Weight Limits**—It may be straightforward to show differences in the costs per ton-mile for vehicles of different sizes. However, a host of related issues directly affect trucking costs. For example, the change in size and weights may apply to an entire region, or solely to specific highway routes or types. These factors, along with behavioral issues such as the speed with which carriers shift to

larger vehicles, will determine the specific cost impact of the new limits. To assess the overall cost impact of the policy, assumptions must be made regarding how rapidly carriers will adopt the new equipment.

- **Changes in Driver Hours-of-Service Regulations**—

The first step is to estimate the effect of the new policy on the total hours drivers could accumulate annually. Any reductions in annual vehicle-miles driven resulting from more stringent new policies would directly raise driver costs per vehicle-mile. However, a full assessment of the policy's impact must address implementation issues. Carriers may change their operational patterns to adjust to the new hours-of-service regulations. These adjustments may mitigate the impact of the changes and allow drivers to accumulate approximately the same number of annual miles. Factors that must be considered include how these adjustments may be made, how many carriers may make the adjustments, and when the adjustments would occur.

- **Increased Roadside Safety Inspections**—Since the mid-1980s, the federal government has significantly increased the number of roadside inspections of commercial vehicles, as well as general reviews of carrier safety performance. Direct, measurable costs associated with the increased inspection activity accrue to the carriers. These costs include the vehicle downtime of 20 to 40 min required for an inspection. If any out-of-service violations are found during an inspection, the vehicle or the driver is placed out of service until the violation is corrected. Reviews conducted on-site at a carrier's office or terminal also involve direct costs in the form of management time devoted to answering the inspectors' questions. If the carrier receives a conditional or unsatisfactory rating, the carrier may lose revenue from some shippers. Consequently, deriving the cost impact of increased safety inspections is complex. The costs that some carriers will incur by enhancing their internal safety programs to ensure compliance may be offset by a reduction in accidents. This calculation, however, requires an estimate of the number and type of accidents avoided as a consequence of the safety programs.

- **Intelligent Transportation Systems (ITS) Operational Tests Dealing with Commercial Vehicles**—Currently, there is considerable interest in the application of advanced technological and communications systems to surface transportation. Several ITS operational tests dealing with commercial vehicle operations (CVO) are underway. A major thrust of the ITS/CVO program to date has been developing methods to automate and expedite vehicle weight, safety, and credentials checks. In programs under development in several states, roadside sensors will be able to "read" electronic data from vehicle tags, and verify information regarding the vehicle's size, weight, credentials, driver, and, in the future, operating condition. These services should reduce the

time required for roadside inspections, thereby providing cost savings to carriers. However, the carriers would incur new costs associated with installing equipment on their vehicles, as well as potential user fees for the ITS/CVO services. The analyst must break down the ITS/CVO program into its components (automatic vehicle identification readers and transponders, weigh-in-motion scales, etc.) to estimate the cost impacts on motor carriers and state agencies.

- **Restrictions on Truck Operating Times**—The Clean Air Act Amendments of 1990 include provisions requiring states and metropolitan areas to initiate a series of policy actions for urban areas with pollution levels above federal standards—the “nonattainment” areas. Some states and metropolitan areas have discussed restrictions on motor carriers during peak traffic hours. Such restrictions have important cost consequences for motor carriers because of industry operating patterns. Depending on the specifics of the plan, there may be cost impacts on interstate carriers as well as local operators. The direct cost impacts would include delays associated with the need to halt operations during certain hours of the day. Indirect impacts may include the costs associated with adding drivers as a result of increased layovers due to hours-of-service restrictions. Other costs may include penalties associated with failures to meet just-in-time delivery commitments. These secondary impacts must be anticipated, and their costs assessed, for the policy to be analyzed properly.

The key point is that the impact of any proposed policy must be disaggregated into a comprehensive set of individual impacts on modal costs. These impacts are summed together to estimate the overall impact of a policy.

### Cost Estimating Procedures

A common approach to estimating transport costs is “activity-based costing” (ABC) analysis, which breaks down a transportation provider’s costs into distinct activities, or cost drivers. In the motor carrier industry, less-than-truckload (LTL) carriers have the following set of cost drivers: line-haul, pick-up and delivery, platform, and billing and collecting. For truckload (TL) carriers, the major cost drivers are: line-haul, loading and unloading, cleaning, and billing and collecting.<sup>1</sup>

Each of these cost drivers encompasses separable costs. Line-haul costs are broken down into a number of distinct subcategories. At the broadest level, the line-haul costs are separated into vehicle costs and driver costs. The vehicle costs include fuel costs (including taxes), tires, maintenance labor, other supplies, depreciation, and all other costs. A final

category would account for overhead costs through some allocation of these costs to the line-haul portion of the trip.

Appendix F discusses simple cost-estimating procedures for truck, rail, water, and air freight. The discussion covers factors influencing costs, typical unit costs, and inflation adjustment techniques.

### ESTIMATING POLICY-RELATED CHANGES IN DEMAND

Once the changes in modal costs have been estimated, they can be translated into changes in modal demand. The usual practice in making this translation is to assume that estimated changes in modal costs will be passed on to the shippers and not absorbed by the carriers. There are several reasons to feel confident about such an assumption as it pertains to motor carriers. First, during the 15 years since deregulation, price decreases have closely paralleled cost decreases (in some cases, slightly exceeding cost decreases as a result of competitive pressures). Second, because profit margins are thin in most areas of the transportation sector (and in the for-hire motor carrier sector in particular), the ability of carriers to absorb cost increases is highly questionable.

Approaches to estimating the effects of changes in costs on demand range from simple elasticity methods to complex structural models involving mode choice models and analyses of shipment routings. The more complex models are of limited use in policy analysis, primarily because of their extensive data requirements.

The use of price elasticities is a relatively simple way of estimating how changes in cost affect demand. Essentially, elasticity is defined as the percent change in demand associated with a 1 percent change in price. For example, a price elasticity of  $-0.5$  indicates that a 1 percent increase in price per unit would cause a 0.5 percent decrease in the number of units demanded. Economists distinguish between *own-price elasticities* and *cross-price elasticities*. An own-price elasticity measures how demand for a good is affected by the price of the good itself; a cross-price elasticity measures how demand for a good is affected by the price of a competing good. For example, a rail ton-mile cross-price elasticity with respect to truck price measures the percent increase in rail ton-miles associated with a 1 percent increase in truck costs.

Any change in modal transport costs can result in some diversion of traffic from one mode to another. However, in practice, estimates of such diversion generally are important only in the case of diversion between rail and truck, and diversion between barge and rail.

### Rail/Truck Diversion

The modal diversion effects of potential policy changes affecting rail and truck transport are of interest because of public concerns about the financial viability of major rail-

<sup>1</sup> Kenneth Manning, Transportation Consulting Group, Bethesda, MD, ATA Sales and Marketing Council, Las Vegas, NV, April 25, 1995.

roads. Past estimates of these modal diversion effects have been obtained using the Intermodal Competition Model (ICM), a proprietary model developed by the Association of American Railroads (AAR),<sup>2</sup> or from consultant or railroad industry<sup>3</sup> analyses. A new nonproprietary model, the Truck-Rail, Rail-Truck (T-R/R-T) Diversion Model, recently was developed by Transmode Consultants for the Federal Railroad Administration.<sup>4</sup> Public release of this model is expected within the next few months.

Appendix H includes reviews of the ICM and the T-R/R-T Model. At the time of this writing, reliable estimates of the key parameters needed to apply the T-R/R-T Model have not yet been developed. As discussed in Appendix H, several of the parameters shown in the draft model documentation could result in serious overestimates of diversion. However, the general modeling approach used in the T-R/R-T Model is promising, and U.S. DOT is sponsoring research to improve the model inputs and parameters.

Appendix G reviews the results of several recent analyses of modal diversion performed using the ICM and other tools. A procedure is developed for using aggregate data and separate estimates of the effects of policy changes on transport costs to produce rough estimates of modal diversion. This procedure requires the use of some judgment, and the estimates it produces may be inaccurate by a factor of two or three. However, it is not proprietary and it does not require the use of disaggregate data on individual shipments. This procedure is presented below:

1. Use procedures presented in Appendix F and other information to estimate the effect of the policy changes under consideration on TLC for the affected modes.
2. For all rail-competitive truck movements in the region of interest, express any estimated change in truck TLC as a percent change in the cost of truck transport, exclusive of other (nontransportation) logistics cost (OLC). Use judgment to distinguish between the effects on rail-competitive truck movements and other truck movements.
3. For all truck-competitive rail movements in the region of interest, express any estimated change in rail TLC as a percentage change in the cost of rail transport, exclusive of OLC. Use judgment to distinguish between the effects on truck-competitive rail movements and other rail movements.

4. Multiply the truck cost percent change by 0.4, the cross-price elasticity of rail tonnage relative to truck costs. Multiply the rail cost percent change by 0.6, the own-price elasticity for rail tonnage. In many cases, one of these factors will equal zero. Subtract the adjusted rail percentage from the adjusted truck percentage.
5. Estimate the total rail tonnage that would be affected by the changes in the rail system, as well as the rail tonnage that is considered to be competitive with trucking and would be affected by the changes in the trucking industry. Include in this estimate all rail tonnage, including tonnage that is very unlikely to be transported by truck.
6. Multiply the percentage developed in Step 4 by the estimate of rail tonnage from Step 5 to obtain an estimate of tons of freight diverted from rail to truck. A negative value represents diversion from truck to rail.

The resulting estimate of diversion, although rough, is likely to be as good as can be obtained without the use of a disaggregate computer model.

### Barge/Rail Diversion

Barge is a low-cost mode that usually is attractive when barge routings are feasible for large shipments of low-value commodities. However, because barge transport usually entails an access haul to or from the water, there is some traffic for which both the rail and barge modes can compete and for which mode choice can be affected by public policy changes that have relatively modest effects on modal costs.

The impact of some potential public policy changes on barge costs may be substantial. The federal government currently uses general revenue to finance much of the operation and maintenance cost of the entire inland waterway system, as well as a portion of all waterway construction projects. If the barge industry were required to pay for all waterway operations and maintenance costs through increased fuel taxes or other user charges, barge rates could rise by an average of about 25 percent.<sup>5</sup> The modal diversion resulting from such a change is relatively difficult to estimate because of the route-specific character of the cost increases and the degree of barge/rail competition.

<sup>2</sup> Scott M. Dennis, *The Intermodal Competition Model*, Association of American Railroads, Washington, D.C., September 1988.

<sup>3</sup> N.A. Irwin and R.A. Barton, *Economics of Truck Sizes and Weights in Canada*, Final Report, Council on Highway and Transportation Research and Development and the Roads and Transportation Association of Canada, Ottawa, July 1987.

<sup>4</sup> Transmode Consultants, Inc., *Truck-Rail, Rail-Truck Diversion Model*, Users Manual, Draft, prepared for the Federal Railroad Administration, Washington, D.C., December 1994.

<sup>5</sup> See the discussion of User Charges in Appendix A.

## APPENDIX A

### FACTORS INFLUENCING FREIGHT DEMAND

This appendix discusses a variety of factors that influence freight demand. These factors are presented in two groups. The first group consists of factors that affect demand relatively directly. The second group consists of factors whose direct effects are on the costs of one or more transport modes and, in some cases, on the services offered; these factors affect demand indirectly as a result of changes in transport costs and rates and in the services offered.<sup>1</sup>

The discussions focus on the influence that each factor currently is having on freight demand and how the factor could change future demand. Where appropriate, historical context is provided (usually for a 10- to 15-year period). Influences on supply are also discussed, particularly when changes in supply (e.g., services offered) can affect demand. However, supply issues that have little effect on demand (e.g., competition between U.S. and foreign carriers) are treated much more briefly, if at all. Where appropriate, the discussions include measures for each factor, sources of data for the measures, and any relevant comments on the usefulness of the data sources.

#### A.1 FACTORS THAT AFFECT DEMAND DIRECTLY

##### The Influence of the Economy

The demand for freight transportation is commonly referred to as a “derived demand”; that is, it derives from a more basic demand—in this case a location-specific demand for a product that results in a need to ship the product to that location. As a derived demand, the most basic influence on total freight demand is the volume of goods produced and consumed. Expansion in the national economy, or the economy of any region, results in increases in overall freight demand, while economic contractions result in reductions in freight demand.

At the national level, the size of the economy is most frequently measured in dollar terms as gross national product (GNP) or gross domestic product (GDP). However, freight demand is more closely related to the goods-production component of GNP or GDP.

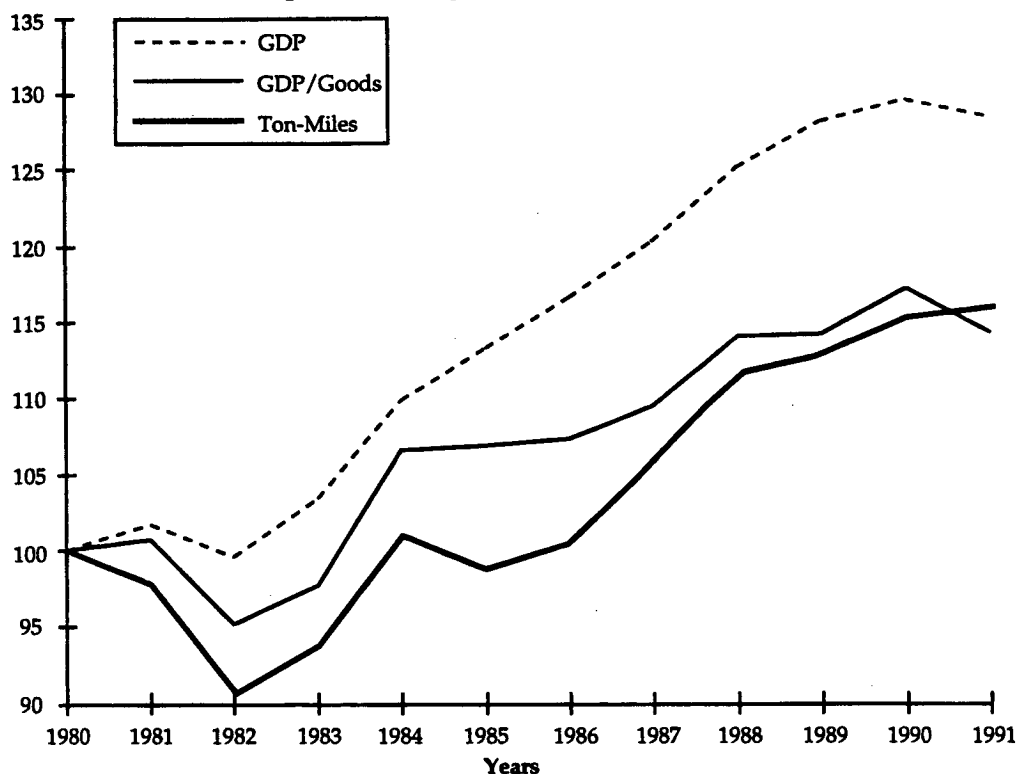
Goods production has tended to grow somewhat more slowly than the overall economy. Goods production represented about 43 percent of total GDP in 1980 and had declined to about 39 percent of GDP in 1991. Goods production, and particularly durable-goods production, also tends to fluctuate with the business cycle more than total GDP does. (The production of services has smaller fluctuations, while the remaining major component, the production of structures, has greater fluctuations.) The relationship between changes in freight demand since 1980 (as measured in ton-miles) and in the real value of goods production can be seen in Exhibit A.1. This exhibit also shows corresponding changes in real GDP, which has grown faster and somewhat more smoothly than freight demand and goods production.

Although real GDP of goods is a reasonable overall measure of the influence of the economy on freight demand, it measures goods production in dollars rather than in tons or volume. The production of low value (dollars per ton) commodities, such as coal and agricultural products, generates a much larger share of total freight demand than their total value would indicate. Commodity value and perishability are also important influences on mode choice, with most low-value commodities commonly transported by the slower, less costly modes (pipeline, barge, and rail) and higher-value and perishable products usually transported by truck and sometimes air. For these reasons, careful forecasts of freight demand usually incorporate forecasts of production (and/or consumption) that distinguish several different commodities. For raw materials, forecasts of production and consumption in physical units (tons, bushels, etc.) usually are available and can be used in generating forecasts of freight demand. However, for manufactured products, production forecasts usually are expressed only in dollars—a somewhat less desirable measure for freight-demand forecasting, since changing technology, packaging, and product mix can result in corresponding changes in the ratios of value to weight or volume.

Some potential sources of economic forecasts are as follows:

- The U.S. Department of Labor, Bureau of Labor Statistics (BLS), which produces low, moderate, and high forecasts of real domestic output, exports and imports by detailed industrial sector for periods extending 10 to 15

<sup>1</sup> Several of the factors discussed in this appendix are being studied in more detail in an NCHRP study, *Economic Trends and Multimodal Transportation Requirements* (Project 2-20), being performed by Louis Berger International, Inc.

**Exhibit A.1. Relationship between freight demand, GDP, and goods production.**

Sources: **Ton-Miles** – Eno Transportation Foundation, *Transportation in America*, Tenth Edition, Vienna, Virginia, 1992.

**GDP and Goods Production** – U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, Various Editions.

years into the future.<sup>2</sup> These forecasts are issued at approximately 2.5-year intervals.

- The Bureau of Economic Analysis' Regional Projections<sup>3</sup> of population, employment, earnings and personal income by 57 sectors by state and region (formerly called the "OBERS" projections). These forecasts are issued at approximately 5-year intervals and extend approximately 50 years into the future. They are based, in part, on the BLS 15-year forecasts. They have the advantage of a longer forecast period, and they also provide 14-sector forecasts for 183 economic areas and for 336 metropolitan areas and aggregates of metropolitan areas. However, they do *not* forecast output; thus their use requires an extra adjustment for growth in output per worker or per dollar of earnings.
- Commercial services, such as Data Resources, Inc., (of Lexington, Massachusetts), Wharton Econometric Forecasting Associates (of Bala Cynwyd, Pennsylvania) and INFORUM (of the University of Maryland), that fore-

cast a variety of economic measures for various time periods.

- A variety of sources of region-specific forecasts (e.g., the Center for the Continuing Study of the California Economy) and commodity-specific forecasts (e.g., fuel-demand forecasts produced by the U.S. Department of Energy).

### Industrial Location Patterns

Just as the economy determines the amount of goods transported, the spatial distribution of economic activities determines the distances they are transported. Thus, industrial location patterns are an essential factor in determining transport demand when it is measured in ton-miles or in any similar units that reflect length of haul. This influence of spatial distribution can best be measured through its actual effect on demand: as average length of haul by commodity or total ton-miles transported. Ideally, such a measure would be applied in mode-neutral form as great-circle miles, though reducing actual origin-to-destination distances to great-circle miles usually entails more effort than is warranted.

<sup>2</sup> E.g., see *Monthly Labor Review*, November 1991; or *Outlook: 1990-2005*, Bureau of Labor Statistics Bulletin 2402, May 1992.

<sup>3</sup> E.g., see U.S. Department of Commerce, Bureau of Economic Analysis, *BEA Regional Projections to 2040*, Three Volumes, U.S. Government Printing Office, October 1990.

The U.S. Departments of Energy and Agriculture publish data on the production of coal, natural gas, and many agricultural products by state; and many corresponding state agencies publish more extensive and/or more detailed data on shipments of these commodities, frequently by county. Most states also publish industrial guides containing the location of manufacturing facilities, etc. The distribution of an industry's production across counties frequently is inferred from employment data by industry and county published annually by the U.S. Department of Commerce in *County Business Patterns*; however, these inferences frequently are misleading, especially for mines, since employment usually is reported by office location rather than by actual place of employment.

The spatial distribution of economic activity also is a major influence on the modes that are used. Many commodities are likely to be shipped by one mode (e.g., truck) when distances are relatively short and by another (e.g., rail or air) when distances are longer. Water transport is competitive for many low-valued commodities being shipped domestically between points at or near appropriate ports, but it is rarely competitive for transport between points that are not located near ports. Plants located on rail lines are likely to use rail for an appreciably greater share of their transport needs than similar plants that are not so located. (Indeed, expected rail use is usually, but not always, the most important factor affecting the decision as to whether or not to locate on a rail line, and accessibility to the Interstate Highway System is a major influence on locational decisions of many plants that expect to make significant use of trucks.)

### Globalization of Business

In recent years, the U.S. economy has become increasingly integrated into the global economy. Today, many companies, both domestic and foreign, are managing worldwide production and distribution systems. In personal computers, a company may source chips, subassemblies such as motherboards, disk drives, and monitors in several different countries in Asia, assemble the computers in Asia, Europe, or the U.S., and warehouse and distribute to retail stores and through direct mail on each continent. In automobiles, Ford and General Motors use parts and subassemblies produced in Europe and Latin America for their domestic production. The Asian and European automobile firms with assembly plants in the U.S. use parts and subassemblies produced both here and abroad. Ford and GM have both announced plans to build certain models in a single plant in Europe for worldwide distribution.

These patterns of domestic and foreign production and distribution vary significantly by industry and by product type. To understand these important determinants of freight demand, it is necessary to understand each specific type of product and its production, distribution, and marketing characteristics. These characteristics are different across products

within a single company. For example, Philips is a Dutch electronics company with major operations in North America, Europe, and the rest of the world. The production and distribution patterns for its light bulbs are different from those for televisions, for VCRs, and for new products such as CD players.

Furthermore, distribution patterns are dynamic, not static. For some products, relatively minor changes in currency exchange rates and market conditions can rapidly change freight patterns; for others, the effects are slower but still can be significant. The 1991 U.S. decision on tariffs on certain types of computer screens forced U.S. computer manufacturers to move computer assembly operations offshore. A reversal of this decision would cause a shift of production back to the U.S. Similarly, in the 1970s and early 1980s electronics production in Japan, Taiwan, and Korea caused declines in major U.S. production of computers and consumer electronics. Today, Japan, Taiwan, and Korea have become relatively high-cost producing areas and much production has shifted to Indonesia, Malaysia, and China. A further westward shift would result in containers being shipped from Asia via the Suez Canal to our East Coast ports. These containers would then require rail or truck transport westward from the Atlantic Coast, instead of the eastbound transport required by containers entering our Pacific Coast ports.

Changing patterns of world trade not only affect transport flows, they affect modes used. Products that are received by truck from domestic suppliers may be obtained by container ship and doublestack train from overseas suppliers or, if their value is relatively high or delivery speed important, by airfreight. Garments may move in the early part of the season by ocean and then by rail or truck; but later in the season, as time to market becomes more critical, significant amounts may move by air and truck.

For some very long distance movements, for example, from Asia to the East Coast or to Europe, the basic choices of air versus ocean are augmented by mixed choices. For example, some commodities may move by sea to the West Coast of the U.S., by truck across the U.S., and then by air to Europe. Movements such as this one, entailing a domestic haul of a shipment that both originates and terminates abroad, are classified as "in-transit." Combination moves of this type provide levels of trip time and cost that are intermediate between the extremes of all-air and all-sea, and are attractive to some shippers under some conditions.

Measures of world trade include value and volume of imports, exports, and in-transit shipments, by foreign country (or region) of origin or destination. Total volume of imports and exports by foreign country is from the Bureau of the Census on CD-ROM. Total volume is also available, by commodity, in commodity-specific units (tons of coal, pairs of shoes, etc.), and volume is available in tons for water and air shipments. Value and weight of in-transit shipments entering or leaving the U.S. by water are also available from the Bureau of the Census in other files. Import, export, and

in-transit data for all low-value shipments (up to \$1,250 for imports, up to \$2,500 for exports) are estimated from historic data without commodity detail.

Another source of import and export data is the *Journal of Commerce's* Port Import/Export Reporting System (PIERS), which provides data on value, weight, commodity, and foreign origin/destination for individual waterborne shipments, and, for containerized shipments, also provides number and size of containers. Other sources include individual ports and airports, United Nations' publications, and trade data from other countries.

### International Trade Agreements

Global patterns of production and distribution are affected by our import restrictions and tariffs, those of our trading partners, and by international trade agreements. Quotas not only have the obvious effects on volumes of goods shipped internationally, but, in the case of natural resources on which quotas are frequently adjusted to reflect changing supply conditions, they encourage the use of foreign distribution warehouses that provide capabilities for responding quickly to quota changes. Most countries exporting to the U.S. qualify for "most-favored-nation" status, and additional arrangements exist with Canada and Mexico.

Duties on goods imported from Mexico's *maquiladora* zones are paid only on non-U.S. components and value added, making these zones attractive places for performing labor-intensive assembly of U.S. components. The result has been an increase in U.S. truck and rail traffic to and from the Mexican border. In recent years, truck border crossings with Mexico have been growing at an annual rate of 7 percent and those with Canada at an annual rate of 12 percent.

The enactment of the North American Free Trade Agreement (NAFTA) in January 1994 created one of the most powerful trading blocs in the world. Over time, this agreement will eliminate tariffs and reduce or eliminate product quotas on international trade among the United States, Canada, and Mexico. Free trade among the three countries will enable companies to change their distribution strategies and thereby have an impact on virtually all modes of transportation. NAFTA also includes a process for harmonizing technical and safety standards for land transport and, by the year 2000, will eliminate or reduce restrictions on cross-border truck access, improving the efficiency of such movements and opening up a new area of carrier competition.

NAFTA will eventually allow truck hauls to or from Mexico to be handled by a single U.S. or Mexican carrier, improving the efficiency of such movements and opening up a new area of carrier competition. NAFTA also provides an opportunity for U.S. and Canadian companies to invest in Mexican port facilities as that country moves to privatize its ports. The potential also exists for the development of containerports on Mexico's Pacific Coast and doublestack trains from these ports to the central United States; such services

could divert much of the container traffic now moving to or from the South Pacific via Los Angeles and Long Beach.

To meet the challenge of growth in north-south trade flows among the three countries, it is necessary to focus attention on developing competitive trade and transportation corridors and carrier services. Efforts are already underway to expand and improve the facilities and streamline customs procedure at international ports of entry along the U.S.-Mexico and U.S.-Canada borders. However, the concern that movements between Canada and Mexico might result in a significant increase in freight traffic in certain corridors is probably exaggerated; such in-transit movements on the I-25 corridor through Denver (which have been mentioned as being of some concern) would be limited by low population densities in Alberta and Saskatchewan and the limited interest to Mexico of the wheat and petroleum produced by these two provinces.

Plans to expand the current NAFTA to include all democratic nations in North, Central, and South America were outlined in December 1994 when representatives of 34 nations agreed to negotiate a free trade zone across the Western Hemisphere by the year 2005. Further analysis is needed regarding the implications of a hemispheric trade pact, particularly the effect it may have on the bond now being forged between the U.S., Mexico, and Canada as a result of NAFTA.

Another international trade development that occurred at the end of 1994 was the passage of a bill that implements broad multilateral tariff cuts that reduce U.S. duties and lower costs to consumers. The legislation implemented an agreement commonly referred to as the Uruguay Round of trade negotiations under the auspices of the General Agreement on Tariffs and Trade (GATT). Renewal of the Generalized System of Preferences (GSP) program was included in the GATT legislation. The GSP provides duty-free treatment for more than 2,000 products from some 80 countries worldwide.

The emergence of the European Community (EC) is also having a significant effect on trade and on freight distribution patterns. The Single Economic Market (SEM), initially targeted for completion by 1992, was a major element of this. The effects of the SEM are of two kinds: the direct effects on production within and outside the EC, and the indirect effects on global competition. The creation of the SEM is being brought about by the relaxation of internal barriers within the 12 member countries of the EC; and, especially important, by the creation of homogeneous product conditions. Previously, an auto manufacturer within the EC had to meet the different noise and air pollution requirements of the 12 different countries, and so had 4 to 12 different versions of each model to manufacture and stock. As a result of standardization of product regulations within the EC, auto manufacturers now need produce only one version of each model. This allows significant economies of scale for both production and inventory maintenance, permitting a complete restructuring of production and distribution, and leading to new alliances between manufacturers (e.g., Volvo and Renault).



The effects of international agreements cannot be readily measured separately from those of other factors affecting world trade discussed in the preceding subsection.

### Just-in-Time Inventory Practices

Just-in-time (JIT) systems, proposed by Peter Deming and originally applied by the Japanese during the 1950s and 1960s, have been embraced by U.S. manufacturers at a rapid pace during the past decade. Industries in which U.S. manufacturers have successfully adopted JIT systems include the metal products, automotive, electronics, food, and beverage industries.<sup>4</sup>

JIT systems focus on keeping inventories at minimum levels through a coordination of input deliveries with production schedules. Adopting a JIT system usually results in increasing the frequency with which inbound shipments are scheduled, decreasing the lead times for these shipments and their size, and increasing the importance of receiving these shipments on time. Firms adopting JIT systems frequently reduce the number of suppliers and transport companies with which they deal, and they require suppliers that are close enough to be able to deliver shipments reliably within the constraints of short lead times.

The effects on freight demand are to increase the number of individual shipments, decrease their length of haul, and, most importantly, increase the importance of on-time delivery. Some shift may occur to modes that are faster or can handle smaller shipment sizes (from rail to truckload, truckload to less than truckload [LTL], or LTL to airfreight or parcel). Within modes, a shift is likely to carriers that are capable of delivering highly reliable service, and, as the emphasis on reliability increases, the total number of carriers used generally falls. Total vehicle miles traveled (VMT) of trucks may rise as a result of diversion from rail and reduced shipment sizes for truckload shipments, but these effects are likely to be partly balanced by reductions in lengths of haul and diversion to air.

Use of JIT systems in this country has been increasing and is likely to continue to increase over the near future. One observer estimates that, by 1995, 55 percent of U.S. manufacturers will be making at least some use of JIT systems.<sup>5</sup> However, this trend will not continue indefinitely. Indeed, in Japan, a decline in transport reliability resulting from increasing highway congestion is now causing a shift away from JIT.

Appropriate measures of the use of JIT systems are the number of companies or plants that consider themselves to be using such systems, the total value of the product of plants using these systems, and the total volume (tons) of inbound

shipments to these companies. These measures are imperfect (in part, because there is substantial variation in the actual inventory practices of companies that identify themselves as using JIT systems), and they are difficult to quantify. However, changes to or from JIT systems are monitored in the logistics literature.<sup>6</sup>

### Carrier-Shipper Alliances

In recent years, stimulated in part by the demands of JIT inventory-control systems, and made possible by deregulation, a number of industrial firms have found that they can obtain more reliable transport service and reduce other logistics costs by reducing the number of carriers they use and by working more closely with the selected carriers to maximize the overall efficiency of the logistics process. Major industrial companies that have formed such alliances or "partner-shiping" arrangements with the carriers that serve them include Black and Decker, Ford, General Motors, GTE, Procter and Gamble, McKesson, 3M, and Xerox.<sup>7</sup>

These carrier-shipper alliances generally result in improvements in on-time delivery and reductions in overall logistics costs for both inbound and outbound shipments. Computerized tracking of shipments usually is an important component of the services provided by the selected carriers, and automation of other services (billing, collections, etc.) is common. The development of these alliances has little effect on the overall demand for freight transport, but it does represent an increase in the quality of service expected of transport companies and does affect competition among carriers.

### Centralized Warehousing

As transportation systems have become more efficient and more reliable, there has been a trend toward using fewer warehouses for the distribution of products. Reducing the number of warehouses reduces inventory requirements but increases the lengths of haul for many shipments from warehouses. This trend is in part the result of increasing use by manufacturing firms of third-party logistics operators that specialize in optimizing the distribution process. The trend results in increasing transport demand and associated costs to achieve a larger saving in inventory costs.

The extreme of this trend consists of serving a company's entire market from one or two centralized warehouses. The Limited, for example, operates a single warehouse near its Columbus, Ohio, headquarters—receiving merchandise from its suppliers around the world, frequently by air, and

<sup>4</sup> Douglas M. Lambert and James R. Stock, *Strategic Logistics Management*, Richard D. Irwin, Boston, Massachusetts, 1993, p. 486.

<sup>5</sup> Isaac Shafran, Louis Berger International, Inc., *A Review of National Domestic Freight Policy*, prepared for AASHTO Joint Committee on Domestic Freight Policy, 1992.

<sup>6</sup> E.g., *Transportation Distribution*, the *Journal of Business Logistics*, *Logistics and Transportation Review*, *Traffic Management*, *Traffic World*, and the *Journal of Commerce*.

<sup>7</sup> Lambert and Stock, *Strategic Logistics Management*, Richard D. Irwin, Boston, Massachusetts, 1993, p. 239; and Donald J. Bowersox, *The Strategic Benefits of Logistics Alliances*, *Harvard Business Review*, July 1990, pp. 36-45.

shipping to its stores throughout the country, predominantly by LTL carriers.

Integrated air carriers have found contract operation of centralized warehouses at their hubs to be a natural extension of their airfreight business. These carriers are able to provide distributors of high-value products (such as computers and computer parts) with efficient airfreight and express delivery while capturing substantial amounts of business for their transport system.

The trend toward centralized warehousing results in increased transport demand (measured in ton-miles, shipment-miles, or value of service) and, in some instances, a shift from truck to air delivery. Appropriate measures of this trend are: the number of companies using one or two warehouses (or otherwise reducing the number of warehouses they use); and the value or volume (tons) of products shipped from these warehouses. These measures, like those for JIT usage, are difficult to quantify; however, changes in warehousing practices are monitored in the logistics literature.

### Packaging Materials

The age of plastics has brought with it the use of Styrofoam, bubble packs, and other very lightweight materials as protective packaging for many manufactured products. The result has been a reduction in the average density of shipments of these products. Since low-density shipments cause trucks to "cube-out" before they "weight-out," the increase in relatively low-density shipments has created a demand for larger truck trailers (such as the 53-foot trailers that are now allowed in most states, as discussed subsequently under "Truck Size and Weight") and shipping containers that are larger than 40 feet.

Although some historic estimates of shipment density exist,<sup>8</sup> there do not appear to be any data on how the shipment density of manufactured products has been changing (and even the historic estimates tend to focus primarily on the density of natural resource shipments—shipments that usually are quite dense and whose density is likely to vary very little). Prohibitions on the manufacture or use of Styrofoam and other laws designed to encourage re-use (rather than disposal) of many plastics will affect which packing materials are used in the future and how they are used; however, the likely effect of such laws on shipment density are not clear at the present time.

### Recycling

Increasing use of recycled materials affects the origin/distribution patterns, lengths of haul, and modal usage of several commodities.

Processing plants that use virgin materials are usually located near a major source of supply of these materials, and

they commonly ship their products long distances to their markets. Thus, most of the paper products used in the Northeast and Midwest historically have been shipped from paper mills in the Southeast, the Pacific Northwest, and Canada, with rail used for much of the long-haul transport.

Recycling plants, on the other hand, usually are located near the markets they serve, which also provide them with substantial volumes of material for recycling. Plants producing products from a combination of raw and recycled materials are likely to be located near sources of supply for their more important inputs and may receive some inputs by rail from more distant sources of supply.

## A.2 FACTORS THAT AFFECT DEMAND THROUGH THEIR INFLUENCE ON COSTS AND SERVICE

The factors discussed below have a less direct effect on demand than those discussed in the preceding subsection. In general, the factors discussed in this subsection affect the transportation industry, its costs, and the services it offers, and they affect supply only through their effects on costs and services. Although some of these factors (such as deregulation and intermodal operating agreements) are significant influences on demand, others affect demand to a very limited extent or only in a very narrow way (e.g., through port choice). Factors of the latter type may be important for specific purposes but there are many applications of freight demand forecasts that do not require consideration of all of these factors.

### Economic Regulation and Deregulation

The deregulation movement of the 1970s culminated in passage of the Airline Deregulation Act of 1978, the Motor Carrier Act of 1980, the Staggers Rail Act of 1980, and the Shipping Act of 1984. These legislative acts had significant impacts on the services offered by the airline, trucking, rail, and ocean transportation industries and on the shippers who utilize those services. The following provides capsule discussions of the effects on each mode.

#### Air

All-cargo air services were deregulated in 1977 and the rest of the industry was deregulated by the Airline Deregulation Act of 1978.

Previously, the Civil Aeronautics Board (CAB) maintained strict regulation of nearly all facets of U.S. commercial air cargo services. The 1978 Act allowed free entry and exit from air cargo markets, freedom to select routes and set fares, and permitted integration of aircraft services within multi-modal integrated systems.

The primary impact of deregulation was a dramatic change in the composition of the carrier group providing all-cargo services. The scheduled combination carriers such as Amer-

<sup>8</sup> E.g., William S. Kuttner, *A Disaggregate File of Commodity Attributes*, Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, Massachusetts, August 1979.

ican Airlines and United Airlines largely have been replaced by the integrated carriers that provide express and standard door-to-door services, as well as specialized air charter operators. The development of new cargo systems has resulted in exceptionally high market growth rates in traffic and carrier revenues, and a substantial increase in the U.S. freighter fleet. Overnight express air services are now available to all U.S. zip codes, and the level of service now available to manufacturers and retailers has revolutionized the distribution of materials and products, extending market ranges and facilitating fast-response parts replacement and catalogue sales.

Deregulation has resulted in a highly competitive market characterized by advanced customer service, high reliability, pickup and delivery, and a wide array of cost/service options. The huge expansion of air cargo activity in the 1980s resulted in a continuing decline in shipper costs, while service levels continued to increase.

Domestic air cargo operations also are affected by regulations of trucking activity that is used by integrated carriers both for local pickup and delivery and as a substitute for air services in short-haul and deferred shipment markets. The Deregulation Act of 1978 permitted vertical integration by freight forwarders, creating the door-to-door integrated carrier prevalent today. More recently, Congress expanded deregulation for trucking operations with legislation restricting state regulation of intrastate air/truck freight and express package shipments.

### *Truck<sup>9</sup>*

The most important effect of the Motor Carrier Act (MCA) of 1980 was a substantial easing of restrictions on the entry of motor carriers into new markets. The burden of proof was shifted from the carrier applying to enter a new market to those opposing the application. Arguments in opposition to new service were limited to showing that the proposed service is inconsistent with the public convenience and necessity (clearly, a difficult, if not impossible, burden to prove). The open competition that has resulted from these entry changes has enabled well-managed motor carriers to enter any market they could serve efficiently and has forced many inefficient carriers out of business. To attract customers, carriers have developed a variety of price and service options tailored to the needs of individual shippers.

In the truckload segment of the industry, several carriers developed operating strategies that made them extremely efficient, enabling them to offer low rates and high-quality service and to expand rapidly. These so-called "Advanced Truckload" firms hire their own drivers, purchase equipment in bulk at discounts in the 20-percent range, and focus their marketing on corridors with medium to high densities of demand that provide them with directionally balanced traf-

fic. This marketing strategy has enabled them to achieve empty backhaul ratios of 6 to 8 percent instead of the 15 percent that is typical of other truckload carriers of general freight. These large firms have achieved significant operating efficiencies, have been leaders in the introduction of new technologies and have established new levels of service, all in a continuing effort to increase their market share.

While the large truckload carriers have concentrated on major general-freight markets that can be served efficiently, a growing number of smaller carriers have focused on a variety of market segments that require more specialized equipment or more specialized service. The result has been a tripling of the total number of Interstate Commerce Commission (ICC)-regulated carriers, from 18,045 in 1980 to 54,624 in 1993.

In the LTL segment, competition was enhanced by prohibiting collective ratemaking for single-line rates, a change that became increasingly significant as major LTL carriers expanded their route systems to reduce the amount of interlining required. In the years following deregulation, mergers and business failures resulted in increasing industry concentration. The number of ICC-regulated LTL carriers fell from 498 in 1980 to 135 in 1993; and market share of the four largest firms rose from 21 percent of total revenues in 1980 to 45 percent in 1990, though it dropped to 44 percent in 1993.<sup>10</sup>

Although it may be premature to draw definitive conclusions, there are some clear signs that the market share of the top four LTL firms may continue to decline. Each of the three leading national LTL carriers (Roadway, Consolidated Freightways, and Yellow Freight) has reconfigured its corporate structure and created a central parent organization to oversee a variety of independent business units, the primary one being the national LTL carrier. This structure has allowed the parent organizations to pursue an aggressive strategy of purchasing (mostly nonunion) regional LTL carriers and operating them as independent business units linked together in some type of formal or informal integrated system. Roadway Services, Inc., recently announced a plan to divide itself into two separate, publicly traded companies. One company would be the national LTL operation (Roadway Express); while the other would include all the regional LTL companies as well as Roadway Logistics Systems, Roadway Package Systems, and Roadway Global Air. This latest move by Roadway reflects a continuing management commitment to de-emphasize the national LTL operation and to emphasize growth in regional LTL activity.

The mostly nonunion regional carriers have established an important market niche in the LTL sector that will continue to grow in importance. With their lower costs and greater efficiency, the regional LTL carriers can provide a higher level of service to industry with regional production and/or distribution patterns. In addition, the regional LTL carriers seem better suited to fit the demands of the just-in-time production systems.

<sup>9</sup> This section draws from Thomas M. Corsi, *Truckload Carriers: Impact of Current and Alternative Federal Truck Size and Weight Policies*, and Thomas M. Corsi, *Less-than-Truckload Carriers: Impact of Current and Alternative Federal Truck Size and Weight Policies*, prepared for the U.S. Department of Transportation, August 1995.

<sup>10</sup> Thomas M. Corsi, "Motor Carrier Industry Structure and Operations," *International Symposium on Motor Carrier Transportation*, National Academy Press, Washington, D.C., 1994, p. 40.

## Rail

While airline and truck deregulation were intended to promote competition, the primary goal of rail deregulation was to improve the profitability of a financially ailing industry. The Staggers Rail Act streamlined the process for abandoning unprofitable branch lines; relaxed the regulation of railroad mergers; and, most importantly, substantially relaxed ICC oversight of railroad rates, eliminating regulation entirely for movements on which a railroad does not have "market dominance" and for movements covered by contract rates negotiated with the shipper.

In the years following passage of the Staggers Act, several major railroad mergers occurred. Class I railroads continued to abandon low-density lines or to sell them to smaller (frequently newly formed) railroads that could operate them more economically (sometimes with public subsidies). Between 1980 and 1993, the number of Class I railroads fell from 40 to 12, primarily as a result of mergers, and the miles of rail line operated by these railroads declined from 165,000 to 110,000. During the same period, miles operated by local and regional railroads rose to 45,000 and the number of such railroads rose to 497.<sup>11</sup> In 1995, a new wave of merger activity has engulfed the western railroads, with the ICC approving a merger of the Burlington Northern and the Santa Fe, with a prospective Union Pacific-Southern Pacific merger currently before the ICC. It seems clear that these major western mergers will be followed by a series of eastern railroad mergers. Some experts believe that, by the early years of the next century, the United States may be left with two transcontinental railroads.

The increased pricing flexibility permitted by the Staggers Act has enabled the railroads to tailor their rates to competitive conditions, to make extensive use of negotiated contract rates, and to develop new services. Although overall rates rose during the first 5 years following deregulation, the average annual increase was only 4.1 percent, appreciably below the 10.9 percent rate of increase in the preceding 5-year period.<sup>12</sup>

Under deregulation, the railroad industry has achieved significant productivity improvements due both to technological innovations and to rationalization of the labor force, fixed plant, and rolling stock. The industry has also achieved significant improvements in rates of return on net investment and in rates of return on shareholders' equity. Indeed, in 1993, the Class I railroads earned \$2.24 billion in net income for an average rate of return on equity of 9.38 percent and an average rate of return on net investment of 7.06 percent.<sup>13</sup> These rates of return far exceed the levels reached in the decade prior to the passage of the Staggers Rail Act.

<sup>11</sup> Association of American Railroads, *Railroad Facts*, 1981 and 1994 Editions, Washington, D.C.

<sup>12</sup> Frank N. Wilner, *Railroads and the Marketplace*, Association of American Railroads, Washington, D.C., 1986.

<sup>13</sup> *Railroad Facts*, 1994 Edition, p. 18 and 21.

## Water

Economic regulation was never as significant a factor for international shipping as it was for air, truck, and rail transport, and so deregulation of international shipping has been less important. Nonetheless, the Shipping Act of 1984 did have some effect on services offered by international shipping companies. One of the more important changes instituted by this Act was the elimination of restrictions on the offering of through rates for transport involving intermodal pickup or delivery, a change that led to the intermodal operating agreements discussed subsequently. The Act also eased restrictions on changing rates and allowed the use of volume-based contracts. The widespread use of such contracts and the restricted availability of information about contract rates makes any rate analysis based on published tariffs highly speculative.

Aside from cabotage laws, which exclude foreign carriers from domestic service, economic regulation of domestic shipping was largely limited to movements of nonbulk commodities—commodities that, for domestic water transport, are significant only for movements to or from domestic non-contiguous locations (Alaska, Hawaii, Puerto Rico, etc.). These movements were originally subject to regulation by the Federal Maritime Commission (FMC), but FMC's regulatory authority was sharply curtailed in 1978 when carriers were allowed to "file annual increases of 5 percent or less with 60 days notice without being subject to suspension."

## International Transportation Agreements

### Air

Traditionally, international air service has been regulated by bilateral agreements between various countries. These agreements control the routes that can be served, the number of carriers from each country that can serve them, level of service, fares, and the size of aircraft that can be operated. Historically, these agreements have concentrated international traffic through three major gateways: New York (JFK), Miami, and Los Angeles. In recent years, several bilateral agreements have been modified to allow additional international service through a score of additional U.S. gateway airports, including so-called "open skies" agreements with some European countries and Canada.

Air cargo agreements usually have been negotiated as part of more general agreements in a process that has been dominated by the passenger carriers. Efforts by all-cargo carriers to have separate negotiations resulted in the renegotiation of the U.S./Japan cargo agreement in 1995.

The percentage of airfreight moving through the major gateways is likely to continue to decline gradually as bilateral agreements are modified to allow additional routing options. However, complete deregulation of air service to and from additional countries is considered unlikely because of the con-

cerns of foreign carriers about their ability to compete effectively with U.S. carriers in a deregulated environment.

Changes in the share of international freight traffic moving through the major U.S. gateways (or any other set of airports) can be derived from freight traffic data by airport in the North American Airport Traffic Report, published annually by the Airports Council International—North America (see Appendix C). However, the shares indicated for individual airports or sets of airports may be affected by inconsistencies in reporting conventions used by different airports (e.g., treatment of transshipments).

An appropriate measure of the extent of complete deregulation is the volume of airfreight transported to and from countries with which air service has been completely deregulated. Export/import data for applying this measure are available in various forms from the U.S. Bureau of the Census (see Appendix C).

### *Water*

International water transport is generally free of the route restrictions that affect air traffic. Accordingly, ports and routes served are determined by market forces rather than by international agreements. However, U.S. carriers do receive preference for carrying military and foreign-aid cargo; and the U.S. does have bilateral agreements with Brazil, Argentina, and China that may limit service to and from those countries.

Several steamship conferences do exert some influence on services of and rates charged by liners (containerships and other vessels providing scheduled service on regular routes). However, the influence of these conferences on services to and from the U.S. is somewhat limited by FMC regulations that prohibit rebating and market-share agreements and require the conferences to be open, to allow free withdrawal, and to provide mechanisms for handling shipper complaints. In 1992, the FMC approved the Trans-Atlantic Agreement (TAA), which provides for a common tariff, open exchange of capacity and equipment, and a capacity management plan for westbound trade. The TAA covers 12 carriers (both conference and independent carriers) that carry about 80 percent of North Atlantic liner traffic.

### *Truck*

Current law allows both U.S. and Canadian motor carriers to operate across the U.S.-Canada border, subject to the laws of the states and provinces in which they operate. Mexican trucks, however, are allowed to operate in the U.S. only within 30 mi of the border, and U.S. trucks are not allowed into Mexico at all.

Over a 6-year period, NAFTA will phase out all prohibitions on the operations of both U.S. and Mexican trucks carrying international traffic, though both U.S. and Mexican

companies continue to be barred from carrying domestic cargo in the other country. Safety standards will be harmonized over the first 3 years of this period. Size and weight regulations are not affected by the agreement, though some U.S. carriers are hopeful that NAFTA will provide leverage for increasing U.S. weight limits. Mexican carriers will be allowed to hold noncontrolling interests in U.S. carriers, but U.S. carriers will not be allowed to have any ownership interest in carriers providing domestic service in Mexico.

The principal effects of NAFTA on motor carrier service include: improved efficiency in transborder trucking operations resulting from the elimination of the interlining required on many international movements; and additional downward pressure on rates for hauls that cross the Mexican border due to the ability of low-wage Mexican companies to compete for this traffic.

### *Rail*

Analogous to the developments on North American international trade, rail carriers in Canada and the U.S. are becoming more integrated and better able to serve shippers beyond their home countries. For example, both major Canadian railroads have reached trackage rights agreements with U.S. carriers to move traffic in the U.S. CP, in addition to its purchase of the Soo Line and Delaware and Hudson, has acquired trackage rights from CSX and Norfolk Southern to serve Chicago and link Chicago with Boston for intermodal traffic. CN, in addition to owning Grand Trunk Western, has reached similar haulage agreements with Burlington Northern and Conrail. These developments will increase rail competition in the U.S., potentially providing lower rates and additional shipments moving by rail.

### **Intermodal Operating Agreements**

Following passage of maritime deregulation, American President Lines (APL) determined that the most efficient means of serving many inland origins and destinations was by doublestack train, and that, under deregulation, it could contract for doublestack services that were specifically tailored to meet its needs. During the next several years, all major containership companies arranged for such service, operated by the railroads but with marketing handled by the shipping companies. To balance the number of loaded containers moving from the Far East to the central and eastern parts of this country, the shipping companies began soliciting domestic business, offering to transport containers at appropriately low backhaul rates and successfully diverting a share of truck traffic to the Pacific Coast.

More recently, in part because of a shortage of drivers, several of the major truckload carriers have determined that such intermodal operating agreements can also be structured to meet their needs for efficient longhaul transport of trailers and containers. Major truckload operators have made commitments to convert their fleets entirely to containers over the

next 5 to 10 years, and J.B. Hunt has already converted 85 percent of its fleet.<sup>14</sup>

Intermodal agreements have played a major role in the growth of rail intermodal services over the past several years. Between 1980 and 1994 intermodal movements grew from 3.5 million trailers and containers to 8.2 million—a 134 percent increase—with the annual rate of increase tending to accelerate over the period.<sup>15</sup> Most new domestic intermodal traffic was previously being shipped entirely by truck, though a small but unknown portion was previously moving by conventional rail. Intermodal agreements with the shipping companies also have resulted in the diversion of truck traffic to doublestack trains, though an appreciable portion of traffic moving under these agreements may have been already moving by container trains, and some was moving by ship through the Panama Canal. The agreements with shipping companies also affect port use, since the intermodal services to or from any area that are offered by any shipping company are usually operated via a single port.

Measures of the role of intermodal agreements are the number of such agreements (reported periodically in the trade press) and the volume of intermodal traffic. The volume of intermodal loadings (trailers and containers, combined) is published by the Association of American Railroads on both a weekly and annual basis for all Class I railroads and selected other railroads.<sup>16</sup> Since all or virtually all intermodal rail movements involve Class I railroads, data on intermodal loadings is essentially complete.

### Single-Source Delivery of International LTL Shipments

A variant of the door-to-door service provided by the major containership operators has been offered by LTL carriers since the early 1980s. These carriers have established separate units, known as non-vessel operating common carriers (NVOCCs), to arrange for the international transport of LTL shipments. Domestic transport of each shipment is handled by the LTL firm, ocean transport of containers filled with LTL shipments is provided by containership operators from whom the NVOCC purchases space, and transport in Europe and Asia is handled by trucking companies and freight agents with whom the U.S. carrier has partnership agreements. U.S. LTL carriers that provide such single-sources delivery of international LTL shipments include ABF, A-P-A Worldwide, Carolina Freight, the Con-

Way Intermodal subsidiary of Consolidated Freightways, Roadway, and Yellow.<sup>17</sup>

### Fuel Prices

Fuel constitutes a moderately significant and relatively volatile component of costs for all freight modes. Fuel consumption and fuel costs are highest for airfreight and generally are lower for the slower, lower quality-of-service modes. Fuel accounts for 7.1 percent of total operating expenses for Class I railroads;<sup>18</sup> fuel, oil, lubricants, and coolants account for about 13.5 percent of operating expenses for 410 truckload carriers of general freight and about 6 percent of operating expenses for 306 LTL carriers;<sup>19</sup> and fuel represents 30 to 40 percent of operating expenses for air carriers. A significant increase in real fuel prices is likely to result in greater rate increases for the faster modes than for the slower ones and some corresponding shift of demand across modes.

In evaluating the effect of fuel price changes on modal demand, it is necessary to consider fuel requirements for competing services rather than modal averages. Typical rail-competitive intercity truckload operators require less fuel per ton-mile than much other truck transport, while rail doublestack and other intermodal services (which have relatively high tare weights, high speed, and poor aerodynamics) require more fuel than much other rail transport. Thus, a significant increase in fuel prices is likely to result in less diversion from truck to rail intermodal service than a simple comparison of overall fuel efficiency for truck and rail operations would suggest. This can be seen from the estimates of fuel and energy intensity of selected modes and submodes shown in Exhibit A.2—though the reader is cautioned that these estimates are more than 10 years old. Most modes have become somewhat more energy efficient in the last several years, and current rail intermodal services are appreciably more energy efficient than trailer-on-flatcar (TOFC) service.

Information on fuel prices is available from a variety of sources. Data on the average retail self-service price of highway diesel fuel are collected weekly by the Interstate Commerce Commission and published in *Traffic World* and other periodicals. Average diesel fuel prices paid by railroads are published annually by the Association of American Railroads (in *Railroad Facts*) and monthly trends can be estimated from Energy Information Administration (EIA) data on average refiner prices of diesel fuel (and other fuels) sold to end users; the latter data are available in two EIA publica-

<sup>14</sup> Daniel P. Bearth, J.B. Hunt: "We're Not Just in the Trucking Business Anymore," *Transport Topics*, January 30, 1995, p. 8.

<sup>15</sup> Association of American Railroads, *Railroad Facts*, 1994 Edition, Washington, D.C., p. 26.

<sup>16</sup> Association of American Railroads, *Weekly Railroad Traffic*, and *Railroad Facts* (annual), Washington, D.C.

<sup>17</sup> Mitchell E. McDonald, "LTL-to-Europe Services Put Accent on Simplicity," *Traffic Management*, September 1992, pp. 51–53, and Mark Soloman, "Roadway Express Enters Race to Capture U.S.-to-Asia Business," *Journal of Commerce*, May 22, 1992, p. 1.

<sup>18</sup> Interstate Commerce Commission, *Transport Statistics in the United States for the Year Ended December 31, 1991*.

<sup>19</sup> The figures shown include taxes. Exclusive of taxes, the percentages are 9.4 and 4.1 percent, respectively (Transportation Technical Services, *TTS Blue Book of Trucking Companies*, Supplement, New York City, 1992). The figures shown in the text incorporate a 44 percent adjustment for taxes.

**Exhibit A.2. Fuel and energy requirements for selected intercity modes and submodes—1977–1980.**

Mode	Route Ton-Miles per Gallon	Circuitry Factor	Great-Circle Ton-Miles per Gallon	BTU per Great-Circle Ton-Mile
Truck				
Overall	60	1.22	49	2,800
Typical Rail-Competitive	80	1.15	70	2,000
Rail				
Overall	223	1.56	143	970
TOFC	105	1.44	73	1,900
Unit Train	415	1.41	294	470
Water				
Coastwise				
Tanker	535	1.30	410	365
Tug/Barge	385	1.30	296	470
Inland Waterways	290	1.83	158	880
Air				
Cargo Plane	5.3	1.05	5.0	27,000
Belly Freight <sup>a</sup>	45	1.05	43	3,100
Overall	12	1.05	11.4	11,800
Pipeline				
Crude Oil	—	1.10	—	275
Petroleum Products	—	1.10	—	330
Coal Slurry	—	1.10	—	1,000

<sup>a</sup> Estimates for belly freight reflect only the incremental energy required for transporting the freight. Since availability of belly freight is now an important influence on the number and size of aircraft flown on some routes, true energy requirements for belly freight are higher than those shown.

Source: Jack Faucett Associates, *Freight Transport Fuel Efficiency and Commodity Flows*, Bethesda, Maryland, 1983, Exhibit 1.3.

tions: *Petroleum Marketing Monthly* and *Monthly Energy Review*. The EIA data can also be used as an indicator of diesel fuel costs to barge operators, though users should be aware that the prices exclude the Inland Waterway Fuel Tax (currently 17 cents per gallon).

Wholesale prices of jet fuel in the United States and Europe, exclusive of taxes, are published daily in *Platt's Oilgram* and mid-month prices are reprinted in *The Avmark Aviation Economist*; and *Petroleum Marketing Monthly* and *Monthly Energy Review* print EIA data on average monthly refiner prices of jet fuel sold to end users (also exclusive of taxes). Daily New York City, Houston, and New Orleans prices of bunker C fuel, used by maritime carriers, are published (in dollars per metric ton) by the *Journal of Commerce*.

### Publicly Provided Infrastructure

Air, water, and truck carriers are all dependent on publicly provided infrastructure.

The FAA is responsible for building, operating, and improving the nation's air traffic control system, for building and expanding airport runways and related infrastructure,

and for certifying airport designs; while individual airports and other local authorities exercise primary control over terminal and land-access development. Actual terminal facilities may be developed by the airports and leased to the carriers or developed by the carriers, usually on land leased from the airport.

The U.S. Army Corps of Engineers maintains waterway channels, operates locks and dams, constructs and maintains anchorages, and monitors the status of ports and harbors; and the Coast Guard provides aids to navigation and has developed and operates Vessel Traffic Services navigational assistance systems in several major ports. Most ports on the inland waterway system are privately owned; but coastal ports generally are the responsibility of a public port authority that owns and operates piers and wharves, intraport roads and rail lines, storage facilities, and major handling equipment, often leasing berths or terminals to carriers or stevedore firms. Private companies also construct, own, and operate port facilities, particularly those dedicated to a specialized use (e.g., refrigerated terminals or bulk loaders).

The Federal Highway Administration (FHWA) is responsible for administering the federal highway aid program, which provides funds for development of the National High-

way System (including the Interstate System) and other highways on a matching formula basis. Most major highways are constructed, operated, and maintained by state highway agencies or state toll authorities, although some major highways are the responsibility of local governments and most minor roads and streets are the responsibility of local governments. Direct federal responsibility for highways occurs only on federally owned land, such as national parks and forests. In a few cases, highways, bridges, and tunnels are owned by interstate compact agencies, such as port authorities, and in a few cases, private organizations own, operate, and maintain toll facilities or private-access roads open to the public.

The public air, water, and roadway infrastructure is supported by a system of user charges, discussed in the following subsection.

All three systems of infrastructure tend to be expanded somewhat more slowly than the users would like, resulting in congestion that: increases travel times and operating costs; can make delivery times less reliable (a particular problem when JIT service is required); and constrains air-carrier schedules. The quality of local infrastructure and the degree of congestion also affect carrier choices of ports and airports.

Public infrastructure can be measured in terms of physical characteristics (lane-miles of road, channel depths, lengths of runways, etc.) or capital, operating, and maintenance expenditures. Measures of condition also exist for some forms of infrastructure (present serviceability ratings for road pavements and sufficiency ratings for bridges). Sources of data and information include the Corps of Engineers,<sup>20</sup> the Maritime Administration,<sup>21</sup> the American Association of Port Authorities,<sup>22</sup> and the Federal Highway and Transit Administrations.<sup>23</sup>

### User Charges

Most publicly provided transportation infrastructure is funded primarily through user charges. The major exception is the inland waterway system. Half the costs of inland waterway construction projects authorized since 1986 are funded with revenue from the Inland Waterway Fuel Tax, which increased to 20 cents per gallon at the beginning of 1995, while operating and maintenance (O&M) costs and all other construction costs are funded from general revenue.

The high degree of subsidy for barge transport is of concern to the primary competing mode—the railroads. If waterway users were to pay the full cost of O&M through a fuel

tax, an *increase* of close to \$1 per gallon would be required. A further increase would be required if the users' share of construction costs were to be increased from 50 to 100 percent.

Any major increase in the fuel tax would have a significant effect on barge operations and on demand for barge transport. A dollar per gallon increase would increase average transport costs by about 0.2 cents per ton-mile,<sup>24</sup> a very significant increase compared to estimated average barge rates of about 0.8 cents per ton-mile.<sup>25</sup> Such a large fuel tax would present enforcement problems. Accordingly, it might be more practical to reduce or to eliminate the subsidy to waterway users by combining a more modest fuel-tax increase with the imposition of other user charges. These could include lockage fees or annual license fees on barges and/or towboats.

Forty percent of construction operations and maintenance costs for coastal harbors is funded with revenue from a Harbor Maintenance Fee, with the remainder funded by general revenue of the federal government and by local sources. The Harbor Maintenance Fee, established by the 1986 Water Resources Act, is levied at a rate of 0.125 percent on the value of all cargo loaded or unloaded at a port for which federal funds were used since 1977 for construction, maintenance, or operation. Maritime carriers also pay a number of other fees to the Coast Guard, the Customs Service, the Federal Maritime Commission, the Maritime Administration, and eight other federal agencies for a variety of services provided. Extensive information about these fees is contained in a recent General Accounting Office Report.<sup>26</sup>

The operations of coastal ports are financed by a variety of user charges. These include wharfage charges (per container or per ton of cargo), dockage charges, lease revenue, equipment rental fees, gate fees (for trucks and rail cars), and franchise fees (for stevedore firms and other vendors). Facility construction is financed primarily by a combination of revenue bonds, general obligation bonds, and federal aid. The inclusion of general obligation bonds in the mix suggests that some port facilities are not fully supported by user charges but may require some financial support from state or local governments.

Federal spending on airports and airways is supported by a 10 percent tax on airline passenger tickets, a 6.25 percent air cargo waybill tax, a 15- to 17.5-cents-per-gallon tax on fuel used in general aviation, and a \$6-per-person charge for international departures. Revenues from these taxes are deposited in the Airport and Airway Trust Fund, which is used to finance the air traffic control system, to provide federal assistance for airport development, and to support related FAA activities. Increases in the two taxes were

<sup>20</sup> U.S. Army Corps of Engineers, Institute for Water Resources, *The Inland Waterway Review and the Great Lakes Review*, Fort Belvoir, Virginia, annual.

<sup>21</sup> U.S. Department of Transportation, Maritime Administration, *United States Port Development Expenditure Report*, annual, and *A Report to the Congress on the Status of the Public Ports of the United States*, biennial.

<sup>22</sup> American Association of Port Authorities, *Finance Survey*, Alexandria, Virginia, annual.

<sup>23</sup> *The Status of the Surface Transportation System: Conditions and Performance*, Report of the Secretary of Transportation to the United States Congress, U.S. Government Printing Office, biennial.

<sup>24</sup> Congressional Budget Office, *Paying for Highways, Airways and Waterways: How Can Users Be Charged?*, U.S. Government Printing Office, May 1992, p. 62.

<sup>25</sup> Frank A. Smith, *Transportation in America*, Tenth Edition, Eno Transportation Foundation, Waldorf, Maryland, 1993, p. 49.

<sup>26</sup> General Accounting Office, *Federal Assessments Levied on Commercial Vessels*, March 1993.



passed in 1990, enabling the Trust Fund to run an annual surplus that could be used for deficit reduction purposes.

The construction and operation of individual airports usually are financed through a combination of federal assistance (from the Airport and Airway Trust Fund), revenue bonds (for facility construction), revenue from leasing the facilities to the carriers, landing fees, and fees for landing slots. Landing fee schedules are regulated by the FAA to reflect the effects of operations and aircraft weight on costs. Massport (the operator of Boston's Logan Airport) has proposed incorporating capacity considerations into its fee schedules, though FAA has not allowed such considerations in the past. If adopted, the Massport proposal would allow market forces to produce more efficient use of peak-hour capacity, though the effect on airfreight transport is likely to be negligible.

Federal highway programs are supported by the Highway Trust Fund, which receives dedicated highway user taxes including 11.5 cents from the 14.1-cent federal tax on gasoline, 17.5—cents from the 20.1-cent federal tax on diesel, an annual Heavy Vehicle Use Tax of from \$100 to \$550 per heavy truck per year depending on registered weight, an excise tax of 12 percent on the retail price of heavy trucks and tractors, and an excise tax of from 15 to 50 cents per pound on new heavy truck tires, depending on the weight of the tire. For many years, federal Highway Trust Fund receipts could only be used for highway capital improvements. However, over the last few years Congress has gradually reduced restrictions on the use of these funds and, under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), a high proportion of the receipts can be used for transit and other transportation programs.

Most of the states also have highway or transportation trust funds or special accounts in which highway user taxes and fees are deposited. In about half the states, there are constitutional restrictions on the use of dedicated highway user revenues for nonhighway purposes.

Data on state and federal highway receipts and expenditures are reported annually in *FHWA's Highway Statistics*.

User charges also are used to fund a variety of other activity relating to transportation companies, their suppliers, and international transport. Such user charges include the following:

- The Leaking Underground Storage Tank (L.U.S.T.) tax of 0.1 cents per gallon, which is assessed on fuel dispensed from underground tanks and used to pay for remedial actions required to address leaks from such tanks.
- The Oil Spill Liability Tax and Hazardous Substance Superfund Tax on imports, exports, and production of crude oil and petroleum products, which is used to pay for cleanup and related costs resulting from oil spills.
- A Merchandise Processing Fee on imported cargo.

## Other Taxes

In addition to user charges (discussed above), transportation companies pay the usual business, sales, and property taxes (though railroads, the only mode that owns its own right-of-way, are exempt from property taxes on their rights-of-way in a few states). Most revenue from these taxes is used for the general operations of federal, state, and local governments, though some is used for specified nonuser purposes, frequently with a transportation application. The last category includes the use of federal Highway Trust Fund revenue for supporting mass transit.

The transportation industry has a particular concern about the use of fuel taxes for nontransportation purposes. This concern is due to the relatively large amounts of fuel used by the industry and the important role that fuel taxes play in the user-charge system. Currently, 2.5 cents per gallon of the federal tax on gasoline and highway diesel fuel (and 3.1 cents of the tax on gasohol) is deposited in the federal General Fund (and referred to as a "deficit reduction tax").

It now appears likely that the deficit reduction legislation currently before Congress will include a new or increased tax of several cents per gallon on transportation fuels with the proceeds to be used for deficit reduction. The national airline commission has indicated its intention to recommend that the airlines be exempted from this tax because of their poor financial condition, but there may be some resistance to opening up the process to what could then become a series of exemptions. New or increased taxes on transportation fuels would result in small increases in transport costs. As discussed previously (under "Fuel Costs"), such increased costs would affect the faster modes (especially airlines, if they are not exempted) somewhat more than the slower modes, and they would produce some relatively small amounts of traffic diversion.

## Government Subsidization of Carriers

Government subsidization of carriers reduces the cost of transport and, because of unevenness in the way classes of carriers are subsidized, it affects competition between these classes. In particular, subsidization affects competition between domestic modes and, internationally, it affects competition between operators of vessels registered in different countries.

Among domestic carriers, subsidization of motor carriers and barges has long been of concern to the railroad industry. Railroads own and maintain their rights-of-way, and, in many states, they also pay property taxes on rights-of-way. Except for public subsidies of operations on a few otherwise unprofitable branch lines, railroads do not currently receive any government subsidies. (However, they were the beneficiaries of very significant historic subsidies: the granting of right-of-way land and, in several cases, substantial amounts of adjoining land that eventually became quite valuable.) On

the other hand, trucks operate on public roads and barges operate on waterways that are operated and maintained by the Corps of Engineers.

Barges pay only a small portion of the cost of constructing, operating, and maintaining the waterways. Efforts to increase the share paid by barges are likely to continue. Any significant increase in the share of costs paid would increase barge costs appreciably and cause some diversion of traffic to rail. Total elimination of the subsidy to barge operators would increase average costs for barge transport by about 25 percent and would result in significant diversion of traffic to rail.

The subsidies to trucks are appreciably smaller, and there are several states that have highway tax structures that yield appropriate amounts of revenue from trucks. However, the 1982 federal highway cost-allocation report indicated that heavy trucks pay less than their share of federal highway taxes; and, increasing truck taxes historically has proven difficult. Among the most significant truck taxes, taxes on fuel increase with truck weight at a far slower rate than cost responsibility, while most weight-indexed taxes and fees, such as state registration fees and the federal heavy-vehicle use tax, cannot be designed to obtain appropriate amounts of revenue from high annual mileage vehicles without significantly overtaxing low annual mileage vehicles. Weight-distance taxes can be designed to be part of a program that better matches taxes to their estimated cost responsibility, but the trucking industry has successfully opposed their use in all but a few states on the grounds that these taxes are subject to high rates of evasion.

The sizes of federal and state subsidies to motor carriers are estimated periodically by highway cost-allocation studies. Significant changes in the subsidies provided by any governmental entity can occur whenever the structure of that entity's highway tax system is changed.

Issues also exist relating to operating subsidies to U.S. flag ships and the possibility that air carriers are not paying their appropriate share of costs for the air traffic control (ATC) system.

The future of operating subsidies for U.S. flag ships currently is unclear. Curtailment or elimination of these subsidies would result in the re-registration of U.S. flag ships in other countries but would have little net effect on shipping costs and no effect on transport rates or demand.

There does not appear to be agreement about the appropriate share of ATC costs to be paid by the air carriers. Figures from a recent CBO study<sup>27</sup> suggest that current user charges, including the 6.25 percent tax on air-cargo waybills, should be increased by about one-fourth for air carriers to meet their full cost responsibility. However, the current financial problems of the airline industry make such a tax increase unlikely in the near future, and the national com-

mission reviewing the financial condition of the industry has indicated that it expects to recommend a 20 percent reduction in these taxes to pre-1990 levels.<sup>28</sup>

## Environmental Policies and Restrictions

All modes are affected by environmental policies and restrictions, though the restrictions of concern vary among the modes.

The water mode is affected by the largest variety of environmental restrictions. About one-fifth of all U.S. ports report that port expansion is "usually or always" constrained by the Clean Water Act policy of "no net loss" of wetlands, and another quarter of all ports are sometimes constrained. Controls on dredge disposal have increased the cost of dredging required for harbors and inland waterways—costs that are borne directly by the Corps of Engineers and, in the case of inland waterways, indirectly by the carriers through the Inland Waterways Trust Fund. Also, some ports and waterways have speed and draft restrictions intended to protect animal or plant life or the disturbance of channel bottoms, and environmental groups oppose expanding the capacity of the inland waterway system because of the effects of barge traffic on the ecosystem.

The Oil Pollution Act of 1990 requires all new tankers serving U.S. ports to have double hulls, regulates navigation systems and manning of single-hull tankers, and requires the phase-out of most such tankers by 2009 (2015 for tankers of less than 5,000 gross tons). The International Convention for the Prevention of Pollution (MARPOL) also mandates the phase-out of single-hull tankers and requires either protectively located segregated ballast tanks or restricted loading. Also, controls on atmospheric emissions of ships while at berth have been considered.

Two related categories of environmental regulations have significantly increased costs and could have some modest effects on demand for truck freight transportation: emissions controls and clean fuel requirements.

Emissions controls on heavy truck engines have been in effect for about 20 years and increasingly strict controls are scheduled to become effective over the next several years. Controls apply to carbon monoxide, nitrogen oxides, hydrocarbons, and particulates. Diesel engines have had to be completely redesigned to meet these requirements at costs of several hundred dollars per engine. Additional controls will require new electronic fuel injection systems and catalytic converters, which will increase costs by another several hundred dollars per engine.

When translated into costs per mile of operation, however, the engine and related retooling and production costs are quite small compared with the anticipated higher costs of clean diesel fuels. Based on experience under existing California regulations, national requirements for low sulfur fuels,

<sup>27</sup> Congressional Budget Office, *Paying for Highways, Airways, and Waterways: How Can the User Be Charged?*, U.S. Government Printing Office, May 1992, pp. 30–37.

<sup>28</sup> *The Washington Post*, July 21, 1993, p. C1.

scheduled to begin in late 1996, will increase diesel prices about 3 to 7 cents per gallon, and low aromatic requirements, scheduled to begin in 1994, will increase the total increment to about 12 to 15 cents per gallon.<sup>29</sup>

More difficult to estimate is the loss of fuel economy due to these regulations. Significant improvements in fuel economy have been made throughout the period in which the emission controls have been imposed. However, knowledgeable industry representatives believe that the costs of the loss in potential fuel economy improvements due to these controls have been even greater than the other costs cited above.

When all of these costs are added, they amount to roughly 3 to 5 percent of the typical costs of operation of a for-hire truckload carrier. The net effect of these cost increases on freight demand will be to cause a slight shift from truck to other modes, primarily to rail. Since these cost impacts are expected to be split roughly between the last several years and the next few years, the diversion impacts are expected to have about the same time dimensions.

The California Air Resources Board is now considering the desirability of imposing emissions restrictions on railroad locomotives, at least for local and switching operations and other intrastate services. However, before proposing any such restrictions, the board intends to consider the emissions effects of any modal diversion likely to result.

The most significant environmental issue affecting air carriers is noise. The federal government has mandated a phased reduction in the number of aircraft that do not meet "Stage 3" noise limits, with all such planes to be removed from U.S. service by January 1, 2000. Older aircraft can be modified to meet Stage 3 noise limits by replacing their engines (at an average cost estimated in 1988 to be just under \$10 million) or, in some cases, by installing hush kits (at an average cost of \$1.5 million).<sup>30</sup> Installation of new engines has the additional benefit of reducing fuel consumption and related operating costs; however, the cost of new engines represents about 20 percent of the cost of purchasing a new Stage 3 plane.

In addition to the above influences of environmental regulation on modal costs, freight demand is also affected by environmental policies that affect the locations at which raw materials (such as coal and timber) are produced and those at which industrial plants are located.

### Safety Policies and Restrictions

Safety regulations have at most a minor effect on freight demand. These regulations increase carrier capital and operating costs while reducing all accident-related costs (insurance, liability payments, loss and damage, and reliability).

The regulations also create some small costs for safety inspections and recordkeeping.

Safety regulations affect carrier behavior only when perceived safety costs exceed the perceived benefits to the carrier (which may be less than society's benefits). Since these perceptions vary across carriers, safety regulations may not affect all competing carriers equally. In the trucking industry, the larger, more established carriers generally believe that good safety practices are in their long-term financial self-interest; while, in part as a result of competitive factors, some smaller, more marginal carriers frequently cut corners to reduce their rates, risking the possibility that a major accident will put them out of business. In part for this reason, major trucking firms generally have supported the recent trend toward an improved motor-carrier safety-inspection system.

One example of a regulatory action that resulted in demonstrable cost savings is the federal 55-mph speed limit. Although originally imposed as an energy conservation measure during the 1973 oil crisis, the action caused a dramatic decrease in accidents and fatalities,<sup>31</sup> and came to be accepted as a significant cost-saving factor by the motor carrier industry. Of course, much of these cost savings have been eliminated by subsequent increases in rural Interstate speed limits, although many carriers have retained speed-limit restrictions on their drivers, and many carriers enforce the limits through electronic monitoring.

The regulation of hazardous materials (hazmat) transport, on the other hand, does increase transport costs. Although we are aware of no data on the costs of hazmat regulation, we believe these costs do represent a significant proportion of carrier operating costs for hazmat shipments. Limited observation of hazmat motor carrier operations as part of previous studies suggests that these costs might reach several percent of operating costs for the products regulated. How these costs relate to safety benefits associated with potential reductions in risks and liability is unknown.

Regulation of very hazardous materials, such as explosives and nuclear waste, is likely to comprise a major share of operating costs and may be an important determinant of choice of mode. No federal hazmat regulations dictate mode choice or prohibit use of any mode, although the issue of higher risks for truck transport is often raised.

Route restrictions for hazmat truck operations are the responsibility of state and local governments. The extent of these restrictions varies widely around the country, but has not been analyzed, to our knowledge. The amount of such route restrictions is probably increasing, and may become a significant factor in choice of mode in the future. Hazmat trucks are commonly prohibited from using major tunnels and bridges. These restrictions are probably a significant factor in the choice of mode in a few areas, such as in the San Francisco Bay Area, where petroleum products reportedly move by pipeline more than in most urban regions, because

<sup>29</sup> Conversation with Larry W. Strawhorn, Director of Engineering, American Trucking Associations.

<sup>30</sup> Cost estimates are from Leeper, Cambridge, and Campbell, Inc., *The All-Cargo Air Carrier Industry: Its Economic Impact and Future Needs*, prepared for the Airfreight Association, Washington, D.C. April 1989.

<sup>31</sup> American Automobile Manufacturers' Association, *AAMA Motor Vehicle Facts and Figures 93*, Washington, DC, 1993, p. 91.

they cannot be transported by truck across the major bridges in the area.

Risk assessment analyses are commonly performed for major hazmat shippers. However, we are not aware of any studies that have developed such data for policy analysis purposes or for general comparisons among modes of transport.

On international shipping routes, U.S. carriers compete with foreign carriers. Historically, many of the latter carriers were subject to much less stringent safety regulations; though, in recent years, the International Maritime Organization has narrowed these differences appreciably. The extra costs of safety regulation are responsible for only a small portion of the cost disadvantage of U.S. flag carriers (a disadvantage that, as discussed previously, has been mitigated by a federal operating cost subsidy).

The one mode that could possibly see some reduction in the costs of safety regulation is air cargo. Currently aircraft safety inspection requirements are based on aircraft age. Because all-cargo planes generally are operated for fewer hours per week than other commercial aircraft, basing inspection requirements on flight hours (or on a combination of flight hours and age) would reduce inspection costs.

Although changes in safety regulations may have some effect on carrier costs and on modal competition, aside from the effects on the cost of hazmat carriage, these effects are likely to be small relative to those of most of the other factors discussed in this section.

### **Effects of Changes in Truck Size and Weight Limits**

Changes in truck size and weight limits can significantly affect the cost of goods movement by truck. Truck size and weight limits control the amount of payload that can be carried on a truck. For high-density freight, the maximum amount of payload is usually controlled by weight limits. For low-density freight, the maximum amount of payload is usually controlled by the cubic capacity of the truck, which is in turn controlled by length, width, and height limits. Because increases in truck size and weight limits increase the payload per trip, fewer truck trips are required to carry the same amount of freight. Longer and heavier trucks generally cost more to operate on a per-vehicle-mile basis; however, higher per-vehicle-mile costs only partially offset the cost savings due to fewer trips.

Changes in truck size and weight limits can result in shifts of freight to or from other modes, most importantly rail. Without the diversion of additional freight from rail, more permissive truck size and weight limits would be expected to reduce truck traffic volumes. However, the extent to which these reductions will be offset by the diversion of freight to trucks is an important issue in the debate over the effects of changes in limits.

Three types of weight limits are commonly applied to trucks: gross weight, weights for single and tandem axles,

and "bridge formula" limits that restrict the maximum allowable weight on a group of axles depending on the number of axles and axle group length. Other commonly regulated dimensions of trucks include overall length, trailer length, width, height, and number of trailers. The American Trucking Associations (ATA) regularly produces a *Summary of Size and Weight Limits*, which specifies height, width, length, and weight limits by state; detailed state access provisions for doubles; and special limits on longer combination vehicles (LCVs), turnpikes, and toll roads. More detailed information on size and weight limits, as well as operating requirements, can be obtained from the ATA's *Motor Carrier Advisory Service*. Also, very detailed information on size and weight limits and operating restrictions for LCVs for the 22 states in which such vehicles operate can be found in the March 20, 1992, *Federal Register*. ISTEA required that states provide this information to facilitate enforcement of the ISTEA freeze on LCVs noted below.

The federal government places both "floors" and "ceilings" on state truck size and weight limits. Floors include the requirements (in the Surface Transportation Assistance Act of 1982) that all states allow the operation of doubles with 28-foot trailers on Interstate and other principal highways, and that all states increase their weight limits on Interstate highways to 20,000 pounds for single axles, 34,000 pounds for tandem axles, and 80,000 pounds for gross weight. Federal ceilings on state size and weight limits generally include grandfather exemptions, which allow states to keep more permissive limits if such limits were in effect when the federal legislation was passed. ISTEA froze maximum size and weight limits and operating requirements for longer combination vehicles at June 1, 1991, levels for each state.

Truck size and weight limits within a state frequently vary by highway system. Thus, just because a state allows longer and heavier trucks on some highways does not necessarily mean that those trucks can be used to access all loading and unloading sites within the state. Most eastern states restrict the operation of double trailer trucks to Interstate and other principal highways, with access to and from this network governed by a permit process or specified provisions based on distance and possibly other factors. "Turnpike doubles" with two 48-foot trailers and gross weights of 127,000 to 143,000 pounds are allowed on turnpikes in several eastern states. However, use of these trucks off the turnpikes is severely restricted. For example, New York restricts turnpike doubles to a distance of 1,500 feet from the Turnpike and operates 32 staging areas for assembling and breaking down these trucks. The need to use staging areas, rather than travel directly from origin to destination, can significantly increase transport costs.

Because federal weight limits are applicable only to Interstate highways, some states may actually have more permissive weight limits on non-Interstate highways. For example, in Delaware, tandem axle limits are 34,000 pounds on Interstates and 40,000 pounds on non-Interstate highways.

The diversion of freight from rail to truck due to changes in limits can have important impacts on railroads. The Transportation Research Board's *Truck Weight Study* estimated that eliminating the 80,000-pound limit on gross weight would, with no other changes in size and weight limits, attract about 20 billion ton-miles of freight from rail to truck, representing a 2.2-percent reduction in rail traffic. This diversion would reduce railroad revenue by about \$750 million per year. In addition, the TRB study estimates that railroads would reduce rates on 63 billion ton-miles of other freight movements to avoid this freight shifting to truck, resulting in another \$210 million reduction in rail revenue. If truck length limits are also increased, additional diversion of freight from rail to truck would be expected. For example, in a study performed for the American Trucking Associations, Sydec estimated that about 5 percent of rail ton-miles would be diverted to truck if the nationwide operation of LCVs (most importantly turnpike doubles) is permitted. The Association of American Railroads (AAR) estimates that nationwide operation of LCVs would directly divert 11 percent of rail traffic to truck. Also, AAR estimates that an additional 8 percent of rail traffic would divert to truck as a result of service cutbacks due to decreases in rail traffic and revenue.

Truck size and weight limits are among the most significant issues dealt with under post-NAFTA "harmonization negotiations." Both Canadian and Mexican trucking companies want the opportunity to haul the freight between their countries that is routed across the United States. Trucking interests in western states have advanced the concept of "NAFTA Corridors" in which longer and heavier combinations would be allowed on selected Interstate highways in western states. Rail interests oppose this limited end to the LCV freeze as leading to a return of the "ratcheting" upward of truck size and weight limits, ultimately resulting in the nationwide operation of LCVs.

In addition to truck-rail diversion, another freight demand issue bearing on the subject of size and weight limits is the question of whether and to what extent cost savings due to increases in size and weight limits will increase the total volume of freight shipped by all modes combined. If, for example, transport cost savings are passed on to consumers in the form of lower prices, then some increase in purchases and, as a result, more freight shipments may result. However, for most commodities, transport costs account for a very small percentage of the price, and even fairly large reductions in transport costs would produce only a small reduction in the price. Changes in size and weight limits might also affect the total amount of freight shipped by encouraging (or discouraging) the use of centralized production facilities—in effect using more transportation to take advantage of economies of scale in production. It is not clear, however, that cost savings such as might be produced by higher size and weight limits are large enough to produce significant changes in production methods.

A number of factors complicate the problem of analyzing the effects of changes in size and weight limits on trucking productivity and freight demand by mode:

- The sizes and weight of trucks traveling in different states (or on different highway systems in a single state) are controlled by the most restrictive set of limits faced along their route. Without some consideration of routing, it is difficult to determine the limits applicable to a given vehicle.
- For many commodities, actual shipment sizes are often less than the maximum shipment sizes permitted under size and weight limits.
- Innovative types of operations have been proposed for using doubles to move pairs of trailers from different shippers to different destinations, but the efficiencies such types of operation will be able to achieve is unclear.
- Vehicles designed to take advantage of higher weight limits frequently are less efficient than current vehicles for carrying cube-limited loads; and vehicles designed to take advantage of increased size limits frequently are less efficient for carrying weight-limited loads. These factors limit the commodities that can be efficiently carried on backhauls and adversely affect the overall utilization of these more specialized vehicles.
- Access restrictions reduce the number of shippers that can be served by longer or heavier vehicles, limiting both the markets that can be served by such vehicles and the opportunities for obtaining backhauls.
- Line-haul costs for new trucks may be affected by restrictions related to safety and traffic operations.
- It may take several years for the effects of changes in size and weight limits to materialize fully because new equipment is often required to take full advantage of these changes.

## Congestion

In many urban areas, increasing highway congestion is affecting the efficiency of reliable truck transport, and the reliability required by just-in-time shipping. Highway congestion affects trucking costs primarily by increasing the number of driver hours and vehicles required to haul a given amount of freight and by reducing truck fuel economies.

Recent studies of congestion have distinguished recurring congestion from the effects of incidents such as disabled vehicles, accidents, and construction or maintenance activities. To meet delivery schedules in congested areas, allowances must be made for the possibility of incident-related delays. Such allowances are costly to truckers, since they increase the time that a driver and vehicle are idle.

Increasing congestion in large metropolitan areas has led to proposals for truck bans during peak periods in some metropolitan areas. In 1988, Los Angeles Mayor Thomas

Bradley proposed a plan for reducing congestion that included a truck-permitting program that would drastically reduce the number of large trucks allowed to operate on the streets of Los Angeles during the morning and evening peak periods. A resulting study undertaken for the California Department of Transportation recommended against area-wide freeway truck bans; however, the study did recommend further research on time-of-day and lane restrictions.<sup>32</sup>

FHWA uses information from its Highway Performance Monitoring System (HPMS) to measure congestion on the nation's highways. HPMS contains data on a stratified random sample of approximately 100,000 highway sections. Among the data items provided for each highway section are annual average daily traffic, capacity of the highway section (measured in vehicles per hour), and peak hour volume-to-capacity ratios. Congestion data from HPMS are summarized in FHWA's biennial report to Congress: *The Status of the Nation's Surface Transportation System: Conditions and Performance*. These data also are used by the Texas Transportation Institute to produce biennial reports on congestion in urban areas.<sup>33</sup>

Another area of congestion is airport customs clearance. The U.S. Customs Service is working with carriers and airports to improve performance through the use of electronic data interchange (EDI) as implemented in the Automated Air Manifest System. U.S. Customs has installed facilities in some of the integrated carriers' hubs and worked to implement preclearance of express packages based on electronically filed documents. Other elements of customs modernization are being addressed in Congress and through industry/government cooperation.

### Technological Advances

One of the most important areas of technological advance in recent years involves the use of computers and telecommunications equipment. Air carriers and many leading trucking companies have implemented sophisticated systems for tracking shipments; integrated carriers now use computers for sorting packages, optimizing the use of both aircraft and ground delivery vehicles, and identifying potential delays or congestion; and computers and telecommunications increasingly are used by the railroads both to track shipments and to control the operations of classification yards and dispatching centers. Automated tariff filing and the use of EDI are expected to expedite cargo processing at ports and airports. Further advances in the use of such systems should contribute to continuing improvements in transport system effi-

ciency and reliability, especially in the handling of parcel and less-than-truck/container-load shipments.

Other important advances in transport technology have related to rail intermodal transport: the development and use of doublestack container cars, Road Railers cars, railcar-mounted "Iron Highway" loading and unloading ramps for trailers, and lighter railcar frames for carrying containers and trailers. The new intermodal equipment achieves better fuel efficiency through improvements in payload/empty-weight ratios and, usually, in aerodynamics. These advances, along with the related decision of the railroads to reduce the number of intermodal transfer facilities to a limited number of well-equipped, high-volume sites and the advent of various intermodal operating agreements (discussed previously), have enabled rail intermodal to become competitive with trucks for a growing portion of the long-distance market.

Improved container designs also have increased the efficiency of rail, air, and maritime intermodal services. The Autostack container, which uses a collapsible rack system for carrying automobiles in one direction and other freight on backhauls, provides better protection for automobiles than the tri-level railcars that were formerly used for such carriage and has reversed the shift from rail to truck for longer distance transport of automobiles.

Railroads are benefiting from improved AC traction and more efficient engines; locomotives designed during the 1980s are about 15 percent more fuel-efficient than earlier models. Innovative freight car wheel designs have reduced wear on both wheels and track and have improved fuel efficiency.

Increases in aircraft size and in the internal configuration of aircraft have resulted in increased space available for carrying cargo on passenger planes. Combination ("combi") configurations for wide-body planes permit cargo to be carried on part of the main deck as well as in the belly to handle over-sized freight or to improve the integration of air containers into stowage plans. "Quick change" designs, now being implemented in Europe, allow aircraft to be readily converted from passenger configurations for daytime operation to freighter configurations for use at night. Aircraft designs now being explored include: a high-capacity plane designed for exclusive freight operation; and helicopter or tilt-rotor aircraft for short-haul operations. Other technological improvements to aircraft include the development of quieter, more fuel-efficient engines, the use of new composite materials to reduce aircraft weight, and aircraft designs that allow reduced crewing levels.

Inland water transport can also benefit from a variety of recent technological advances.<sup>34</sup> Systems for monitoring fuel consumption and controlling tow steerage and throttle to optimize fuel use are capable of reducing fuel consumption by 15 to 20 percent. Kort nozzles can also improve fuel effi-

<sup>32</sup> Grenzeback, Reilly, Roberts, and Stowers, "Urban Freeway Gridlock Study: Reducing the Impacts of Large Trucks on Peak-Period Urban Freeway Congestion," *Transportation Research Record 1256: Trucking Issues—1990*, Transportation Research Board, 1990, pp. 16–26.

<sup>33</sup> D. Schrank, S. Turner and T. Lomax, *Trends in Urban Roadway Congestion—1982 to 1991*, Two Volumes, Texas Transportation Institute, Report 1131-6, College Station, Texas, 1994.

<sup>34</sup> Leeper, Cambridge and Campbell, Inc., *Upper Mississippi River Transportation Economic Study*, prepared for the Maritime Administration, the U.S. Department of Agriculture, and five midwestern states, April 1989.

ciency by reducing power loss. Improved equipment for rigging barge tows has been developed that reduces crew requirements, increases safety, and reduces time for splitting and rerigging tows to transit locks. Lockage time, safety, and lock availability can also benefit from improved lock approaches, tow holding areas, and automated handling in the lock. Improved channel markers have been developed that can be more readily repositioned when conditions change and, once positioned, move less, thus providing more accurate indication of channel conditions and reducing groundings. Tow engines designed to use lower-cost, heavier fuel oil (bunker C and residual) are being developed, but these engines are expected to be more expensive to produce and to maintain.

The Intelligent Transportation System (ITS) Act (Part B of Title VI of ISTEA) establishes a new program "to research, develop, and operationally test intelligent vehicle-highway systems and promote implementation of such systems as a component of the Nation's surface transportation systems." ITS can affect freight demand by improving the efficiency of truck transportation, reducing total logistics costs for truck shipments, and making the use of trucks more attractive to shippers. However, ITS-related improvements

in trucking efficiency are not expected to be of sufficient magnitude to significantly affect the volume of freight shipped by truck. ITS can also reduce illegal overloading and evasion of motor carrier taxes, through monitoring of truck traffic.

In other areas, the effects of technological advances on transport costs and services are not expected to be significant.

In the maritime area, research continues on hull forms; power plants and power plant systems; propulsor technology; navigation systems; and maneuvering and control systems. However, the cost savings produced by resulting advances are expected to be much less significant than those produced in the recent past by improved cargo handling, larger vessels, and more fuel-efficient technology.

The fuel efficiency of trucks, which has increased by about 20 percent in the past two decades, is not likely to change appreciably, as the introduction of new efficiency improvements is expected to slow and their effects are expected to be balanced by new emissions-control standards and fuel-blending requirements. Potential truck productivity improvements resulting from the use of larger or heavier vehicles are a regulatory issue rather than a technological one and have been discussed previously.

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## APPENDIX B

### REVIEWS OF FREIGHT DEMAND FORECASTING STUDIES

#### B.1 GENERAL OVERVIEW OF FREIGHT DEMAND PLANNING: POLICY ISSUES TO BE ADDRESSED

##### General Overview of Freight Planning Process: Relevant Policy Issues

Frank Southworth, Yong Jae Lee, Cynthia S. Griffin, and David Zavattero, "Strategic Motor Freight Planning for Chicago in the Year 2000," *Transportation Research Record*, No. 920, 1983, pp. 45–48.

This paper focuses on freight planning in a metropolitan area. The policy decisions such as the clustering of for-hire freight terminals, channeling heavy freight vehicle flows along a designated truck-route network, and an expansion of a motor carrier commercial zone are investigated.

The study provides examples of the kinds of policy decisions and needed tools that are relevant for urban transportation planners.

##### Alternative Planning Approaches: Structural and Direct

Cambridge Systematics, Inc., *Statewide Freight Demand Forecasting*, NCHRP 20–17, May 1980.

This report divides freight demand forecasting into two basic approaches: a structured approach and a direct forecasting approach. The structured approach is comprehensive. It recognizes that freight demand is derived from underlying economic activities and subject to intermodal and intramodal competitive forces and government actions. It involves a comprehensive linkage of current or long-range economic activity, production and consumption nodes, distribution or linkages between production and consumption nodes, mode choice and shipment size decisions, vehicle trips, and route assignments.

The challenge of effective execution of the structured approach is that there is no consistent source of data for each of the components of the approach. The authors state "all of the pieces of the structured forecasting approach exist in varying degrees of completeness, integration with other components, and public availability." Furthermore, most of the existing components are based on national data, not state data. The authors argue: "These various models are not designed for state or local applications, have diverse and sometimes incompatible data requirements, are not maintained by any government agency for use by freight trans-

portation planners outside the developing agency, and are frequently not specified with the goal of implementation within a larger system of freight demand analysis."

Direct forecasting methods are defined as those which ignore (to varying degrees) some of the interrelationships that are analyzed in the full structured model—i.e., interrelationships among long-range economic activity, production and consumption, distribution among production and consumption nodes, mode choice and shipment size, vehicle trips, and route assignment. The direct forecasting approaches are generally tailored to the needs of a particular component of the structured model and fail to account for all of the variables considered in the structured approach. The authors state: "It is useful to think of direct forecasting techniques as simplifications to the structured approach described above, where only a subset of the possible interrelations are examined in detail."

A major limitation of direct forecasting methods is their inability to analyze a wide range of problems. Because they do not consider all the complex interrelationships that are part of the structured analysis, the direct forecasting methods must make simplifying assumptions that limit the complexity and variety of problems that they can deal with.

The authors conclude: "Direct forecasting approaches have been and will continue to be the mainstay of state and local freight transportation planning. While direct forecasting techniques can, in principle, incorporate all of the independent variables found in the structured forecasting approach, limits on empirical model building will force the analysts to limit attention to a subset of possible interactions. . . . The analyst must recognize the true structure of freight demand and decide, based upon agency objectives, planning issues, and resources, which aspects of the structure will be emphasized and which will be de-emphasized or ignored altogether."

#### B.2 THE STRUCTURAL APPROACH: FREIGHT PLANNING PATTERNED AFTER THE URBAN PLANNING PROCESS—TRIP GENERATION, TRIP DISTRIBUTION, MODE CHOICE, AND ROUTE ASSIGNMENT

##### 1. Overview of Similarities Between Freight and Urban Planning

**Guidebook for Comprehensive Freight Planning: Four Step Urban Planning Approach Applied to Freight Planning**



Frederick Memmott, Roger Creighton Associates, *Application of Freight Demand Forecasting Techniques*, National Cooperative Highway Research Program, Report No. 260, 1983.

This NCHRP Report presents a methodology for states to use in conducting freight studies to be used to meet a wide range of needs including: facility, service, or regulatory problems; state policies toward infrastructure investment, energy use, life cycle costs; and freight components of statewide master plans.

It appears to be the most recent and comprehensive effort to assist states with freight demand forecasting. As such, it is very relevant for our current study. It would be useful to have more information on how this report has been used by states. The report, itself, includes several prototypes of how the procedures suggested can be implemented to solve practical transportation questions. It would be relevant to determine how many additional applications resulted from the suggested procedures. It would also be useful to know if the outlined procedures have been updated or whether such an updating is a desired output of the current NCHRP effort.

This report provides a user manual of the three steps involved in freight forecasting. These steps are borrowed from the urban transportation passenger travel forecasting model. They include: freight generation and distribution; mode choice; and traffic/route assignment. Each of these components is described in detail in a separate chapter of the study. There is a complete reporting of the state-of-the-art developments in each component. Specific references are provided for each of the individual model components. There is a description of how to accomplish each component of the model regardless of the type of data that are available for the state.

The first step in the freight planning process is freight traffic generation and distribution. This involves estimating current volumes of traffic and flows of different types of traffic between specific origins and destinations.

Accordingly, a base case commodity flow matrix is developed. This is used as the basis for making projections and future year commodity flow matrices. A variety of options are available to move from the base year to the future year matrix. One is to project future traffic flow directly from the base year matrix. A second is to project commodity production and consumption on an individual commodity basis and adjust the commodity flow matrix accordingly. A third is to forecast macro-economic indicators and adjust the base year commodity flow matrices.

The next step is modal division, i.e., splitting commodity movements among competing modes. Again, a variety of options are available to accomplish a modal division. Modal cost and rate comparisons can be developed and employed as the basis for splitting the traffic. The comparisons of modes can also be made from the perspective of shipper logistics. The author provides some detail regarding the available methods for costing of the services of different modes.

While claiming to be a user's manual, the study appears more like a catalog of state-of-the-art develop-

ments in freight forecasting. It seems clear that any state wanting to initiate a specific freight study using this report would still need the services of an outside consultant to link the individual components in a comprehensive fashion. There are a lot of individual pieces and good advice about the relevant ones depending on the specific circumstances, but insufficient guidance on the linkage across components or the development of an integrated package.

This is not a user-friendly, how-to integrated freight package.

### **Guidebook for Comprehensive Freight Planning: Four Step Urban Planning Approach Applied to Freight Planning**

Frederick W. Memmott and Russell H. Boekenkroeger, "Practical Methodology for Freight Forecasting," *Transportation Research Record*, No. 889, 1982, pp. 1-7.

The authors present a straightforward procedure for freight forecasting. This is a more condensed format of the methodology and approach outlined in *NCHRP Report No. 260*.

It is driven by a base case commodity flow matrix. Added onto this are cost and rate data for the individual transportation modes. The heart of the model lies in a series of basic cost and revenue relations or estimating equations—one applicable for each commodity-flow/routing possibility.

In summary, this provides a fairly simple, yet practical method for freight forecasting. The authors note that current techniques for modal choice forecasting remain very elementary and are not yet suited for inclusion in freight forecasting models.

### **Application of Four Step Urban Planning Model Approach to Freight Planning**

T. John Kim and Jere J. Hinkle, "Model for Statewide Freight Transportation Planning," *Transportation Research Record*, No. 889, 1982, pp. 15-19.

The authors employ the standard urban transportation modeling process to the freight area. That process involves essentially four steps: trip generation (total volumes), trip distribution (origin-destination commodity flows), modal split, and route assignment.

The authors do not provide details beyond a general sketch of how the elements of the urban transportation modeling process can be adapted to the freight modeling situation.

D. Kurth, et al., *A Research Process for Developing a Statewide Multimodal Transportation Forecasting Model*, prepared by Barton-Aschman Associates, for the New Mexico State Highway and Transportation Department, Santa Fe, August 1991.

This report presents the results of a two-day, April 1991, workshop intended as the first phase of an effort to produce a statewide multimodal forecasting model. The workshop produced a proposal for an effort that would focus on producing an intercity passenger model and a goods movement model. The latter was envisioned as a three-stage model consisting of: commodity generation; commodity distribution and mode choice (combined); and assignment. New Mexico subsequently provided Barton-Aschman with funds to begin development of this model; however, this effort has since been placed on hold, and no further reports have been issued.

## 2. Trip Generation and Trip Distribution

### A. Forecasts Based on Macro-Economic Data

#### Trip Generation and Trip Distribution: Forecasts of O/D Freight Flows Using Various Macro-Growth and Micro-Production Models.

David P. Middendorf, Mark Jelavich, and Raymond H. Ellis, "Development and Application of Statewide, Multimodal Freight Forecasting Procedures for Florida," *Transportation Research Record*, No. 889, 1982, pp. 7-14.

Beginning with base year freight origin-destination volumes by type of commodity, information from input-output models, forecasted personal income, forecasted industry earnings, in combination, are used to give commodity consumption growth and production growth. These growth projections are combined with the base year tables to give projected origin-destination volumes by type of commodity.

The authors also indicate that efforts to develop a modal split model through a logit formulation were unsuccessful. The difficulties associated with development of a modern discrete choice modal split model seem to be a common observation across a number of these studies.

Jack Faucett Associates, Inc., *California Freight Energy Demand Model*, California Energy Commission, 1983.

H. Weinblatt, "The California Freight Energy Demand Model," *Transportation Research Record*, No. 935, 1983, pp. 26-32.

The California Freight Energy Demand (CALFED) Model uses estimates of base-year truck stock and rail freight and truck activity in five regions of California and forecasts of changes in California production and employment by sector to produce forecasts of changes in truck stock and rail freight and truck activity. Truck activity is estimated by vehicle size class and trailer/body type for freight and non-freight purposes (combined). Rail freight activity is estimated for trailer-on-flatcar service and seven types of carload freight. Diversion of nonlocal freight

between truck and rail is estimated using forecast changes in relative costs and pseudo-elasticities for ten commodity groups using aggregate data from the 1977 Commodity Transportation Survey and from other sources. The disaggregate forecasts of truck and rail activity and truck stock are combined with exogenous forecasts of fuel efficiency and fuel prices by fuel type to produce forecasts of truck and rail freight energy demand.

### Forecasts of O/D Flows Based on Input-Output Models

G. Treyz, B. Stevens, and D. Ehrlich, *A State Core Forecasting and Policy Simulation Model*, NCHRP Project 8-15A, Handbook 2, Regional Science Research Institute, July 1982.

This is the second of two handbooks produced to facilitate use of input-output (IO) models by state transportation planners. In this part of the study, more attention is placed on using IO as a forecasting and policy simulation model (FPSM). In addition to its potential usefulness in assessing the economic impacts of transportation investment, these techniques could also be used to assess the effects of transportation policies such as an additional tax on motor fuel. Computer programs were also supplied with the handbook. In this regard, the results could fit with a comprehensive structural approach to forecasting impacts of policy changes. However, it appears that these input-output models have been little used for actual state planning activities.

Jack Faucett Associates, *The Department of Transportation Long-Range Forecast Model*, U.S. Department of Transportation, Office of the Secretary, January 1980.

The Department of Transportation Long-Range Forecast Model consists of an input-output model (the INFORUM model of the University of Maryland) and a transportation submodel, with detail for 31 commercial and private transportation modes. The submodel calculates output levels for the transportation modes consistent with the economic projects and industrial detail from the main model.

The transportation submodel distinguishes six major modes for transporting domestic intercity freight (rail, commercial and private trucking, inland and coastal water, and petroleum pipelines). A modal split model incorporating own and cross-price elasticities is used to estimate modal diversion among the first four of these modes (rail, inland water, and the two truck modes) resulting from changes in modal costs. Other modes distinguished include air freight, international water freight, commercial and private local trucking (separately), non-freight trucking, government trucking, and transportation services and warehousing. Total freight traffic is estimated separately for 48 commodity groups using INFORUM forecasts, with additional analyses performed for grain, coal, crude oil, and petroleum products.

Passenger transportation forecasts are exogenous and are specified as inputs to the transportation submodel. The transportation submodel also calculates input requirements for each transportation mode, including detailed inputs of fuels.

### **Forecasts of O/D Flows Based on Reebe and Rail Waybill Data**

V. Eusebio and S. Rindom, *Interstate Movements of Manufactured Goods in Kansas*, Kansas Department of Transportation, May 1991.

This study was done for the purpose of determining the flow of manufactured goods between Kansas and various origins/destinations, and also to determine the flows of goods moving by rail and truck. The Reebe Associates Transearch data base was used for truck data, while the ICC Waybill tape was used to obtain rail data. The bulk of the report is a series of 57 tables noting various commodity flows. This type of state study points to the value of providing better access to the states for rail and truck flows data.

### *B. Flows Based on Linear Programming Models*

#### **Trip-Generation and Trip-Distribution Forecasts Based on Linear Programming Models**

Mary Marchant, "Analysis of the Effects of Rising Transportation Costs on California's Fresh Fruit and Vegetable Markets," *Journal of the Transportation Research Forum*, Vol. XXXII, No. 1, 1991, pp. 17-32.

This article looks at a linear programming model to allocate freight (i.e., competitive agricultural crops) among several producing regions and various markets in order to minimize total costs (the sum of production and transportation costs) subject to various production and consumption constraints. In particular, the model analyzes the impact of rising transportation costs (from increased fuel prices) on California's produce market share. The analysis suggests the complexity of analyzing impacts of factors such as changing fuel costs on freight traffic flows.

The implication of this type of study is that freight allocation models could go beyond taking a base set of freight flows adjusting for prospective changes in the economy and changes in modal split to utilizing an input-output framework and incorporating changes in shipping patterns as this study has done for produce.

#### **Trip Generation and Trip Distribution: Linear Programming and Network Approach**

Michael Florian and Teodor Crainic, editors, *Strategic Planning of Freight Transportation in Brazil: Methodology and Applications*, University of Montreal, July 1989.

This study lays out a comprehensive network modeling approach toward strategic planning for freight transport services. Network model methods are used to simulate flows, service levels, and costs for alternative modes. The models used are multi-product, multi-commodity network flow problems. The transportation system is specified in terms of links and nodes with given capacities among them. Added to this are data on service and cost characteristics of each mode as well as origin to destination demands for products.

The output of the model are flows on a particular mode between a particular origin and destination on the network. The study provides detailed analytical procedures and applications in the Brazilian context. This type of methodology is quite complex and may be extremely difficult to transport to other regions/nations. It was designed specifically to use available data from Brazil.

#### **Trip Generation and Trip Distribution: Linear Programming and Network Approach**

Jacques Guelat, Michael Florian and Teodor Crainic, "A Multimode Multiproduct Network Assignment Model for Strategic Planning of Freight Flows," *Transportation Science*, Vol. 24, No. 1, February 1990, pp. 25-39.

This provides a journal-length description of the full study discussed above. The authors point out that previous uses of network models have been confined mainly to urban transportation studies for prediction of passenger transportation flows within an urban area. Less attention has been given to the freight flow problem as a result of the inherent complexities of freight transportation.

Spatial price equilibrium models have been previously used for predicting inter-regional freight flows. This study uses network models. One aspect of this network model which differs from previous work is that individual shippers and carriers are not identified explicitly. This type of approach is more appropriate for strategic planning at a national level.

This article provides a good review of network models and their use in freight planning applications. From a network modeling standpoint, there are a number of technical innovations associated with the Brazilian project.

#### **Trip Generation and Trip Distribution: Combination of Approaches—Manufacturing Data, Network Modeling**

W. Black and J. Palmer, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment Phase I*, Transportation Research Center, Indiana University, February 1993.

This study is one of the most sophisticated modeling exercises done by or for state transportation departments. The purpose is to produce an extensive analysis of key rail and

highway flows in the state of Indiana. Network models are used, drawing from the FHWA highway network model and the Census TIGER files. Data was drawn from the ICC Waybill tapes, energy data bases, grain flow data and the now somewhat dated 1987 Census of Manufacturing tapes. One use of the study is to designate key highway corridors for upgrading and maintenance. Indiana is continuing with follow-up studies for more accurate determination of traffic flows. This study suggests that national freight data, made more readily available to the states, would be of use in such studies. In particular, truck flow data is very critical for planning purposes and difficult to obtain. It also points to the potential usefulness of updated and more readily available rail and highway network models. It should be noted that this study did not involve forecasts of future flows, but only determination of current flows.

### C. Various Forecasting Methods

#### **Trip-Generation and Trip Distribution: A Survey of Methods Used to Predict Future Trends**

David V. Grier and L. Leigh Skaggs, *A Review of 16 Planning and Forecast Methodologies Used in U.S. Army Corps of Engineers Inland Navigation Studies*, U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources, Fort Belvoir, Virginia, June 1992.

The projection methodologies of the 16 studies reviewed as part of this effort fall into four broad groups: (1) the application of independently derived commodity-specific annual growth rates to base year traffic levels; (2) shipper surveys of existing and potential waterway users to determine future plans to ship by barge; (3) statistical analysis using regression and correlation to predict future waterborne traffic based on independent economic variables; and (4) a detailed long-range commodity supply-demand and modal split analysis incorporating the production and consumption patterns of individual economic regions within the waterway hinterland.

The basic focus of these studies is the prediction of traffic on all, or a portion, of the inland waterway system. As such the studies lack the comprehensiveness of the integrated structured approach outlined in the Statewide Demand Forecasting study.

The authors ask the question: "What is the best kind of method" for forecasting inland waterway traffic. The authors set some assessment criteria: the most practical methodology appears to be one that uses a consistent set of macroeconomic assumptions in generating international, national, and regional level projections. Methodology should be easily updatable based on latest historic and forecast data, be relatively low-cost for the project manager to implement, and be PC-based.

The authors find that "the methodology incorporating commodity-specific growth rates applied to one or more base year traffic levels appears to best meet the established criteria." In contrast, methods which rely on shipper surveys tend to build in an optimistic bias and do not sufficiently address

long-term forecast issues. Statistically based regression and correlation methods inherently assume a continuation of past trends. Finally, a long-term evaluation of regional market demands, resource bases, production levels and transportation modes, while detailed, extensive and methodologically defensible—is unfortunately the type of massive forecasting effort that is not easily updated and may be impractical for smaller planning staffs.

Unfortunately, these commodity-specific top-down growth rate projections are often too general to be disaggregated to the local level without a serious loss of reliability. However, the authors believe that this forecast method can be used to provide a consistent national framework that can be refined in a project level analysis by planners equipped with knowledge of local industry, markets and transportation patterns.

#### **Sources of Truck Data for Determining Trip Generation and Trip Distribution**

P. Hu, T. Wright, S. Miaou, D. Beal, and S. Davis, *Estimating Commercial Truck VMT of Interstate Motor Carriers: Data Evaluation*, Oak Ridge National Laboratory Report, November 1989.

Data availability is a key issue for freight forecasters, and this report provides information about a number of data sources for commercial trucks:

1. Truck Inventory and Use Survey from the Bureau of the Census
2. Nationwide Truck Activity and Commodity Survey from the Bureau of the Census
3. National Truck Trip Information survey from the University of Michigan Transportation Research Institute
4. Highway Performance Monitoring System from the FHWA
5. State fuel tax reports from each individual state and the International Fuel Tax Agreement
6. International Registration Plan of the American Association of Motor Vehicle Administrators.

This report evaluates each of these data sources in subsequent chapters, with particular attention to the ability of each source to estimate vehicle miles of travel by carrier type and by state. This type of data is useful for determining accident rates, highway investment needs, and economic impacts of FHWA policies. The report would also be useful for anyone seeking further details on truck data sources.

### **3. Mode Split and Mode Choice**

*A. Aggregate Approach Mode-Split/Mode-Choice Model: Aggregate Approach*

Michael W. Babcock and H. Wade German, "Changing Determinants of Truck-Rail Market Shares, *Logistics*

and *Transportation Review*, Vol 25, No. 3 (1989), pp. 251–270.

This analysis provides an equation to estimate rail market share as a function of rail/truck rate and service comparisons, macro-economic interest rates, and a time trend variable. The equation is estimated separately for a pre- and post-1980 time period.

There is an equation to estimate rail market share in each two-digit STCC classification aggregate annually for the entire United States. While data are available on rail tonnage by commodity, truck tonnage, and, therefore, gains or losses in traffic, is imputed by comparing rail tonnage with total industrial production.

The authors rely on time dummy variables to estimate the effects of such factors as a shift to just-in-time production, changing oil prices, and changes in size and weight regulations on market share changes between rail and truck. The single time dummy variables do not allow the researcher to untangle or to measure explicitly the impact of each of these factors individually in the model.

This technique provides a rough, aggregate measure of changes in market share between rail and truck. It deals only with some broad, overall measures and provides little insight into the incremental contribution of specific factors. Furthermore, the broad product categories employed may mask many differences that exist in each of the disaggregated product categories.

#### **Freight-Demand/Mode-Split Estimation Based on Aggregate Commodity Data**

Ann F. Friedlaender and Richard H. Spady, "A Derived Demand Function for Freight Transportation," *Review of Economic and Statistics*, Vol. 16 (1980), pp. 432–441.

This article develops improved estimations of freight demand. One improvement is explicitly treating transportation as an input in the production process and using Shepard's Lemma, deriving transportation demand functions from initial cost equations. The empirical work also takes into account the interdependence of rates and service characteristics. Freight demand equations are estimated using a cross-section of 96 three-digit Standard Transportation Commodity Code industries. This methodology can be used to derive estimates of modal split and effects of policy changes on the demand for rail and truck services.

#### **Aggregate Mode-Shift Models: Explanation of Traffic Shifts Among Modes Due to Productivity Changes**

Martha B. Lawrence and Richard G. Sharp, "Freight Transportation Productivity in the 1980s: A Retrospective," *Journal of the Transportation Research Forum*, Vol. XXXII, No. 1, 1991, pp. 158–171.

Authors assess general issues relating to productivity growth in the transportation sector during the 1980s. Authors

advocate use of the total factor productivity (TFP) techniques in order to improve comprehensiveness and eliminate biases from single factor productivity measures. Authors generally criticize a number of productivity studies because of an undue reliance on financial indicators as a substitute for physical productivity measures and inadequate controls for changes in output mix.

Perhaps the most relevant section for our purposes is one on productivity and traffic shifts between modes. The authors cite data on the continued loss of market share to motor carriers in the 1980s and its effects on overall productivity changes.

The authors also highlight the importance of service advantages of trucks arguing that trucks provide a fundamentally different type of service from rail. Trucks offer service ubiquity, freedom from sunk cost facility commitments, and adaptability to smaller units of shipment. Accordingly, mode choice studies must go beyond the traditional service characteristics of transit time and variation and rates in modeling shipper choice.

#### **Aggregate and Disaggregate Freight Demand Models: Survey of Previous Efforts and Prospect of Combining Approaches**

Clifford Winston, "The Demand for Freight Transportation: Models and Applications," *Transportation Research*, Vol. 17A, No. 6 (1983), pp. 419–427.

This review article classifies freight demand models as being aggregate (where the unit of observation is the aggregate share of a particular mode in a broad product and geographic market) or disaggregate (where the unit of observation is an individual shipper or shipment). While Winston argues that disaggregate models are more attractive from a theoretical viewpoint since they can be derived from cost-minimizing behavior by firms, he also notes that some of the more recent aggregate models have also been derived from firm cost-minimizing behavior and, therefore, have a stronger theoretical basis.

The Oum and Friedlaender and Spady models, estimated from aggregate data, might be more useful in the analysis of freight flows for policy analysis or practical prediction in the context of large, scale regional or national studies.

Two types of disaggregate freight demand models have been developed: behavioral and inventory. The behavioral models take the perspective of the physical distribution manager in making mode choice decisions to maximize utility with respect to expense and service. Typically, a random utility model is used with discrete choice estimation tools. Inventory-based models analyze freight demand from the perspective of an inventory manager in an attempt to integrate the mode choice and production decisions.

The article discusses a number of applications of freight demand models, including intermodal competition, regulatory analysis, and forecasting of freight flows. Most relevant for this project is the latter application. Previous attempts to

forecast freight flows have used techniques such as input-output and regional flow models, but have not combined these techniques with a realistic freight demand model. It is Winston's opinion that the combination of a forecasting system with a realistic freight demand model imbedded into it could contribute significantly to the accuracy of freight flow forecasts.

Thomas L. Zlatoper and Ziona Austrian, "Freight Transportation Demand: A Survey of Recent Econometric Transportation, Vol. 16 (1989), pp. 27-46.

This paper surveys econometric studies of freight transportation demand published between the mid-1970s and the mid-1980s. It describes the variables, data sources, and estimation procedures utilized by the studies. In addition, it summarizes their statistical results. The studies included in this survey typically accounted for freight rates and service characteristics (e.g., transit time and reliability). Data sources often varied across the studies.

Based on the data they utilized, the surveyed studies are classified as either aggregate or disaggregate. The data in the aggregate studies consist of information on total flows by modes at the regional or national level, while the data in the disaggregate studies pertain to individual shipments. The earlier aggregate studies estimated linear logit models. It has been pointed out that when they are estimated on aggregate data, these models are subject to certain shortcomings. To avoid these shortcomings, more recent aggregate studies have estimated flexible forms such as translog functions. The disaggregate studies surveyed in this paper used either logit or probit models.

Statistical results often varied with the commodities analyzed, making it somewhat difficult to generalize the findings of the different studies. One finding common to several studies reviewed is that freight rates have a significant impact on shipment decisions. Certain theoretical and empirical limitations of the surveyed studies are discussed; and suggestions for future research in freight transport demand are offered.

#### *B. Discrete Choice Models: Individual Shipper Selection Models*

#### **Mode-Split/Mode-Choice Models: Discrete Individual Shipper Choice**

F. R. Wilson, B. G. Bisson, and K. B. Kobia, "Factors That Determine Mode Choice in the Transportation of General Freight," *Transportation Research Record 1061*, 1986, pp. 25-31.

This study relies on data collected from a survey of manufacturers regarding their modal selection and shipment characteristics. It uses the survey data in a linear logit model to determine the variables that influence the selection of the

various modes and the relationship between each mode and the explanatory variables. Shippers are asked to state their preferred shipping mode for their main product over their primary origin-destination link.

The modal choice explanatory variables are divided into the following categories: characteristics of the transportation system; characteristics of the shipment; characteristics of the carriers; and characteristics of the shipper. The model has quite a comprehensive set of considerations as explanatory models.

The model has most relevance for predicting how an individual shipper might select a particular model based on shipment characteristics as well as firm characteristics (such as firm size, volume of business). The model would not be appropriate if the researcher were attempting to look at overall shipment levels and model uses. However, the model does suggest that a number of quite detailed individual firm characteristics do influence the selection of mode.

#### **Mode-Split/Mode-Choice Models: Discrete Individual Shipper Choice**

A.S. Narasimha Murthy and B. Ashtakala, "Modal Split Analysis Using Logit Models," *Journal of Transportation Engineering*, Vol. 113, No. 5, September 1987.

Extensive survey of over 7,000 shippers in Alberta, Canada, used to develop a cross-classification table looking at modal split as a function of the following variables: shipment size; full load vs. less-than-full load; private or for-hire transportation; control over mode choice; and type of commodity.

This cross-classification table provides the input for a multi-way contingency analysis (logit analysis) specifying the relationship between each of the variables, by itself and interacting with the other variables, and mode split.

The coefficients developed in the model can be employed to predict modal shares under a variety of scenarios regarding each of the analysis variables. However, it should be noted that the model gives no consideration to modal rate or service comparisons. Thus, the model could not be used to analyze how modal shares would change based on relative rate and service changes in the various modes. This would be a serious drawback for many of the uses of the model contemplated by policy makers.

Saleh Ali and Yorgos J. Stephanedes, "Policy-Sensitive Disaggregate Techniques for Estimating Freight Highway and Rail Use," *Journal of the Transportation Research Forum*, Vol. XXV, No. 1, 1984, pp. 155-164.

The authors develop a mode split model based on data from Midwest grain elevators. One of the main variables included in the model was rate information. Truck rates were considered as a function of distance, while rail rates were

considered as a function of shipment size and distance. The authors also included transit times for rail and truck and service time availability (i.e., the time between the equipment is ordered by the shipper and the time it is received at the grain elevator). Further, the authors include a measure of transit time variability in their model.

Results indicate that the freight rate and service availability time were the most significant determinants of modal decisions.

Vivien P. Jeffs and Peter J. Hills, "Determinants of Modal Choice in Freight Transport: A Case Study," *Transportation*, Vol. 17, 1990, pp. 29–47.

Authors surveyed a number of organizations with regard to the following variables which influence the modal choice at the firm level: customer-requirements; product characteristics; company structure/organization; government interventions; available transport facilities; and perceptions of the decision maker in the firm. The authors argue that it is the interactions and inter-relationships among these variables that influence the modal split. Thus, the relevant focus of modal split analysis should be on the firm and its characteristics.

The authors support their viewpoint with a survey of firms in England in the paper, printing, and publishing sector. They rely on factor analysis to show that many of the individual items discussed above interact to influence mode choice.

The main contribution of the paper is the viewpoint that modal choice is influenced by a large variety of characteristics of the firm, including ones that are individual firm-specific. For example, the urgency of delivery as well as the timing of delivery are factors that could be relevant in developing some inferences on the just-in-time trends that are becoming so important in our economy.

While showing that many of these firm-specific factors are important, this paper provides no explicit framework for entering these considerations into a modal choice model.

However, this methodology (i.e., survey shippers about their modal choices and influencing factors) could be employed to analyze the impact of future policy decisions and freight trends. For example, the impact of restricting truck access during peak hours could be analyzed through such an approach.

J. Pike, *Major Factors Influencing Modal Choice in the UK Freight Market*, Transport Operations Research Group, University of Newcastle upon Tyne, Department of Civil Engineering, December 1982, National Technical Information System.

The basic source of information for this study was information from ten companies who provided detailed data regarding their modal choice decision processes. In their study, the authors have uncovered a variety of modal rate and

service characteristics that affected shipper choice. The authors conclude that the wide range of non-rate factors influencing modal choice decisions suggests that modal split models must be conducted at a disaggregate level.

The authors do not develop their own model, but discuss the importance of modal service characteristics in the decision process of the individual firm.

### **Mode-Choice/Mode-Split Considerations: Need to Include Shipment Size and Inventories in Discrete Shipper Selection Models**

Y.S. Chiang, Paul O. Roberts, Jr. and M. Ben-Akiva, "Short-Run Freight-Demand Model: Joint Choice of Mode and Shipment Size," *Transportation Research Record*, No. 838, 1981, pp. 9–12.

This paper estimates a freight demand model that involves the choice of mode as well as the choice of shipment size. A disaggregated approach is used. The basic data employed in the model comes from the 1972 Commodity Transportation Survey. One innovation of the model is to include from an inventory theory elements of logistics costs, including capital carrying costs in storage and in transit, order costs, loss of value during transit and storage, and direct transportation charges. One result of the model is that shippers put a very high value on improved travel times.

### **Mode-Choice Models: Discrete Individual Choice with Elimination of Choices Based on Attributes**

W. Young, A.J. Richardson, K.W. Ogden, and A.L. Rat-tray, "Road and Rail Freight Mode Choice: Application of an Elimination-by-Aspects Model," *Transportation Research Record*, No. 838, 1981, pp. 38–44.

These authors challenge the notion of most mode choice models that each individual considers all alternatives, and each attribute that describes those alternatives, before making a choice. Rather, the authors argue, shippers may attempt to simplify the choice process by eliminating many alternatives and/or attributes from active consideration. Models that allow for the elimination of attributes, such as the Elimination-by-Aspects approach, are viewed as preferable.

One feature of the model is that it assumes that individuals search modal attributes in a sequential fashion, proceeding from those attributes considered most important through to those that are considered least important. As each attribute is considered, each alternative is compared to that attribute. If the alternative fails this test (i.e., less than minimally acceptable), it is no longer considered. This process continues until only one alternative is left.

The Elimination-by-Aspects model considers nine modal attributes: transit time, reliability, equipment availability,

frequency of service, freight rates, loss and damage, convenience of service times, and communication with the carrier. The model is calibrated for different shipper classes. Depending on the type of shipper, different sets of attributes are shown to have a significant impact on mode choice.

The model's most significant contribution is to show that different factors influence the mode choice of shippers of manufactured and non-manufactured goods. Models assuming that all attributes affect the choice of all shippers are inconsistent with this finding.

#### 4. Network Assignment

##### Network Assignment Models for Freight Planning

Cynthia Barnhart and H. Donald Ratliff, "Modeling Intermodal Routing," *Journal of Business Logistics*, Vol. 14, No. 1 (1993), pp. 205–223.

Consider a set of shipments with known origins and destinations and several potential multimodal routings for each shipment. Assume that the costs for each mode used and for all transfers are known. The authors show that the problem of identifying the least-cost routings for these shipments can be solved by using standard algorithms for finding the shortest path through a graph.

Michael C. Bronzini, *Freight Transportation Energy Use*, prepared by CACI, Inc., for U.S. Department of Transportation, Transportation Systems Center, four volumes, July 1979.

This is one of a series of multimodal network models developed by CACI in the late 1970s. The models consist of node and link representations of rail, highway, waterway, and pipeline systems plus a set of intermodal links. Time and cost functions are associated with each node and each link. Mode and route choice for individual shipments or commodity flows are determined to minimize a commodity-specific function of time and cost. The commodity-specific values of time used in this function were adjusted to calibrate the model to base-year (1972) data. A comparison of the resulting values of time used to initial estimates based on commodity values indicates that significant difficulties were encountered in this calibration process.

Robert C. Bushnell, and Edward S. Pearsall, "Applications of a Freight Network Model to the Analysis of Competitive Situations," *Proceedings, Transportation Research Forum*, Vol. 22, 1981, pp. 379–393.

The Integrated Transportation Network Model contains representations of the highway, rail, and waterway networks, as well as costs and time delays resulting from mode transfers, operations through railroad yards, and transfers between rail carriers. This model was developed in the late 1970s

under contracts with the U.S. Departments of Transportation and Energy and the State of Michigan. However, it was never developed as fully as the CACI model described above. An updated version of the rail component of this model with 1989 routings of doublestack trains and the location of container loading facilities was used as the first stage of a two-stage model of container import and export traffic recently developed by Jack Faucett Associates (*The U.S. Export/Import Containerized Freight Model*, 1990).

Teodor Crainic, "Operations Research Models of Intercity Freight Transportation: The Current State and Future Research Issues," *Logistics and Transportation Review*, Vol 23, No. 2 (1987), pp. 189–206.

The author argues that it is now possible to build comprehensive interactive graphic-planning systems that run on micro-computers and thus put impressively powerful computational and planning means within easy financial reach of practically every size of organization (carrier, shipper, etc.) involved in the transportation system.

The author provides a classification of how network models can be used according to three alternative planning horizons: strategic or long-term planning, which may include decisions such as facility location and physical network design and upgrading; tactical or medium-range planning, which would involve service and routing decisions; and operational or short-term planning, including scheduling and routing of vehicles.

The main focus of this article is on tactical level issues. However, the decisions faced by state transportation departments would most often include the strategic planning variety.

##### Network Assignment Models for Freight Planning: Rail Models

Teodor Crainic, Michael Florian, and Jose-Eugenio Leal, "A Model for the Strategic Planning of National Freight Transportation by Rail," *Transportation Science*, Vol. 24, No. 1, February 1990, pp. 1–24.

This article describes in more detail the rail portion of the multimodal, multiproduct network model done for Brazil. It provides a review of network models for rail transportation, updating earlier reviews by Assad (1980), Crainic (1987), and Freisz (1983).

It provides an illustration of how the model can be used to assess the impact of a new rail construction project on current and projected freight flows in a Brazilian rail corridor.

Jerome M. Lutin and Alain L. Kornhauser, "Development of a Differential Route Share Model for Railroad Freight Traffic," 1980.

This article describes the railroad network model developed by Kornhauser and used over a number of years through ALK & Associates. The model provides a comprehensive



replication of the US railroad network. Traffic data were obtained from the ICC's waybill sample. Regression models were used to predict how traffic would flow across alternative rail routings. The main variables which predict traffic flow are: impedance, which includes track condition, total distance, and originating carrier length of haul; total route length; and junction frequency. This model has been used in a number of policy applications, including traffic diversion effects from railroad mergers.

### **Network Assignment Models: Review and Ability to Incorporate Behavioral Intentions of Individual Shippers**

Terry L. Friesz, Roger Tobin, and Patrick Harker, "Predictive Intercity Freight Network Models: The State of the Art," *Transportation Research*, Series A, Vol. 17A, pp. 409-417 (1983).

This is a review article of network models. Table 1 reviews six major network models (Harvard-Brookings, CACI, Peterson, Lansdowne, Princeton, Penn/ANL) on sixteen criteria (multiple modes; multiple commodities; sequential loading of commodities; simultaneous loading of commodities; congestion; elastic transportation demand; explicit shippers; explicit carriers; sequential shipper and carrier submodels; simultaneous shipper and carrier submodels; sequential macroeconomic and network models; simultaneous macroeconomic and network models; nonmonotonic functions; explicit backhauling; blocking strategy; and fleet constraints). The article includes a section on recent advances and suggestions for future research, including more attention to behavior intentions for shippers and carriers.

### **B.3 THE DIRECT APPROACH: MICRO AND FACILITY RELATED PLANNING**

#### **Use of Input-Output Models to Assess Economic Impact of Investments**

B. Stevens, *Basic Regional Input-Output for Transportation Impact Analysis*, NCHRP Project 8-15A, Regional Science Research Institute, July 1982.

This ambitious project is an effort to provide state highway and transportation planners with hands-on input-output analysis tools. Input-output (IO) models can be used in a number of planning activities. In a structural approach to freight forecasting, such models can be used to determine flows of goods from various origins to destinations. The emphasis in this report is on the use of IO models for analyzing economic impacts of state highway investment and other similar investment. Such investment generates employment from construction activity, and can also result in more travel, new businesses locating in the area and the like. Estimating the cumulative economic impact, including these multiplier effects, is the subject of this report. Although not specifically in the purview of freight demand forecasting, this was an area cited by transportation planners in Iowa as an important tool in analyzing proposed transportation investment, to be used in conjunction with forecasting tools in determining where investment dollars might best be spent.

#### **Use of Simple Time-Series Forecasts to Predict Trends in Freight Flows of Particular Industry Sectors**

V. Eusebio and S. Rindom, *Grain Transportation Service Demand Projections for Kansas: 1995 and Beyond*, Kansas Department of Transportation, July 1990.

This study provides an example of state use of direct forecasting techniques. The first stage of the study projects grain production and livestock and poultry populations for the state. Then time series methods, specifically exponential smoothing and an autoregressive component from the SAS statistical package, are used to produce forecasts. Finally, with production data forecast, transportation is assumed at 95% of production. This study suggests that simple, time series forecasting techniques, now available through standard statistical packages, can be well utilized by state planners without the aid of outside consultants. Also, it points to the state-specific type of data sometimes used in forecasting studies, suggesting limitations to our ability to provide all-encompassing forecasting data.

## APPENDIX C

### FREIGHT ACTIVITY DATA SOURCES

Exhibit C.1 contains a selected list of data sources that contain particularly useful information relating to freight transport activity and demand. The first section of Appendix C discusses these data sources in terms of structure and coverage for specific demand characteristics, and full descriptions of each source are contained in a second section.<sup>1</sup>

Additional information on transportation data sources is available in the **Directory of Transportation Data Sources**, available on paper, diskette, or CD-ROM from the Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation. The 1995 edition of this publication describes approximately 300 transportation and economic data sources produced by Federal agencies, and more than 100 additional data sources produced by private organizations in this country and by the United Nations and the Canadian and Mexican governments. Other BTS products include a CD-ROM compilation of databases of transportation facilities for use with GIS software (**National Transportation Atlas Databases**). Additional information about BTS products and other data sources is available from the BTS home page (<http://www.bts.gov>).

#### C.1 STRUCTURE AND COVERAGE OF THE DATA SOURCES

Each of the data sources in Exhibit C.1 is described below in terms of:

- source and availability;
- scope of coverage (mode);
- data structures and orientation;
- data collection method and source;
- coverage of specific freight demand characteristics; and
- limitations in coverage and use.

#### Scope and Structure

Scope of coverage can be defined relative to mode, subsystem, market, or type of activity measured. Databases typ-

ically cover one mode or several substitutable modes, and they may focus on a particular transportation subsystem (e.g., Great Lakes), type of operations (e.g., containerized vessel statistics), market (e.g., international trade) or commodity group. Exhibit C.2 describes the scope of coverage of sources identified. Exhibit C.3 further categorizes the sources in terms of their modal coverage, basic structure and level of detail.

The multi-modal sources include the Commodity Flow Survey and TRANSEARCH, both of which provide information on modal share on an origin/destination basis. The Census foreign trade statistics distinguish vessel and air movements from total shipments, and will provide rail/truck breakdowns for border traffic in future years. Multi-modal sources also include those which identify, without characterizing, modal use (e.g., Directory of Importers/Exporters) or profile individual modes in standardized formats without considering modal split (e.g., National Transportation Statistics).

In Exhibit C.2, several types of database are distinguished:

- Shipment-based
  - true origin-destination flows
  - modal origin-destination flows;
- Transport-based
  - modal origin-destination flows
  - point activity at transportation nodes
  - subsystem profile
  - carrier profile
  - modal profile; and
- Other
  - point activity at origin or destination
  - commodity or market profile.

The shipment-based category consists of databases that contain separate records for individual shipments (on either a comprehensive or sample basis). The two subcategories of this category distinguish between general databases that cover movements between production and consumption locations (“true origin-destination flows”) and modal databases that cover only (or primarily) that portion of each movement made on a specific mode. Some of the databases in this second category (e.g., PIERS) contain some information on actual origins or destinations.

<sup>1</sup> A further evaluation of some of these data sources is being conducted as part of a recently initiated NCHRP study, *Multimodal Transportation Planning Data* (Project 8-32(5)), being performed by Jack Faucett Associates.

## Exhibit C.1. Selected data sources.

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1993 Commodity Flow Survey (CFS)  
 Transearch  
 Freight Transportation and Logistics Service  
 U.S. Imports/Exports of Merchandise on CD-ROM  
 U.S. Exports of Domestic and Foreign Merchandise by State/Region/Port  
 (State of Export Tapes)  
 U.S. Exports by State of Origin of Movement (MISER State of Export)  
 U.S. Exports and Imports Transshipped via Canadian Ports Annual  
 Report  
 The Directory of U.S. Importers/Exporters  
 Surface Transborder Trade-Flow Data  
 National Transportation Statistics, Annual Report  
 U.S. Air Freight Origin Traffic Statistics (Colography)  
 U.S. Air Carrier Traffic and Capacity Data by Nonstop Segment and On-  
 Flight Market (Form 41 Schedule T-100)  
 Airport Activity Statistics of Certificated Route Air Carriers  
 Worldwide (North American) Airport Traffic Report  
 ICC Carload Waybill Sample  
 Freight Commodity Statistics  
 North American Trucking Survey (NATS)  
 LTL Commodity and Market Flow Database  
 Truck Inventory and Use Survey (TIUS)  
 Nationwide Truck Activity and Commodity Survey (NTACS)  
 State Estimates of Truck Traffic  
 Port Import/Export Reporting Service (PIERS)  
 U.S. Waterborne General Imports (Exports) and Inbound (Outbound)  
 Intransit Shipments  
 Waterborne Commerce and Vessel Statistics  
 Ship Movements Database  
 World Sea Trade Service  
 Lock Performance Monitoring System (PMS)  
 St. Lawrence Seaway Traffic Reports  
 Annual Report Lake Carriers' Association  
 Exports from Manufacturing Establishments  
 Fresh Fruit and Vegetable Shipments by Commodities, States, and Months  
 Fresh Fruit and Vegetable Arrival Totals for 23 Cities  
 Quarterly Coal Report  
 Natural Gas Monthly  
 Natural Gas Annual  
 Petroleum Supply Monthly  
 Grain Transportation

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Although the "true O/D" subcategory sounds like it is more specific than the "modal O/D" subcategory, for many databases, true origins and destinations are specified only at a fairly aggregate level of detail and usually the modal specification covers only the principal mode (or, for import/export data, the mode used for entering or leaving this country).

The transport-based category includes databases measuring transportation flows for modal system or subsystems. Some of these databases provide aggregate data on transportation flows. Others provide point activity at ports, locks, terminals or border crossings without further information about movements. Measurements of freight demand within this category generally include distributions and cross-tabulations over key factors relevant to the operations of a particular transport system. For example, port statistics might include breakdowns by commodity, vessel type, origin, and destination, but exclude detail on inland mode or shipment size distributions. Data on subsystem activity such as inland waterways or highway segments are similarly structured.

Profiles of carrier operations such as those provided by the Truck Inventory and Use Survey (TIUS) and the National

Truck Activity and Commodity Survey (NTACS) can describe demand patterns or trends through association with traffic activity for particular regions of operations, equipment types or commodities. More generalized profiles of modal activity (i.e., without carrier or network orientation) provide similar information at a regional or national level.

The "other" category consists of two subcategories. The larger of these contains databases showing point activity at an origin and/or destination but without any linkages and, except for the Colography Group's air freight statistics, without any modal detail. The last subcategory consists of a single database, the Grain Transportation Report, which is essentially a profile of rail and water transport of grain.

Other key factors in the definition of freight demand databases include the level of detail, and whether or not both domestic and international shipments are covered and whether they are distinguishable.

### Coverage of Commodity Characteristics

The relevance of commodity detail in freight demand analysis was detailed previously and the coverage of relevant characteristics is summarized in Exhibit C.4.

The extent and method of commodity detail in individual data sources reflects the data source and its intended orientation. Trade flow databases use product-based classification systems such as the Harmonized Schedule (HS) of Foreign Trade and the Standard International Trade Classification (SITC), while transport-oriented sources use classifications such as the Standard Transportation Commodity Codes (STCC) or specialized categories of products. Commodity-specific sources may use descriptive categories unique to a particular industry and without a formal coding system, while modal point-specific sources may classify freight solely based on handling characteristics (e.g., bulk, container, or breakbulk) or general service categories (e.g., air freight, express and mail).

The influence of data users is also indicated for certain sources. The importance of monitoring hazardous material activity has resulted in special designations in some sources (e.g., the ICC waybill statistics). The increased importance of trade activity to the U.S. economy resulted in the creation of specialized end-user codings for foreign trade, and an expansion in the concordance of trade schedules between countries.

### Coverage of Origin/Destination Characteristics

Origin and destination detail is either explicitly represented in the shipment-based sources, or it can sometimes be inferred from the routing patterns of transport-based sources (see Exhibit C.5). Origin and destination can be directly linked (e.g., PIERS), represented separately (Fresh Fruit and Vegetable Shipments) or represented for just one point (e.g., Colography Group origin areas).

<b>Data Base</b>	<b>Scope of Coverage</b>
<b>1993 Commodity Flow Survey (CFS)</b>	Originating shipments for all U.S. manufacturing, mining, wholesale and selected retail and service establishments
<b>TRANSEARCH (Reeble)</b>	Traffic between 183 BEAs compiled from several sources
<b>Freight Transportation and Logistics Service (DRI/MH)</b>	Regional commodity traffic by barge, rail and truck compiled from several sources
<b>U.S. Imports/Exports of Merchandise on CD-ROM</b>	Quantity and value of merchandise shipped between U.S. and foreign countries; weight for air and vessel
<b>U.S. Exports by State of Origin (Census)</b>	Value of U.S. exports for all modes; weight for air and vessel
<b>U.S. Exports by State of Origin (MISER)</b>	Value of U.S. exports for all modes; weight for air and vessel
<b>U.S. Exports and Imports Transshipped via Canadian Ports</b>	Value and weight of U.S. imports and exports to foreign countries via Canadian ports
<b>The Directory of U.S. Importers/Exporters</b>	Listing of U.S. companies engaged in international trade; total traffic shown when available
<b>National Transportation Statistics, Annual Report</b>	Activity and industry statistics by mode
<b>U.S. Air Freight Origin Traffic Statistics (Colography)</b>	Weight, value and number of air cargo shipments for selected top U.S. producing industries
<b>U.S. Air Carrier Traffic and Capacity (T-100) Data</b>	Airport-to-airport domestic air freight tonnage for reporting U.S. carriers
<b>FAA Airport Activity Statistics (T-3)</b>	Airport air freight enplaned weight for reporting U.S. carriers
<b>Worldwide (North American) Airport Traffic Report (ACI)</b>	Air freight weight for ACI-member airports
<b>ICC Carload Waybill Sample *</b>	Sample of all rail waybills for movements terminating on U.S. railroads meeting reporting standard
<b>Freight Commodity Statistics (AAR)</b>	All commodity traffic for U.S. Class I railroads
<b>North American Trucking Survey (NATS)</b>	Truck stop sample of truck weights; predominantly long-haul truckload carriers
<b>LTL Commodity and Market Flow Database</b>	Weight, number of shipments, and number of pieces by traffic lane for participating carriers
<b>Truck Inventory and Use Survey (TIUS)</b>	Sample of trucks (including pickups and vans) registered in each state
<b>Nationwide Truck Activity and Commodity Survey (NTACS)</b>	Sample of daily/weekly activity for trucks (including pickups and vans) registered in each state
<b>Port Import/Export Reporting Service (PIERS)</b>	International waterborne shipments entering or exiting U.S. ports (excluding some small-volume ports)
<b>U.S. Waterborne General and Intransit Shipments</b>	Value and weight of waterborne trade between U.S. and foreign ports; low value shipments are estimated
<b>Waterborne Commerce and Vessel Statistics (ACOE) *</b>	Weight and vessel trips for all domestic and waterborne movements on U.S. waterways or via U.S. ports
<b>Ship Movements Database (Lloyd's)</b>	Vessel movements on international trade routes as reported at principal world ports
<b>World Sea Trade Service (DRI/MH)</b>	Weight and containerloads for ocean traffic on over 700 major world trade routes
<b>Lock Performance Monitoring System (PMS) *</b>	Activity at locks owned or operated by the U.S. Army Corps of Engineers
<b>St. Lawrence Seaway Traffic Reports</b>	Weight and number of vessel transits on the St. Lawrence Seaway
<b>Lake Carriers' Association Annual Report</b>	Weight and number of vessels on the Great Lakes reported by LCA members
<b>Exports from Manufacturing Establishments</b>	Export value and related employment for all U.S. manufacturing establishments
<b>Fresh Fruit and Vegetable Shipments</b>	Fresh fruit and vegetable weight by month collected from various sources
<b>Fresh Fruit and Vegetable Arrival Totals for 23 Cities</b>	Fresh fruit and vegetable weight for 23 U.S. and 4 Canadian cities estimated from various sources
<b>Quarterly Coal Report</b>	Weight of coal shipped by all U.S. companies which own, purchase, or distribute 50,000 tons per year
<b>Natural Gas Monthly</b>	Shipment activity for all generating electric utilities and a sample of companies delivering natural gas to consumers
<b>Natural Gas Annual</b>	Activity for all companies that deliver to consumers, handle interstate movements, or are licensed to import/export
<b>Petroleum Supply Monthly</b>	Shipment activity by survey of U.S. refiners, blenders, plant operators, transporters, and importers
<b>Grain Transportation Report</b>	Grain traffic and carloads compiled from various sources

\* Public Use Data Only

Exhibit C.3. Mode, type, and structure of freight databases.

Data Base	Mode	Data Base Type	Level of Detail	Domestic/ International
1993 Commodity Flow Survey (CFS)	M	Shipment - True O/D	NTAR-NTAR Combinations	Not Identified
TRANSEARCH (Reeble)	M	Shipment - True O/D	BEA-BEA Combinations	Not Identified
Freight Transportation and Logistics Service (DRI/MH)	M	Transport - Modal Profile	National/Regional Aggregates	Not Identified
U.S. Imports/Exports of Merchandise on CD-ROM	M	Shipment - Modal O/D	Country-U.S. Customs District Combinations	International
U.S. Exports by State of Origin (Census)	M	Shipment - True O/D	State-Country Combinations	International
U.S. Exports by State of Origin (MISER)	M	Shipment - True O/D	State-Country Combinations	International
U.S. Exports and Imports Transshipped via Canadian Ports	M	Shipment - Modal O/D	Country-U.S. Customs District Combinations	International
The Directory of U.S. Importers/Exporters	M	Other - Origin Activity	Company	International
National Transportation Statistics, Annual Report	M	Transport - Modal Profile	National Aggregates	Not Identified
U.S. Air Freight Origin Traffic Statistics (Colography)	A	Other - Origin Activity	U.S. County	Domestic & Intl.
U.S. Air Carrier Traffic and Capacity (T-100) Data	A	Transport - O/D	Airport-Airport Combinations	Not Identified
FAA Airport Activity Statistics (T-3)	A	Transport - Point Activity	Airport	Not Identified
Worldwide (North American) Airport Traffic Report (ACI)	A	Transport - Point Activity	Airport	Domestic & Intl.
ICC Carload Waybill Sample *	R	Shipment - Modal O/D	BEA-BEA Combinations	Domestic & Intl.
Freight Commodity Statistics (AAR)	R	Transport - Modal Profile	Regional Aggregates	Not Identified
North American Trucking Survey (NATS)	T	Shipment - Modal True O/D	City-City Combinations	Not Identified
LTL Commodity and Market Flow Database	T	Shipment - Modal True O/D	ZIP3-ZIP3 Combinations	Domestic & Intl.
Truck Inventory and Use Survey (TIUS)	T	Transport - Carrier Profile	Vehicle	Not Identified
Nationwide Truck Activity and Commodity Survey (NTACS)	T	Transport - Carrier Profile	Vehicle	Not Identified
Port Import/Export Reporting Service (PIERS)	W	Shipment - Modal O/D	Port-Port (Some Shipper/Consignee Locations)	International
U.S. Waterborne General and Intransit Shipments	W	Transport - O/D	Port-Port Combinations	International
Waterborne Commerce and Vessel Statistics (ACOE) *	W	Transport - Point/Sub-system Activity	Port/Waterway Segment	Domestic & Intl.
Ship Movements Database (Lloyd's)	W	Transport - O/D	Vessel Trip (Port-Port)	International
World Sea Trade Service (DRI/MH)	W	Transport - O/D	Coastal Range-Coastal Range Combinations	International
Lock Performance Monitoring System (PMS) *	W	Transport - Point Activity	Waterway Lock	Not Identified
St. Lawrence Seaway Traffic Reports	W	Transport - Sub-system Activity	Waterway Segment	Domestic & Intl.
Lake Carriers' Association Annual Report	W	Transport - Point Activity	Origin Port or Lake	Not Identified
Exports from Manufacturing Establishments	N	Other - Origin Activity	State	International
Fresh Fruit and Vegetable Shipments	MC	Other - Origin Activity	State/Country	Domestic & Intl.
Fresh Fruit and Vegetable Arrival Totals for 23 Cities	MC	Transport - O/D	State-City Combinations	Domestic & Intl.
Quarterly Coal Report	MC	Other - O/D Activity	State/Country Combinations	Domestic & Intl.
Natural Gas Monthly	MC	Other - O/D Activity	State/Country Combinations	Domestic & Intl.
Natural Gas Annual	MC	Other - O/D Activity	State/Country Combinations	Domestic & Intl.
Petroleum Supply Monthly	MC	Transport - O/D	Region-Region (State) Combinations	Not Identified
Grain Transportation Report	MC	Other - Commodity Profile	Coastal Range/Lock	Not Identified or Intl.

\* Public Use Data Only

Mode: M=Multimodal, A=Air, R=Rail, T=Truck, W=Water, MC= Multimodal, Commodity-Specific

Exhibit C.4. Commodity information in freight databases.

Data Base	Commodity Classification (Level of Detail)				Comments
	Product	Producer	Transport	Other	
1993 Commodity Flow Survey (CFS)			STCC (5)	Hazmat	STCC (5) for National, STCC(3) for NTAR-NTAR
Transearch (Reebie)			STCC (4/5)		Detail dependent on mode
Freight Transportation and Logistics Service (DRI/MH)			STCC		
U.S. Imports/Exports of Merchandise on CD-ROM	HS (10), SITC (5)	SIC (4)		End User (4)	
U.S. Exports by State of Origin (Census)	SITC (4)	SIC (2)			
U.S. Exports by State of Origin (MISER)		SIC (2)			
U.S. Exports and Imports Transshipped via Canadian Ports	HS (4)				
The Directory of U.S. Importers/Exporters	HS (10), Desc.				
National Transportation Statistics, Annual Report					
U.S. Air Freight Origin Traffic Statistics (Colography)		SIC (4)		Size	Shipment-size categories possible (e.g., Express, Heavy)
U.S. Air Carrier Traffic and Capacity (T-100) Data				Size/Priority	Size/Priority: Express, Freight, Mail (Priority/Non-Priority)
FAA Airport Activity Statistics (T-3)				Size/Priority	Size/Priority: Express, Freight, Mail (Priority/Non-Priority)
Worldwide (North American) Airport Traffic Report (ACI)				Size Group	Size: Freight, Mail
ICC Carload Waybill Sample *			STCC (5)	Hazmat	
Freight Commodity Statistics (AAR)			STCC (5)		
North American Trucking Survey (NATS)			STCC (3)		
LTL Commodity and Market Flow Database				Service	Service: Standard/Non-Standard, Special Equipment
Truck Inventory and Use Survey (TIUS)			TIUS	Hazmat	Survey Classifications
Nationwide Truck Activity and Commodity Survey (NTACS)			TIUS	Hazmat	Survey Classifications
Port Import/Export Reporting Service (PIERS)	HS (10), PIERS				PIERS groups; Full manifest description also available
U.S. Waterborne General and Intransit Shipments	HS (6), SITC				
Waterborne Commerce and Vessel Statistics (ACOE) *			CCDWC		
Ship Movements Database (Lloyd's)					
World Sea Trade Service (DRI/MH)	SITC Groups				Specialized SITC groupings
Lock Performance Monitoring System (PMS) *			PMS (2)		Corps-developed groups
St. Lawrence Seaway Traffic Reports	Special Groups			Toll-Based	
Lake Carriers' Association Annual Report	Special Groups				Bulk Groups, Petroleum, Grains
Exports from Manufacturing Establishments		SIC (3)			
Fresh Fruit and Vegetable Shipments	Desc.				Some grouping for low volume or mixed commodities
Fresh Fruit and Vegetable Arrival Totals for 23 Cities	Desc.				Some grouping for low volume or mixed commodities
Quarterly Coal Report	Desc.				Some commodity breakdown for physical characteristics
Natural Gas Monthly	Desc.				
Natural Gas Annual	Desc.				
Petroleum Supply Monthly	Desc.				
Grain Transportation Report	Special Groups				Total grains; wheat, corn and soybeans

\* Public Use Data Only

HS= Harmonized Schedule, SITC= Standard International Trade Classification, SIC=Standard Industrial Classification, STCC=Standard Transportation Commodity Code,

CCDWC=Commodity Classification for Domestic Waterborne Commerce, Desc.= Product Descriptions (with no coding system)

Exhibit C.5. Origin/destination information in freight databases.

Data Base	Origin/Destination Detail	Comments
1993 Commodity Flow Survey (CFS)	State-State, NTAR-NTAR	Anticipated structure
TRANSEARCH (Reeble)	BEA-BEA	Also Canadian province detail
Freight Transportation and Logistics Service (DR/MH)	Region-Region	For rail traffic only
U.S. Imports/Exports of Merchandise on CD-ROM	U.S.-Country	U.S. trade only
U.S. Exports by State of Origin (Census)	State/Region-Country	U.S. detail differs for 3 data extracts
U.S. Exports by State of Origin (MISER)	State-Country	
U.S. Exports and Imports Transshipped via Canadian Ports	U.S.-Country	Transshipments identified based on non-Canada shipments via Canada border
The Directory of U.S. Importers/Exporters	Address/City	May not assign activity correctly for multi-location companies
National Transportation Statistics, Annual Report		
U.S. Air Freight Origin Traffic Statistics (Colography)	County of Origin	Colography also defines market areas relative to airports
U.S. Air Carrier Traffic and Capacity (T-100) Data		May be inferred from airport O/D
FAA Airport Activity Statistics (T-3)		May be inferred from airport origin
Worldwide (North American) Airport Traffic Report (ACI)		May be inferred from airport origin
ICC Carload Waybill Sample *	BEA-BEA	International shipments are identified
Freight Commodity Statistics (AAR)	2 U.S. Regions	Regions based on railroad headquarters, not operations.
North American Trucking Survey (NATS)	City-City	
LTL Commodity and Market Flow Database	ZIP3-ZIP3/Foreign Area	
Truck Inventory and Use Survey (TIUS)		May be inferred from registration state or states of operations
Nationwide Truck Activity and Commodity Survey (NTACS)	None on Public Use Tape	May be inferred from registration state or states of operations
Port Import/Export Reporting Service (PIERS)	U.S. City-Foreign City/Country; Shipper	Foreign city and shipper only available for exports
U.S. Waterborne General and Intransit Shipments	U.S.-Country	May be inferred from port routing
Waterborne Commerce and Vessel Statistics (ACOE) *		May be inferred from port/waterway routing
Ship Movements Database (Lloyd's)		May be inferred from port routing
World Sea Trade Service (DR/MH)	U.S.-Country	May be inferred from coastal routing
Lock Performance Monitoring System (PMS) *		May be inferred from lock pool O/D based on lock-to-lock comparisons
St. Lawrence Seaway Traffic Reports	U.S., Canada, Foreign	Inferred from port of lading location
Lake Carriers' Association Annual Report		May be inferred from port of lading location
Exports from Manufacturing Establishments	State of production	
Fresh Fruit and Vegetable Shipments	State of origin; U.S./foreign destination	May only capture modal routing
Fresh Fruit and Vegetable Arrival Totals for 23 Cities	State/country of origin; city destination	23 U.S./4 Canadian cities; may only capture modal routing
Quarterly Coal Report	State/country of origin/destination	Flows by O/D pairs not available.
Natural Gas Monthly	State/Country-U.S./Country	Destination use sector (e.g., utilities) also identified
Natural Gas Annual	State/Country of production/consumption	
Petroleum Supply Monthly	Country for foreign	May be inferred from routing
Grain Transportation Report		

\* Public Use Data Only

NTAR=National Transportation Analysis Region, BEA=Bureau of Economic Analysis Region, ZIP3=3-digit U.S. zip code

Detailed locations are generally aggregated into groupings (e.g., BEA, NTAR or ZIP3), although PIERS includes actual shipper and consignee names and locations. Other O/D definitions follow political (e.g., state or county) or international boundaries.

Besides the lack of coverage and the limitations of non-shipment-based data, additional problems shown in the O/D characteristics include:

- Traffic may be assigned based on billing/documentation locations or the location where the survey information is provided, rather than the actual point of production or consumption;
- Multi-location traffic by one shipper may be assigned to a single location;
- O/D definitions may not be directly correlated with other data sources (e.g., BEA definitions vs. state-based statistics); and
- Data aggregations for confidentiality purposes may prove ambiguous relative to the transport network (e.g., Regional state of export data).

### **Coverage of Shipment Characteristics**

The representation of shipment activity in the databases is based on descriptions of shipment volume, seasonality and other factors (see Exhibit C.6).

The most common volume measure is weight, which is utilized in most of the data sources. Total shipment value is available for the trade-related sources, and is primarily measured at the U.S. point of import or export. The Colography Group's air freight statistics are the only current domestic source measuring value; although the Commodity Flow Survey (CFS) will include total value.

Some of the commodity-based sources use specialized volumetric units such as bushels of grain, barrels of petroleum, and cubic feet of natural gas. The ICC Waybill Sample identifies number of carloads for each shipment. The Colography and LTL truck statistics measure the number of shipments, which is also implicitly available for shipment-based databases such as PIERS and the CFS. The number of generic "pieces" is defined for the LTL truck source, while number of units for specified package types are shown in PIERS. For intermodal movements, several sources identify numbers of containers or trailers (as shown in Exhibit C.7, below).

The Census foreign trade statistics includes a unit of quantity at the most detailed commodity-level based on definitions in the Harmonized Schedule (HS). These units can represent weight, dimensional measures (metric board feet), or physical units (pairs of shoes), and generally cannot be aggregated to higher commodity levels without conversion to common units. Each HS commodity can have up to two quantity definitions, although some commodities (typically high value consumer goods) have no unit specified.

A major problem with the foreign trade statistics for Canada and Mexico has been the lack of weight detail for modes other than vessel and air. Statistics for rail and truck since April 1993 are contained in the Surface Transborder Trade-Flow Data, but shipment weight is provided only for U.S. imports from Canada.

Another key shipment characteristic is the measure of traffic by time period for use in identifying seasonal or other peaking patterns. Some of the shipment-based sources such as PIERS and the ICC waybill statistics provide actual dates of shipment, although both provide transport dates as opposed to true shipment or delivery dates. The detailed PMS lock records, which are only available for internal Corps studies, include date and time of transit which are also valuable in measuring peaking activity.

Seasonal detail for other sources may be obtainable from the release frequency of the data. For instance, Census publishes monthly foreign trade statistics which can be used to develop general seasonal patterns, while other foreign trade data are released in quarterly form based on confidentiality requirements and economic considerations. Some sources related to highly seasonal flows (e.g., published PMS reports and fruit and vegetable statistics) explicitly present peaking patterns in reports. Several annual sources include no seasonal detail.

### **Coverage of Transport Characteristics**

The representation of transport characteristics can be categorized by the following factors (shown in Exhibits C.7 through C.9):

- modal coverage;
- equipment detail;
- measures of transport system utilization;
- routing detail;
- carrier/service detail; and
- cost/rate information.

Modal coverage techniques include:

- single mode orientation;
- profiles of individual modes (e.g., National Transportation Statistics);
- modal distributions for origin/destination flows (CFS and TRANSEARCH); and
- appropriate modal coverage for commodity flows (e.g., fruit and vegetable data).

Equipment type information includes identification of intermodal activity or the allocation of traffic to equipment categories which are mode-specific. Container weight is typically distinguished for deep water vessel activity (e.g., Census statistics, PIERS, and the World Trade Sea Service) in order to associate traffic with both service patterns and



Exhibit C.6. Shipment information in freight databases.

Data Base	Volume Detail			Seasonal Detail	Comments
	Weight	Value	Other		
1993 Commodity Flow Survey (CFS)	X	X			
TRANSEARCH (Reeble)	X				
Freight Transportation and Logistics Service (DRU/MH)	X				
U.S. Imports/Exports of Merchandise on CD-ROM	X	X	Unit Quantity	Month	Weight and value for water/air; value for all modes combined
U.S. Exports by State of Origin (Census)	X	X		Quarter	Weight and value for water/air; value for all modes combined
U.S. Exports by State of Origin (MISER)	X	X		Quarter	Weight and value for water/air; value for all modes combined
U.S. Exports and Imports Transshipped via Canadian Ports	X	X			
The Directory of U.S. Importers/Exporters	X	X			Shown for total trade when available
National Transportation Statistics, Annual Report	X				
U.S. Air Freight Origin Traffic Statistics (Colography)	X	X	No. of Shipments		Weight/Number by Shipment Size Categories
U.S. Air Carrier Traffic and Capacity (T-100) Data	X			Month	By cargo type
FAA Airport Activity Statistics (T-3)	X			Month	By cargo type
Worldwide (North American) Airport Traffic Report (ACI)	X				By cargo type
ICC Carload Waybill Sample *	X		Carloads	Day	Rail origination date
Freight Commodity Statistics (AAR)	X			Quarter	
North American Trucking Survey (NATS)	X				
LTL Commodity and Market Flow Database	X		No. of shipments & pieces	Month	
Truck Inventory and Use Survey (TIUS)					
Nationwide Truck Activity and Commodity Survey (NTACS)					Not available for Public Use Tape
Port Import/Export Reporting Service (PIERS)	X	X	No. of packages by type	Day	Vessel arrival date, number of containers also available
U.S. Waterborne General and Intransit Shipments	X	X		Month	
Waterborne Commerce and Vessel Statistics (ACOE) *	X				
Ship Movements Database (Lloyd's)				Day	Weight may be inferred from vessel capacity & assumed load factor
World Sea Trade Service (DRU/MH)	X				Number of containers also available
Lock Performance Monitoring System (PMS) *	X			Month	No. of barges also available; some weekly data is published.
St. Lawrence Seaway Traffic Reports	X				
Lake Carriers' Association Annual Report	X				
Exports from Manufacturing Establishments		X			Total and export shipment by type (direct, support)
Fresh Fruit and Vegetable Shipments	X			Month	
Fresh Fruit and Vegetable Arrival Totals for 23 Cities	X			Month	
Quarterly Coal Report	X			Quarter	
Natural Gas Monthly			Volume (cubic feet)	Month	Price data available
Natural Gas Annual			Volume (cubic feet)		Price data available
Petroleum Supply Monthly			Volume (barrels)	Month	
Grain Transportation Report	X		Volume (bushels)	Week	Number of carloads, price data available

\* Public Use Data Only

Exhibit C.7. Information on modal coverage and equipment in freight databases.

Data Base	Modal Coverage						Equipment			
	A	T	R	I	W	O	All	Other	Intermodal	Other
1993 Commodity Flow Survey (CFS)	X	X	X	X	X			Pipeline, parcel	Container Weight	
TRANSEARCH (Reebie)	X	X	X	X	X				No. of Containers	No. of Units by Mode
Freight Transportation and Logistics Service (DRI/MH)		X	X	X						Unit traffic/fleet size by mode
U.S. Imports/Exports of Merchandise on CD-ROM	X				X	X			Container weight (vessel)	
U.S. Exports by State of Origin (Census)	X				X	X			Container weight (vessel)	
U.S. Exports by State of Origin (MISER)	X				X	X			Container weight (vessel)	
U.S. Exports and Imports Transshipped via Canadian Ports								Surface total		
The Directory of U.S. Importers/Exporters								List of modes		
National Transportation Statistics, Annual Report	X	X	X	X	X			Pipeline, parcel		Vehicle inventory
U.S. Air Freight Origin Traffic Statistics (Colography)	X									
U.S. Air Carrier Traffic and Capacity (T-100) Data	X									Aircraft departures by equipment type
FAA Airport Activity Statistics (T-3)	X									Aircraft departures by equipment type
Worldwide (North American) Airport Traffic Report (ACI)	X									Aircraft operations by type
ICC Carload Waybill Sample *			X						No. of trailers/containers	Car type
Freight Commodity Statistics (AAR)			X							
North American Trucking Survey (NATS)		X								Trailer type
LTL Commodity and Market Flow Database		X							Identified	Special equipment use identified
Truck Inventory and Use Survey (TIUS)		X								Vehicle type/configuration
Nationwide Truck Activity and Commodity Survey (NTACS)		X								Vehicle type/configuration
Port Import/Export Reporting Service (PIERS)					X				Container no., size and volume	Vessel name
U.S. Waterborne General and Intransit Shipments					X					Tanker identified
Waterborne Commerce and Vessel Statistics (ACOE) *					X					
Ship Movements Database (Lloyd's)					X					Vessel name
World Sea Trade Service (DRI/MH)					X				Containerloads	Vessel type/size categories
Lock Performance Monitoring System (PMS) *				X						Tow, barge type and size
St. Lawrence Seaway Traffic Reports				X					Container weight	Vessel type, class and size category
Lake Carriers' Association Annual Report				X						
Exports from Manufacturing Establishments						X				
Fresh Fruit and Vegetable Shipments	X	X	X		X	X			Piggyback identified	
Fresh Fruit and Vegetable Arrival Totals for 23 Cities	X	X	X		X					
Quarterly Coal Report		X	X	X	X	X		Slurry		
Natural Gas Monthly					X			Pipeline		
Natural Gas Annual					X			Pipeline		
Petroleum Supply Monthly				X	X			Pipeline		
Grain Transportation Report			X	X	X					Rail carloadings, barge, export ship calls

\* Public Use Data Only

A=Air, T=Truck, R=Rail, IW=Inland Waterway/Coastal, OW=Other Water, All=Combined All Modes

Exhibit C.8. Information on system use in freight databases.

Data Base	System Utilization	
	Point	Sub-system
1993 Commodity Flow Survey (CFS)	Port of exit: wgt.	O/D Corridor: Ton-miles, wgt.
TRANSEARCH (Reeble)		O/D Corridor: wgt.
Freight Transportation and Logistics Service (DRI/MH)		
U.S. Imports/Exports of Merchandise on CD-ROM	Customs District: wgt., val., qty.	Modal Route: tons, value, qty.
U.S. Exports by State of Origin (Census)	Customs District/Port: wgt., val.	O/D-Port: wgt., val.
U.S. Exports by State of Origin (MISER)		O/D: wgt., val.
U.S. Exports and Imports Transshipped via Canadian Ports	Customs District/Port: wgt., val.	
The Directory of U.S. Importers/Exporters		
National Transportation Statistics, Annual Report		Modal total: Vehicle-, ton-miles
U.S. Air Freight Origin Traffic Statistics (Colography)		
U.S. Air Carrier Traffic and Capacity (T-100) Data	Airport: wgt.	Modal Route: wgt., ton-miles
FAA Airport Activity Statistics (T-3)	Airport of enplanement/departure	
Worldwide (North American) Airport Traffic Report (ACI)	Airport of enplanement/departure	
ICC Carload Waybill Sample *		Modal Route: wgt., ton-miles, carloads
Freight Commodity Statistics (AAR)		Modal Total: wgt., carloads
North American Trucking Survey (NATS)	City: O/D wgt.	
LTL Commodity and Market Flow Database	City: O/D wgt., # of shpmts./pieces	Modal Route: wgt., ton-miles, shpmts./pieces
Truck Inventory and Use Survey (TIUS)		Modal Total: vehicle miles
Nationwide Truck Activity and Commodity Survey (NTACS)		Modal Total: vehicle miles, operating weeks
Port Import/Export Reporting Service (PIERS)	City, Country, Port: wgt., val., packages	Modal Route: wgt., val.,
U.S. Waterborne General and Intransit Shipments	Port: wgt., val.	Modal Route: wgt., val.,
Waterborne Commerce and Vessel Statistics (ACOE) *	Port: wgt., ton-miles	Waterway: wgt., ton-miles
Ship Movements Database (Lloyd's)	Port: vessel calls, capacity	Modal Route: capacity
World Sea Trade Service (DRI/MH)	Coastal: wgt., containerloads	Modal Route: wgt., containerloads
Lock Performance Monitoring System (PMS) *	Lock: wgt., barges, tows	
St. Lawrence Seaway Traffic Reports		Waterway: wgt., vessel GRT, transits
Lake Carriers' Association Annual Report	Port: wgt., vessel calls, shipments	Modal Route: wgt., vessel calls, shipments
Exports from Manufacturing Establishments		
Fresh Fruit and Vegetable Shipments		Modal Route: wgt.
Fresh Fruit and Vegetable Arrival Totals for 23 Cities		Modal Route: wgt.
Quarterly Coal Report	Customs District/Port: wgt., val.	
Natural Gas Monthly		Pipeline: volume
Natural Gas Annual		
Petroleum Supply Monthly		Modal Route: volume
Grain Transportation Report		Coast, Lock: wgt., units

\* Public Use Data Only

## Exhibit C.9. Information on routing, carrier, and cost in freight databases.

Data Base	Routing		Carrier/ Service	Cost/ Rate
	Definition	Distance		
1993 Commodity Flow Survey (CFS)	Port of exit for exports	Estimated from O/D & Mode		
TRANSEARCH (Reeble)				
Freight Transportation and Logistics Service (DR/MH)				Modal profiles
U.S. Imports/Exports of Merchandise on CD-ROM	Customs District			Import freight charges
U.S. Exports by State of Origin (Census)	Customs District/Port			
U.S. Exports by State of Origin (MISER)				
U.S. Exports and Imports Transshipped via Canadian Ports	Customs District			
The Directory of U.S. Importers/Exporters	List of ports			
National Transportation Statistics, Annual Report		Avg. length of haul		
U.S. Air Freight Origin Traffic Statistics (Colography)	Domestic/Export		Shipment size groupings (e.g., express)	
U.S. Air Carrier Traffic and Capacity (T-100) Data	Airport-Airport Segments	Segment miles (estimated)	Carrier	
FAA Airport Activity Statistics (T-3)	Airport of enplanement		Scheduled/non-scheduled	
Worldwide (North American) Airport Traffic Report (ACI)	Airport of enplanement			
ICC Carload Waybill Sample *	BEA O/D; Interchange states	Short line miles (estimated)		Carrier revenue
Freight Commodity Statistics (AAR)				Carrier revenue
North American Trucking Survey (NATS)	City-City			
LTL Commodity and Market Flow Database	ZIP3-ZIP3	from ton-miles	Standard/non-standard	Revenue
Truck Inventory and Use Survey (TIUS)	Intra-/extra-state activity			
Nationwide Truck Activity and Commodity Survey (NTACS)	No. of states, highway type	Annual		
Port Import/Export Reporting Service (PIERS)	City-City/Country via Ports		Carrier	
U.S. Waterborne General and Intransit Shipments	Port-Port		Liner, non-liner, tanker	Import freight charges
Waterborne Commerce and Vessel Statistics (ACOE) *	Waterway-Waterway	from ton-miles		
Ship Movements Database (Lloyd's)	Port-Port		Carrier name	
World Sea Trade Service (DR/MH)	Coast-Coast		Liner/non-liner	
Lock Performance Monitoring System (PMS) *	Lock			
St. Lawrence Seaway Traffic Reports	Waterway sections		Flag of carrier	Revenue
Lake Carriers' Association Annual Report	Intra-lake Port-Port		Flag of carrier	
Exports from Manufacturing Establishments				
Fresh Fruit and Vegetable Shipments	State/country origin - dom./intl.			
Fresh Fruit and Vegetable Arrival Totals for 23 Cities				
Quarterly Coal Report	Customs District (intl. only)			
Natural Gas Monthly	Pipeline company		Pipeline company	Company financials
Natural Gas Annual				
Petroleum Supply Monthly	U.S. Region-Region			
Grain Transportation Report	U.S. export coast; river lock			Ship charter rates

\* Public Use Data Only

requirements for terminals and handling equipment. The CFS will also identify containerized shipments and provide the only recent source for domestic and cross-border container activity. Piggyback or TOFC operations are also described for rail activity in the ICC waybill statistics and the Fresh Fruit and Vegetable Shipments.

Some sources provide either traffic or transit activity for mode-specific types of equipment. The available distinctions are geared towards specifying equipment/vehicle handling capabilities, size and capacity, or the type of service or operating patterns.

The ICC waybill statistics identifies rail-car type, NATS identifies rail car and trailer type, and the TIUS and NTACS surveys distinguish vehicle type, trailer type, and configuration. Aircraft type in FAA statistics is defined by cargo capacity and carrier type (combination vs. all-cargo), while vessel categories in the World Sea Trade Service distinguish type of vessel and size (e.g., container ships of varying capacities). The PMS lock statistics differentiate between standard mixed barge configurations and integrated tug-barges, a distinction which conveys information on tow operating patterns (multi-stop vs. dedicated pattern) and equipment ownership (common carrier vs. private).

Some sources such as the Freight Transportation and Logistics Service and the National Transportation Statistics also include information on fleet inventories.

Routing information generally is limited to origin and/or destination for a single mode and may aggregate those points into regions. The proprietary waybill statistics identify rail line routings, but the public use tape only provides the BEAs for the origin and destination stations and intermediate interchange states. Similarly, PIERs only identifies port of export and import relative to the international vessel service, but provides a foreign transshipment port if appropriate. PIERs also identifies the carrier and vessel name, so it is possible to associate traffic activity with actual vessel routings or services as derived from other sources (published service listings or Lloyd's). Some sources also provide distance information, usually estimated from known or inferred routings.

A key element of transport-based data is the ability to estimate utilization for elements of the transport system, which in turn can be related to system capacity, congestion conditions or maintenance requirements. Data sources which identify flows through modal nodes (e.g., port statistics) can be used to define utilization in terms of total cargo and transportation volume. Sources identifying flows over modal routes or corridors can similarly be used to derive utilization estimates such as ton- or vehicle-miles.

Where routing detail is not available, aggregate system activity can be estimated and associated with a widely-defined modal system. For example, annual data on total rail carloads from the Freight Commodity Statistics provides some measure of rail system utilization and trends, assuming a relatively stable pattern of origin/destination.

The final category of transport characteristics relates to the type of transportation carrier or service and the associated cost or rate structures. Carrier name is identified in some sources such as PIERs and the FAA air carrier reports. Carrier/service type is identified in Census waterborne sources as tanker, liner or non-liner based on the type of vessel and vessel itinerary. The FAA airport statistics characterize carrier and service type by allocations into the general categories of scheduled/non-scheduled service.

Other carrier-related characteristics can also affect freight demand. For example, identification of vessel flag in waterborne statistics can be used to identify the impact of cabotage and other cargo reservation schemes, as well as to evaluate the general openness of the market.

Cost and revenue information is very limited in these data sources, mostly being confined to:

- revenue data provided for individual shipments (ICC waybill and LTL databases);
- total system revenue (Freight Commodity Statistics);
- financial information for transportation companies or modal groups; and
- import freight charges for foreign air and waterborne imports in Census statistics based on the difference between shipment value at foreign port of export and at U.S. port of entry.

The increasing use of contract and volume-based rates for the different modes has decreased the usefulness of tariff rates in measuring transportation costs. Transportation costing is often based on the allocation of carrier financial statistics over some generalized measures of total activity (e.g., truck maintenance per vehicle-mile) to derive unit cost factors applied over a wide range of operations.

## C.2 DATABASE DESCRIPTIONS

Each of the data sources discussed above are described more fully below. Abbreviations used in these descriptions are defined in Exhibit C.10.

### 1993 Commodity Flow Survey (CFS)

**Mode:** All modes  
**Source:** U.S. Bureau of the Census  
**Contact:** Mr. John Fowler, Chief, Commodity Flow Survey Branch, (301) 457-2108  
**Description:** This survey captures shipment data from manufacturing, mining, wholesale and selected retail and service establishments. The shipment data includes distance distributions and origin-destination flows by commodity type, mode, shipment size and value. The Bureau of the Census conducts the CFS as part of its quinquennial Economic Censuses, with two week samples collected dur-

### Exhibit C.10. Abbreviations used in the database descriptions.

BEA	Bureau of Economic Analysis, U.S. Department of Commerce
BTS	Bureau of Transportation Statistics, U.S. Department of Transportation
CFR	Code of Federal Regulations
CIF	Customs, insurance, and freight value at port of import
DWT	Deadweight tons
FAA	Federal Aviation Administration
FAS	Free alongside ship value at port of export
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
HS	Harmonized Schedule of Foreign Trade
ICC	Interstate Commerce Commission
MISER	Massachusetts Institute of Social and Economic Research
NTAR	National Transportation Analysis Region
PIERS	Port Import/Export Reporting System, Journal of Commerce
PMS	Performance Monitoring System (U.S. Army Corps of Engineers)
SIC	Standard Industrial Classification
SITC	Standard International Trade Classification
STCC	Standard Transportation Commodity Code
USBOC	U.S. Bureau of Census, U.S. Department of Agriculture
USDA	U.S. Department of Agriculture
USDOT	U.S. Department of Transportation
VMT	Vehicle-miles of travel

ing each quarter of the sample year. The first survey covered 12 million shipments for over 200,000 establishments.

**Structure:** Tabulations include a 5-digit STCC commodity summary at the national level and a geographic summary (by state and BEA based National Transportation Analysis Regions—NTARS) at the 3-digit STCC level.

**Data Source:** 1993 CFS Questionnaire

**Scope:** Originating shipment activity for all U.S. establishments with one or more employees in the industry sectors cited above.

**Availability:** The 1993 CFS will cover 1992 activity. Reports will be published during 1995 and 1996.

**Comments:** The survey is limited to shipments by U.S.-based establishments which limits coverage of import shipments. The impact of confidentiality requirements on the available detail is unknown.

#### Freight Demand Characteristics

**Commodity:** 5-digit STCC (national); 3-digit STCC (regional); SIC-based summary planned; hazardous materials also designated.

**O/D:** State; 89 National Transportation Analysis Regions (NTARs) based on aggregations of BEAs; foreign country for exports.

**Routing:** Port of exit for exports

**Shipment:** Weight and value

**Transport:** Mode (air/surface parcel, private and for-hire truck, rail, inland waterway, deep sea, pipeline, air and other); distances estimated

using modal networks; containerized shipments identified.

**Other:** On- and off-site facility type; equipment use by type; rail car ownership; responsibility for choice of mode (supplemental survey)

#### TRANSEARCH

**Mode:** Water, air, rail and truck

**Source:** Reebie Associates (Greenwich, CT)

**Contact:** Ms. Jean Thomson, Librarian, Reebie Associates, (203) 661-8661, (203) 661-8886 (fax)

**Description:** Traffic statistics between 183 Business Economic Areas (BEA) by mode of transport and commodity. Database incorporates modal data from various sources.

**Structure:** Detail available by origin/destination BEA, tonnage 4-digit STCC commodity and mode (private/for-hire truckload, LTL, rail carload/intermodal, water and air)

**Data Sources:** Traffic flow data: state-to-state data for a sample of movements by 2-digit SIC from a significant number of truckload and LTL carriers, ICC Carload Waybill Sample, Corps of Engineers Waterborne Commerce Statistics, FAA Airport Activity Statistics, Census of Transportation—Commodity Transportation Survey (1977), Bureau of Census Foreign Trade Statistics, commodity-based sources (e.g., Departments of Agriculture and Energy). Traffic production and shipment data: Survey of Manufactures, AAR Freight Commodity Statistics, county employment and population data, inter-industry trade patterns.

**Scope:** Truck (all manufacturing industries and some other), rail, domestic waterborne, and domestic air (all industries).

**Availability:** Data reports are available in a variety of formats (by origin/destination market, commodity, or traffic lane); annual data available about 15 months after end of period.

**Comments:** The accuracy of this database will differ by mode and commodity based on the timeliness and accuracy of the data source. The limited number of carriers providing truck data may produce some regional or commodity biases. Forecast estimates are also available.

#### Freight Demand Characteristics

**Commodity:** 4-digit STCC (5-digit available for rail and water)

**O/D:** State; 183 U.S. BEAs (some Canadian province data is also available); can also be customized at the county or zip code level

**Routing:** Highway routings have been imputed from O/D data

Shipment: Total weight  
 Transport: Mode of transport, number of transportation units  
 Other:

#### **Freight Transportation and Logistics Service**

Mode: Barge, rail and truck  
 Source: DRI/McGraw-Hill (Lexington, MA)  
 Contact: Ms. Jill Thompson, DRI/McGraw-Hill, (617) 863-5100, (617) 860-6463 (fax)  
 Description: Historical and forecast data for commodity and modal traffic and cost, rate and equipment demand.  
 Structure: This set of over 400 data series can be categorized as:  
 • Commodity traffic by mode and region  
 • Financial and operating data by mode and carrier  
 • Rate and cost data by mode, region and carrier  
 • Transportation equipment supply and demand by mode.  
 Data Source: Proprietary  
 Scope: Not available.  
 Availability: Available in both printed and on-line electronic formats.  
 Comments: Detailed information on the contents of this database were not provided to the study team. DRI/McGraw Hill also produces the World Trade Sea Service trade route forecasts.

#### **Freight Demand Characteristics**

Commodity: STCC (detail differs by mode)  
 O/D: Regional detail available for rail only.  
 Routing: Not available.  
 Shipment: Cargo tonnage by mode  
 Transport: Equipment volumes by mode and type of equipment  
 Other: Cost and rate profiles; equipment fleet size.

#### **U.S. Imports/Exports of Merchandise on CD-ROM**

Mode: All modes combined; water; air  
 Source: U.S. Bureau of the Census, Data User Services Division  
 Contact: Ms. Reba Higbee, Data Manager, USBOD, Foreign Trade Division, (301) 457-2227, (301) 457-2647 (fax)  
 Description: These monthly CD-ROMs contain the most detailed published Census data on U.S. foreign trade imports and exports.  
 Structure: The detailed Customs files are aggregated separately for imports and exports by commodity, Customs District of exit, unloading and entry, foreign country, domestic origin for exports, foreign origin for re-exports, and rate provision category (imports only). Sum-

mary files are also available for U.S. Customs Districts, commodity and foreign country.

Data Source: Import—U.S. Customs Entry Summary (Form 7501)  
 Export—Shipper's Export Declaration (SED) (filed electronically or in hard copy)  
 Scope: All government and nongovernment shipments of merchandise between U.S. Customs territories and foreign countries. Low value shipments (less than \$2,501 for exports and less than \$1,251 for imports) are not reported; all data for these shipments are estimated from historical statistics without commodity detail. The import statistics cover both "General Imports" (all shipments entering the U.S. economy including those destined for foreign trade zones) and "Imports for Consumption" (only those shipments actually clearing Customs).  
 Availability: The CD-ROM is available for purchase on a subscription or ad hoc basis about 4 months after close of period (month or year).  
 Comments: The Bureau of Census is prevented by law from publishing statistics at a level of detail that could be used to identify individual shipper's activity. The estimated data for low-value shipments accounts for a significant portion of air traffic weight. Comparable data is available on magnetic tape for shipments of merchandise between the United States and Puerto Rico and shipments from the United States to the Virgin Islands (EM595/EA695).

#### **Freight Demand Characteristics**

Commodity: 10-digit Harmonized Code with concordance available to SITC (Revision 3), Standard Industrial Classification (SIC), BEA end-user category, and USDA agricultural product code.  
 O/D: Foreign country of origin/destination; no domestic origin/destination (beyond imputation based on district of entry/exit)  
 Routing: U.S. Customs District of exit (Exports); or unloading and entry (Imports).  
 Shipment: Value and quantity (all modes combined); value and weight (vessel and air separately)—monthly and year-to-date. Import value statistics cover Customs value, C.I.F. value and dutiable value, while export statistics show F.A.S. value at the port of export. Value for surface and pipeline modes (combined) can be derived by subtraction; for commodities for which quantities are given in units of weight (generally for bulk commodities), weight for surface and pipeline modes (combined) can also be derived by subtraction.

Transport: C.I.F. value and import freight charges for vessel and air (imports)  
 Other: Number of shipment documents filed; calculated duty (imports)

**U.S. Exports of Domestic and Foreign Merchandise  
by State/Region/Port (State of Export Tapes)**

Mode: All modes combined; water; air  
 Source: U.S. Bureau of the Census, Data User Services Division  
 Contact: Mr. Richard Preuss, Assistant Division Chief, USBOC, Foreign Trade Division, (301) 457-2311, (301) 457-4615 (fax)  
 Description: These extracts of the export detailed ("net") files providing commodity and routing profiles for state/region-country combinations are available on a quarterly and annual basis.  
 There is no allocation of shipments where state of export is unknown (see MISER).  
 Structure: The three combinations are:  
 SOE1 State of origin by foreign country of destination by 2-digit SIC commodity (EQ912/EA917)  
 SOE2 Domestic region of origin by foreign country of destination by 4-digit SITC commodity and domestic port and district of export (EQ932/EA937)  
 SOE3 State of origin by foreign country of destination by domestic port and district of export (EQ952/EA957)  
 Data Source: Import—U.S. Customs Entry Summary (Form 7501)  
 Export—Shipper's Export Declaration (SED) (filed electronically or in hard copy)  
 Scope: All exports of domestic and foreign merchandise.  
 Availability: Tapes are available for purchase on a subscription or ad hoc basis about 4 months after close of period (month or year).  
 Comments: The "state of export" data use general aggregations to preserve confidentiality, and are only available in tape format (except for an expanded extract provided by MISER as detailed below). The "state" data has some limitations based on requirements to aggregate the available data and problems with ambiguous state assignments for selected flows. The "state of export" may not accurately reflect the true origin of export shipments, particularly for commodities which may be stored at the export port and lose origin identity, or when corporate locations are reported instead of production state.

Freight Demand Characteristics

Commodity: 2-digit SIC (SOE1) and 4-digit SITC (SOE2)  
 O/D: State or region (SOE2) of origin and foreign country of destination  
 Routing: U.S. port and district of export (SOE1 and SOE2)  
 Shipment: Total value (all modes), total value and weight (vessel and air), containerized weight and value (vessel)  
 Transport: Vessel, air and "all other" value; containerized weight and value (vessel and air)  
 Other: None

**U.S. Exports by State of Origin of Movement  
(MISER State of Export)**

Mode: All modes; water; air  
 Source: Massachusetts Institute for Social and Economic Research (MISER)—University of Massachusetts—Amherst  
 Contact: Ms. Linda Downs, MISER, (413) 545-3460, (413) 545-3686 (fax)  
 Description: MISER utilizes the raw data from USBOC's state of export tapes EQ912 and EA917 to develop a modified file for state, country and SIC industry flows which reallocates shipments with unknown state or SIC designations.  
 Structure: Aggregated by state of export, foreign country of import, and 2-digit SIC commodity group.  
 Data Source: U.S. Bureau of the Census' EQ912 and EA917 magnetic tapes.  
 Scope: All exports of domestic and foreign merchandise.  
 Availability: MISER provides reports and data files by state, which are also available on the National Trade Data Bank CD-ROM issued by the U.S. Department of Commerce. Lag time is approximately 6 months.  
 Comments: The "state of export" may not accurately reflect the true origin of export shipments, particularly for commodities which may be stored at the export port and lose origin identity, or when corporate locations are reported instead of production state.

Freight Demand Characteristics

Commodity: 2-digit SIC  
 O/D: State of origin and foreign country of destination  
 Routing: Not available  
 Shipment: Total value (all modes), containerized and total value and weight (water and air).  
 Transport: Vessel, air and "all other" value; containerized weight and value (vessel and air)  
 Other: None



### **U.S. Exports and Imports Transshipped via Canadian Ports Annual Report**

**Mode:** Water and surface (rail and truck combined)  
**Source:** Maritime Administration  
**Contact:** Mr. Robert Christensen, Maritime Administration, (202) 366-5507  
**Description:** This annual report estimates U.S.-international commodity flows moving via Canadian ports based on foreign trade statistics. Trade value is estimated by 4-digit Harmonized commodity code, foreign country, and U.S. Customs District based on the residual value of surface exports (after vessel and air value are removed) moving via northern border Districts. Weight is then estimated based on the average value per pound by commodity for vessel shipments.  
**Structure:** Detail available by U.S. Customs District of import/export, foreign country, and 4-digit HS commodity code.  
**Data Source:** Bureau of Census EA-622 and IA-245 tapes from import and export documents  
**Scope:** All import and export shipments to overseas destinations using a Canadian border Customs District and not moving via vessel or air.  
**Availability:** Annual printed report available up to eighteen months after period.  
**Comments:** Estimating procedure assumes a uniform weight and value relationship by commodity for all countries and between vessel and surface modes.

#### Freight Demand Characteristics

**Commodity:** 4-digit Harmonized Schedule  
**O/D:** Foreign country of origin/destination  
**Routing:** U.S. Customs District of exit/entry  
**Shipment:** Value and estimated weight  
**Transport:** Surface traffic only (no rail-truck breakdown)  
**Other:**

### **The Directory of U.S. Importers/Exporters**

**Mode:** All modes (not mode specific)  
**Source:** The Journal of Commerce (New York, New York)  
**Contact:** Ms. Dana Bauer, Journal of Commerce, (800) 222-0356 ext. 6877, (908) 454-6507 (fax)  
**Description:** These annual directories identify U.S. importers and exporters by state with a cross reference by name, product description and HS commodity code. The descriptive fields include address, key personnel, commodity description, foreign countries, ports, employees, shipment value, and modes utilized.

**Structure:** Individual listings are single establishments identified by name and location; there may be multiple listings for some companies.  
**Data Source:** Proprietary listing updated annually; PIERS import and export activity statistics are used to update list.  
**Scope:** Identified companies involved in foreign trade; PIERS update restricted to waterborne users who may also use other modes.  
**Availability:** Annual directory available at beginning of year; CD-ROM and diskette extracts are also available.  
**Comments:** All data items may not be available for all listings. In some cases, corporate location may be listed and not actual origin/destination locations. The directory may miss shippers using air or surface modes exclusively. It is unclear whether or how listings are purged from directory.

#### Freight Demand Characteristics

**Commodity:** Actual commodity descriptions cross-referenced to 10-digit Harmonized Schedule  
**O/D:** Address of importer/exporter (may not indicate true origin/destination), foreign country markets served/utilized  
**Routing:** List of ports; modes utilized without allocation of volume.  
**Shipment:** Total shipment value (if available)  
**Transport:** See Routing  
**Other:** Bank, broker, and freight forwarder.

### **Surface Transborder Trade-Flow Data**

**Mode:** Truck, Rail and Pipeline  
**Source:** Bureau of Transportation Statistics, USDOT  
**Contact:** Mr. Joel Palley, FRA, (202) 366-0348  
**Description:** This database was jointly developed by the U.S. Bureau of the Census and the Federal Railroad Administration to provide modal breakdowns of non-vessel and non-air trade between the U.S. and Mexico/Canada. BTS currently provides monthly summaries of this data.  
**Structure:** The detailed data is provided monthly, separately for Mexico and Canada, in two aggregated formats for imports and exports to satisfy Census' confidentiality requirements. The "commodity detail" databases provide total value by mode, state/province of origin and destination, and 2-digit commodity group. The "geographic detail" database has no commodity information, but instead provides a breakdown by border port of exit/entry and NTAR-level detail for U.S.

exports. Import data includes shipping charge information and weight information for Canada only. Mexican import data excludes state of destination.

- Data Source:** U.S. Imports—Automated Broker Interface (ABI) filings (95% of document), U.S. Customs Entry Summary (Form 7501), and tape filings for foreign trade zone entries.  
U.S. Exports to Mexico—Shipper's Export Declaration (SED) and automated exporter filings.  
U.S. Exports to Canada—Data from Canadian import documents as provided through U.S.-Canada data interchange.
- Scope:** All non-vessel surface trade between U.S. and Canada or Mexico excluding in-transit shipments between those two countries (see "U.S. Imports/Exports of Merchandise on CD-ROM" for more detail on overall coverage). Data first became available for April 1993 trade with the data structure revised in April 1994.
- Availability:** Monthly data files are available on diskette in quarterly sets in DBF and text formats approximately four months after the end of the quarter. CD-ROMs with complete historical data (since April 1993), by month, are issued quarterly.
- Comments:**

#### Freight Demand Characteristics

- Commodity:** 2-digit TSUSA/HS (for commodity detail files only)
- O/D:** U.S. state/Mexican state or Canadian province of origin/destination (all files); U.S. NTAR of origin for U.S. exports (geographic detail files only)
- Routing:** U.S. Customs port of exit/entry for border points and Customs District for non-border points (commodity detail files only).
- Shipment:** Value of shipment; shipment weight (Canadian imports only); and containerized designation (U.S. imports only)
- Transport:** Import freight charges and containerized designation (U.S. imports only)
- Other:**

#### **National Transportation Statistics, Annual Report**

- Mode:** All
- Source:** Bureau of Transportation Statistics, USDOT
- Contact:** Ms. Marilyn Gross, Data Manager, USDOT/RSPA, Volpe Center, DTS-930, (617) 494-2088, (617) 494-3387 (fax); Mr. Richard Feldman, Data Manager, Volpe Center, (617) 494-2272, (617) 494-3387 (fax); and Ms.

Kathleen Bradley, Project Manager, USDOT/BTS, K-20, (202) 366-3282, (202) 366-3640 (fax)

- Description:** A compendium of selected transportation-related data sources with modal profiles of revenues, expenses, fleet sizes, employment and traffic. Historical data are provided for 10 years in most cases, and back to the 1950s for some. Information on energy in transportation (e.g., fuel consumption) and the transportation of energy-related commodities is also provided. Longer-term trend data and comprehensive mode "tree diagrams" are also available for certain items. Prepared by Volpe National Transportation Systems Center for BTS.
- Structure:** Detail available by mode and annual time period.
- Data Source:** Various published sources for each mode
- Scope:** All transportation activity covered by various sources
- Availability:** Annual printed report is available about 19 months after end of period (e.g., 1988 modal profiles appeared in June 1990 report).
- Comments:** This source presents multi-modal information in a common format. Somewhat similar statistics are published in **Transportation in America—A Statistical Analysis of Transportation in the United States** (Annual Report) by the Eno Foundation for Transportation.

#### Freight Demand Characteristics\*

- Commodity:** Not available
- O/D:** Not available
- Routing:** Not available
- Shipment:** Total traffic by mode
- Transport:** Average length of haul, and vehicle-, passenger- and ton-miles by mode
- Other:**
- Financial (operating revenue and expenses by type of operation, government expenditures)
  - Inventory (number of companies, vehicles and employees, mileage of highways and pipelines)
- \*The level of detail varies significantly by mode.

#### **U.S. Air Freight Origin Traffic Statistics (Colography)**

- Mode:** Air
- Source:** The Colography Group (Marietta, Georgia)
- Contact:** Ms. Loree Sherck, The Colography Group, Vice President, (770) 565-0464, (770) 977-7383 (fax)

**Description:** Annual domestic and export shipment statistics for selected air-cargo producing industries by U.S. geographical location groups. The database combines data in three areas: (1) industrial use of expedited cargo, (2) trends in industrial production for top air cargo industries, and (3) geographic locations of these industries. Based on government data sources and Colography's sales lead surveys.

**Structure:** Data items are provided by geographic location group (county, state, "market area") and 4-digit SIC industry group

**Data Source:** Colography plant surveys (air cargo frequency, weight, value, employment per plant); Department of Commerce and other industry studies (production value trends and unit prices); Department of Commerce County Business Pattern survey (plant location).

**Scope:** Highest air cargo producing industries at 4-digit SIC level (accounting for at least 90 percent of total shipments); 73 industries were covered in 1991.

**Availability:** Database extracts and summary reports available directly from Colography; annual data available in May of following year with revised/estimated data available by special request.

**Comments:** This database is one of few that make the direct connection between cargo flows and industrial location patterns; however, it does not associate cargo production with transportation patterns (e.g., airport or carrier).

#### Freight Demand Characteristics

**Commodity:** Industry-based (4-digit SIC industry)

**O/D:** State, county and "market area" of origin. Destinations characterized as domestic or foreign but not otherwise distinguished. Colography-defined "market areas" are aggregates of counties corresponding to local hinterland of U.S. airports or customized set of counties.

**Routing:** Not available

**Shipment:** Annual domestic and export shipment weight, value and number of shipments (with weight and number of shipments shown by shipment size categories).

**Transport:** Shipment size categories corresponding to standard market classifications in air freight industry (express, heavy freight).

**Other:** Total employment and number of plants (total and by employment size) by area.

#### **U.S. Air Carrier Traffic and Capacity Data by Nonstop Segment and On-Flight Market (Form 41 Schedule T-100)**

**Mode:** Air

**Source:** Federal Aviation Administration

**Contact:** Mr. Paul Gavel, Senior Database Administrator, Federal Aviation Administration, (202) 366-4391, (202) 366-3383 (fax)

**Description:** Traffic, operating and capacity statistics by nonstop and on-flight market segment for Form-41 large certificated air passenger carriers (those operating aircraft with more than 60 seats or payload capacity of 18,000 pounds). Only passenger carriers file, but both passenger and freight operations are covered. The "nonstop segment" data refers to all traffic on a single nonstop segment of a flight, while the "on-flight market" data refers to traffic on one or more segments of a single flight. All-cargo carriers are not covered.

**Structure:** Airport-to-airport segment or market pairs by carrier and aircraft type (for segment data)

**Data Source:** Monthly T-100 electronic filings of U.S. Form 41 air passenger carriers

**Scope:** All scheduled revenue operations of reporting U.S. and foreign air passenger carriers.

**Availability:** Data services provide extracts of domestic data about 3 months after filing date; may also provide partial filings as available. International data is withheld for three years. Access to the data is available through independent services such as Database Products (Dallas, TX) or BACK Associates (Stamford, CT), or on magnetic tape direct from FAA.

**Comments:** Routing information available for domestic movements only. The limited coverage of carrier filings restricts the value of the freight data, particularly in markets where all-cargo service or hub-and-spoke systems are prevalent.

#### Freight Demand Characteristics

**Commodity:** Not available

**O/D:** Not available

**Routing:** Non-stop segments (shipment from A to C via B shows up in A-B and B-C segments); On-flight markets (shipment from A to D using flight over A-B connecting to B-C-D flight will show up in A-B and B-D markets).

**Shipment:** Segment (revenue freight tons by carrier and equipment type); market (enplaned freight and mail tons by carrier)

**Transport:** Segment (departures and aircraft hours by carrier and equipment type); carrier; equipment type

**Other:**

#### **Airport Activity Statistics of Certificated Route Air Carriers**

**Mode:** Air

**Source:** Federal Aviation Administration

**Contact:** Ms. Patricia Beardsley, Statistician, USDOT/FAA, APO-110, (202) 267-8032, (202) 267-9636; and Mr. Paul Gavel, Data Manager, USDOT/RSPA, DAI-20, (202) 366-9059, (202) 366-3383 (fax)

**Description:** This report summarizes the filings of Schedule T-3 reports by U.S. Form-41 large certificated air carriers (those operating aircraft with more than 60 seats or payload capacity of 18,000 pounds). Airport statistics on departures and enplaned freight are shown for scheduled and non-scheduled service by carrier.

**Structure:** Annual or monthly enplanement data by airport, carrier and type of service (scheduled/non-scheduled); departure data by airport, carrier, type of service and equipment type.

**Data Source:** Schedule T-3 reports filed by U.S. Form 41 air carriers (as specified in CFR 14, Part 241).

**Scope:** All operations for passenger and freight carriers required to file with USDOT

**Availability:** Calendar year printed reports are available by August or September; monthly and quarterly database versions are available sooner. International data is withheld for three years. The detailed T-3 data is also available in electronic formats from independent data services such as Database Products (Dallas, TX) and BACK Associates (Stamford, CT).

**Comments:** There are significant gaps in this database, due to suppression of international data, the restriction to large certificated carriers, the lack of standard filings for carrier partnerships, and the lack of deplaned and in-transit statistics. Carriers which do not file the T-3 may account for a significant portion of individual airports' traffic. The T-3 data can be combined with T-100 data (see preceding page) as is done by Database Products. Also, freighter versions of aircraft are not separately designated.

#### Freight Demand Characteristics

**Commodity:** Not available

**O/D:** Airport of enplanement

**Routing:** Carrier with no routing information

**Shipment:** Enplaned tons of freight (express and non-express) and mail (priority, non-priority and foreign).

**Transport:** Departures by service type (scheduled or non-scheduled) and equipment type.

**Other:**

#### **Worldwide (North American) Airport Traffic Report**

**Mode:** Air

**Source:** Airports Council International (ACI) and Airports Council International North America (ACI-NA)

**Contact:** Staff, Airports Council International, (011-41-22) 798-4141, (011-41-22) 788-0909 (fax)

**Description:** Annual passenger and freight traffic and operating statistics for major airports responding to ACI survey.

**Structure:** Airport

**Data Source:** ACI survey of airports

**Scope:** All commercial passenger and freight operations at participating airports

**Availability:** Annual hard-copy report available in June of next year; reporting period may differ by country (e.g., fiscal vs. calendar years); worldwide report includes some U.S. airports.

**Comments:** This source represents carrier statistics as collected and compiled by individual airports, as compared to carrier-filed statistics with FAA. The availability of deplaned statistics, as well as operations of carriers not required to file with the FAA, make this a more reliable source for total traffic than the Form 41 statistics. Some inconsistencies across airports regarding treatment of transshipments, etc.

#### Freight Demand Characteristics

**Commodity:** Freight, express or mail

**O/D:** Domestic/international flight

**Routing:** Airport

**Shipment:** Type of shipment (freight and express or mail) plus total international freight plus mail

**Transport:** Total weight by airport and direction (enplaned or deplaned); airport domestic and international aircraft operations by aircraft and type

**Other:**

#### **ICC Carload Waybill Sample**

**Mode:** Rail (with some identification of intermodal activity)

**Source:** Interstate Commerce Commission/Association of American Railroads

**Contact:** Mr. James Nash, Data Manager, ICC, Office of Economic and Environmental Analysis, (202) 927-5740, (202) 927-6225 (fax)

**Description:** A stratified sample of rail carload waybills for all classes of railroads based on traffic volume containing detailed data on traffic, commodity, revenue, and routing characteristics. The data are collected for the ICC under contract by AAR. Traffic and revenue values can be expanded to annual values based on the sampling ratios. Proprietary data identifying specific railroads, rail equipment and station locations are eliminated from the 151-field master file (MF) to produce an annual public use file (PUF) of 62 fields.

**Structure:** Individual records represent single rail shipments

**Data Source:** Actual waybills filed in hard copy or in machine-readable-input (MRI) format by the terminating railroad.

**Scope:** A sample of all railroad freight waybills for movements terminating on U.S. railroads that meet minimum filing requirement (4,500 carloads per year within last 3 years or 5 percent or more of any state's traffic). Canadian originating traffic is included, if reported by a U.S. railroad. The sampling rate varies based on the number of carloads on the waybill and the method of filing, with higher sampling for larger shipments and for MRI railroads.

**Availability:** The Master File is proprietary and not available to the public. The annual Public Use File is available on tape from the AAR about the end of July. The PUF for 1988–1993 is also available on CD-ROM from BTS. The Federal Railroad Administration produces an annual summary of traffic by STCC between five freight-rate territories. ALK Associates produces an annual summary with traffic density maps by commodity and car type, commodity carload volumes, and state-level inbound and outbound volumes by commodity.

**Comments:** Specific problems include:  
 —the billing of multi-car shipments as single car movements  
 —over-reporting of revenues for contract movements  
 —the use of billed (minimum tariff) vs. actual weight  
 —the rebilling of through movements as local.  
 Also, terminating traffic for some non-reporting Class II and III railroads is not covered due to reporting thresholds and fee-based arrangements with major railroads.

#### Freight Demand Characteristics

**Commodity:** 7-digit STCC on MF; 2- to 5-digit STCC on PUF excluding hazardous materials (STCC 49) and bulk materials in boxcars (STCC 50) which are classified separately.

**O/D:** Origin and destination of rail movement identified by BEA Region. Intermodal, import, export and mini-bridge shipments are flagged. MF also contains 6-digit Standard Point Location Code (SPLC) and a Freight Station Accounting Code.

**Routing:** Interchange states and number of interchanges (PUF); Full railroad and station itinerary (MF)

**Shipment:** Billed and actual tons, carloads, trailers, containers, and revenue (sample and expanded universe totals); date of shipment/waybill

**Transport:** Equipment type, shipment and expanded revenue by type (freight, transit, miscellaneous), short line miles, number of interchanges, number of intermodal units (PUF and MF); carrier and equipment type, design, capacity, dimensions, and ID number (MF). Short line miles is the shortest rail distance between origin and destination.

#### **Freight Commodity Statistics**

**Mode:** Rail

**Source:** Association of American Railroads

**Contact:** Mr. A. Clyde Crimmel, Jr., Data Manager, Association of American Railroads, Economics and Finance Department (202) 639-2309, (202) 639-2156 (fax)

**Description:** Quarterly and annual summaries of commodity statistics for all U.S. Class I railroads collected since 1964. Individual railroad's statistics are combined for publication into the Eastern and Western Districts based on corporate headquarters locations.

**Structure:** Traffic aggregated by Eastern/Western District and 2- to 5-digit Standard Transportation Commodity Code (STCC)

**Data Source:** Railroad reports filed with ICC

**Scope:** All commodity traffic for U.S. Class I railroads (revenues greater than \$94.4 million in 1987 dollars)

**Availability:** Published reports available from AAR about five months after end of quarter

**Comments:** Class II and III carriers, accounting for about 9 percent of total revenues, are not required to file this report.

#### Freight Demand Characteristics

**Commodity:** 2-, 3-, 4- and 5-digit STCC; some shipments cannot be classified at the 5-digit level based on available documentation or mixed loadings, so higher-level groupings may not be fully described at disaggregated levels.

**O/D:** Not available

**Routing:** Not available

**Shipment:** Total tons for the following type of shipment:  
 (1) Originated and terminated  
 (2) Originated and delivered to another carrier  
 (3) Received and terminated  
 (4) Received and delivered to another carrier  
 The published report provides the following combinations:  
 Revenue Freight Originated (1)+(2)  
 Revenue Freight Terminated (1)+(3)  
 Total Freight Traffic (1)+(2)+(3)+(4).

Transport: Freight revenue and carloads by commodity for originated freight, terminated freight, and total freight.  
 Other: None

**North American Trucking Survey (NATS)**  
**(replaces National Motor Transportation Database)**

Mode: Truck  
 Source: Association of American Railroads  
 Contact: Mr. Bill Linde, Association of American Railroads, (202) 639-2312, (202) 639-2312 (fax)  
 Description: Information on a sample of predominantly long-haul truckload movements, operator characteristics, and annual VMT of driver.  
 Structure: Each record corresponds to a truckload shipment.  
 Data Source: Survey of drivers conducted at 46 truck stops under contract by Arthur D. Little, Inc. Each driver is asked about current movement and preceding loaded movement.  
 Scope: A sample of predominantly long-haul truckload movements using sampled truck stops.  
 Availability: Database is proprietary. However, AAR often cooperates with federal and state agencies when requested.  
 Comments: First-time collected in 1993. Discontinued August 1994. Replaced the similar National Motor Transportation Database (NMTDB) conducted for AAR by Transportation and Research Marketing (of Challis, Idaho). The probability that any truckload shipment will be sampled is approximately proportional to its length of haul.

Freight Demand Characteristics

Commodity: STCC (3-digit for major commodities)  
 O/D: City and state of origin and destination.  
 Routing: Not available.  
 Shipment: Weight in tons.  
 Transport: Trailer type  
 Other: Annual VMT of driver; operator characteristics (private, for-hire, owner-operator); additional questions included as needed.

**LTL Commodity and Market Flow Database**

Mode: Truck (LTL)  
 Source: American Trucking Associations (ATA)  
 Contact: Mr. Tom Sullivan, ATA, and Mr. Jim Hendricks, Martin Labbe Associates, (703) 838-1978, (703) 683-9751 (fax)  
 Description: Traffic lane statistics for all LTL shipments of subscribing carriers. These carriers have access to resulting database with carrier detail obscured. Weight, revenue, shipment, piece

and mileage statistics are categorized by origin/destination pairings, length of haul, commodity type, and weight. International origins and destinations are included.

Structure: Flow data is disaggregated by traffic lane (zip3-to-zip3 or foreign area), length of haul, commodity classification, weight class, service code, intermodal indication, and interline indication; disclosure restrictions may require additional aggregation.

Data Source: Collected under contract to ATA by Martin Labbe Associates from subscribing carriers.

Scope: All shipments for subscribing carriers excluding intra-company and pooled shipments.

Availability: Standardized reports and data files only available to subscribing carriers; available one week after all carrier data is received.

Comments:

Freight Demand Characteristics

Commodity: Categorized by service type (standard, non-standard delivery time, special equipment/handling)

O/D: Origin/destination zip codes or foreign area (Canada, Mexico, Asia, Europe or Other)

Routing: Mileage.

Shipment: Weight, number of shipments, and number of pieces.

Transport: Ton-miles, revenue, service type, intermodal and interline indication.

Other: Intermodal shipments are identified.

**Truck Inventory and Use Survey (TIUS)**

Mode: Truck  
 Source: U.S. Bureau of the Census  
 Contact: Mr. Bill Bostic, Project Manager, USBOC, (301) 457-2797, (301) 457-2374 (fax)

Description: A vehicle-based survey of truck, van and minivan annual activity conducted by the Bureau of Census as part of the quinquennial Census of Transportation based on vehicle registrations. The survey covers ownership, equipment type, leasing activity, configuration, dimensions, capacity, mileage and commodities carried.

Structure: Individual sample vehicles identified by a serial number and state of registration

Data Source: 1987 Census of Transportation Truck Inventory and Use Survey Forms (TC-9501/9502) sent to owners of 154,000 vehicle out of a universe of 45 million vehicles with a response rate of 78 percent (105,000 vehicles).

Scope: All state-registered vehicles except buses, automobiles, mobile homes, motorcycles, and vehicles owned by government.

**Availability:** The 1987 TIUS public use tape and national summary report were released in August 1990.

**Comments:** This database provides vehicle type, ownership and operating characteristics which can be associated with the type of use (type of business and commodities). No geographic detail is available beyond identifying vehicles by state of registration and range of operation. Sample values can be expanded to the universe within state and vehicle type stratum. Safety data was aggregated in the public use tape to address problems of confidentiality.

#### Freight Demand Characteristics (on Public Use Tape)

**Commodity:** Percent of annual mileage for 26 commodity categories including non-freight activity (personal, idle, and empty haul use) and (separately) for 17 categories of hazardous material.

**O/D:** Not available

**Routing:** Not available

**Shipment:** Not available

**Transport:** Percent of annual miles outside of designated "base" state and percent by range of operation categories.

**Other:** Type of business in which vehicle was used; for for-hire vehicles: type of operations, kind of carrier, and jurisdiction served.

Vehicle (make, year, dimensions, body/trailer type, capacity, axle and operating configuration, equipment, maintenance)

Acquisition/Disposition (year, method, lease/ownership)

Utilization (annual and lifetime mileage, fuel efficiency, state of operation, type of use, Hazmat activity, commodity types, accident incidence)

#### **Nationwide Truck Activity and Commodity Survey (NTACS)**

**Mode:** Truck

**Source:** Oak Ridge National Laboratory (ORNL)

**Contact:** Ms. Stacy Davis, Data Manager, ORNL, (615) 574-5957, (615) 574-3851 (fax); and Mr. Jim March, Data Manager, USDOT, FHWA, HPP-12, (202) 366-9237, (202) 366-7969 (fax)

**Description:** A detailed survey (conducted every five years) of trip characteristics and other information for trucks identified in the Truck Inventory and Use Survey (TIUS). The survey was conducted by the U.S. Bureau of the Census for FHWA, FRA and USDOT's Office of the Secretary. Annual, weekly and

sample day (over one- and two-day intervals) activity was measured during the 12-month period from October 29, 1989 to October 27, 1990 (known as 1990 survey). The public use tape (PUT), available from ORNL, consists of three files:

NTAC1 NTACS Annual/General Activity (1990)

NTAC2 NTACS Sample Day/Week Activity (1990)

NTAC3 TIUS Annual/General Activity/Characteristics (1987)

**Structure:** Each data record represents a sample response for a single truck as identified by the Truck Identifier (Region of registration, type of commodity/haul, vehicle type, and sample stratum ID number)

**Data Source:** USBOC survey forms NTACS-1 for short-haul and non-freight vehicles and NTACS-2 for long-haul commodity haulers with above data

**Scope:** The sample universe includes all trucks operating during the sample period (October 1989-October 1990), registered in one of the 50 states or DC on July 1, 1987, and which responded to the 1987 TIUS survey.

**Availability:** The 1990 public use tape was released at the end of 1992.

**Comments:** The 1990 NTACS public use tape is considered of poor quality due to low response rates and other non-sampling problems, and it required extensive imputation for certain data items.

#### Freight Demand Characteristics

**Commodity:** 26 TIUS commodity categories (including empty) plus Hazmat categories

**O/D:** Sample day cargo load and discharge patterns \*

—stop location

—type of place (e.g., warehouse, port)

**Routing:** Sample day cargo routing patterns \*

—detailed stop locations

—type of stop activity (e.g., pick up, delivery)

—arrival and departure time

**Shipment:** 1987 percent of total mileage by commodity (TIUS)

1990 sample day weight by commodity and load/discharge stop \*

**Transport:** Annual

—weeks of operation

—annual mileage

—number of states

—top 3 states of operation \*

—Canada/Mexico \*

—type of use  
 —configuration and body/trailer type  
 Sample Day  
 —ton-miles for top commodity  
 —days of week and time of day use  
 —number of stops  
 —type of use  
 —mileage  
 —type of highways  
 —fuel use and tolls  
 —dimensions, capacity and load

Other: Vehicle (model year, ownership, operation)

\* Master File Only

### State Estimates of Truck Traffic

Mode: Truck  
 Source: State highway agencies and FHWA  
 Contact: For FHWA data: Mr. Don Kestyn, Transportation Specialist, USDOT, FHWA, HPM-20, (202)366-0175, (202)366-7742 (Fax).  
 Description: Estimates of annual average daily traffic (AADT) of trucks for selected sections of road, and truck VMT by vehicle configuration for several systems of roads.  
 Structure: State estimates of the distribution of VMT across vehicle classes (including nine or ten truck classes) by highway functional system are submitted annually to FHWA in Lotus 123 files. Estimates of total AADT, percent single-unit trucks, and percent combination trucks (and an extensive amount of additional data), are submitted annually to FHWA in a uniform ASCII format for a sample of highway sections on magnetic tape or diskette. States may have substantial additional truck AADT and VMT estimates in various formats.  
 Data Source: Vehicle counts collected by state and local highway agencies.  
 Scope: Data from automatic vehicle classifiers used at a small number (typically 50 to 100) permanent count sites in each state and at a larger number of temporary classification sites; and counts of total traffic volume (without vehicle classification) collected at an even larger number of temporary count sites. Counts at temporary sites are most frequently collected for a 48-hour weekday period once every three years.  
 Availability: AADT estimates for single-unit and combination trucks for selected sections of nonlocal road and VMT estimates for nine classes of truck by highway functional system are incorporated into FHWA's Highway Performance Monitoring System and are available from

FHWA. Additional AADT estimates are available from individual state highway agencies.

Comments: The most common "factoring" procedures currently used for estimating truck AADT from 48-hour weekday classification counts fail to reflect the lower truck volumes that occur on weekends, producing overestimates of truck AADT that apparently average about 30 percent. For sections on which only volume counts are collected, truck AADT is estimated using total AADT for the section and estimated truck AADT on other sections.

### Freight Demand Characteristics

Commodity: Not available.  
 O/D: Not available.  
 Routing: Not available.  
 Shipment: Not available.  
 Transport: VMT for nine truck configurations (distinguished by numbers of trailers and numbers of axles) plus, in some states, separate VMT estimates for four-tire trucks; AADT generally for two or three types of truck (distinguished by length or numbers of trailers).  
 Other: None.

### Port Import/Export Reporting Service (PIERS)

Mode: Water  
 Source: The Journal of Commerce  
 Two World Trade Center, 27th Floor, New York, NY 10048  
 Contact: Ms. Traci Bevacqua, Journal of Commerce, (800) 222-0356 ext. 6698, (908) 454-6507 (fax)  
 Description: The Journal of Commerce PIERS data contains detailed shipment information for most U.S. waterborne foreign trade including shipments entering or exiting Puerto Rico. Bill of lading data are collected from electronically-filed Customs manifest data or directly from hard copy reports.  
 Structure: Each data record represents a single shipment as listed on the manifest.  
 Data Source: Vessel manifests—hard copy or Customs Automated Manifest System (AMS)  
 Scope: Excludes manually-filed manifest data at smaller ports.  
 Availability: The most recent 24 months of complete data are available on-line on a subscription basis with customized reporting and database development also available. Historical months are archived and available. A complete month's data is available the first Monday of the fourth week following the end



of the month, although individual vessel's activity may be available sooner.

**Comments:** This is the most timely and detailed source for waterborne foreign trade shipments. Shipper names must be withheld at the request of the shipper. The designated U.S. O/D may represent a corporate location or distribution point, rather than the true origin or destination. TRADE, Inc. (San Mateo, California) provides a comparable database of vessel manifest information.

#### Freight Demand Characteristics

**Commodity:** 6-digit Harmonized, 7-digit PIERs Comcode (loosely based on 1979 TSUSA), and actual manifest/bill of lading description.

**O/D:** U.S. shipper/consignee and foreign shipper (import only)  
 —name  
 —U.S. city of origin/destination (as recorded)  
 —foreign country of import/export (city for export)

**Routing:** U.S. port of loading/unloading  
 —Foreign port of ultimate origin/destination  
 —Foreign port of transshipment  
 —No inland mode designation.

**Shipment:** Shipment weight and value  
 —Package type and quantity.

**Transport:** Carrier and vessel name  
 —Container size, number and estimate of cubic volume utilized  
 —Package type

**Other:** U.S. port date, linkage to other company information for importers/exporters is available

#### **U.S. Waterborne General Imports (Exports) and Inbound (Outbound) Intransit Shipments**

**Mode:** Water

**Source:** U.S. Bureau of the Census, Data User Services Division

**Contact:** Mr. Norman Teague, Data Manager, USBOC, Foreign Trade Division, (301) 457-2317, (301) 457-1237 (fax)

**Description:** Port-to-port flows of U.S. foreign trade and intransit shipments with commodity, vessel type and country detail available on monthly (TM) and annual (TA) magnetic tapes.

**Structure:** Detailed records are aggregates based on commodity, type of vessel service, U.S. port, foreign port, and foreign country.

**Data Source:** Import—U.S. Customs Entry Summary (Form 7501)  
 Export—Shipper's Export Declaration (SED) (filed electronically or in hard copy)

**Scope:** All government and nongovernment waterborne shipments of merchandise between

U.S. Customs territories and foreign countries including intransit shipments. Low value shipments (less than \$2,501 for exports and less than \$1,251 for imports) are not reported and are estimated from historical statistics without commodity detail.

**Availability:** Tapes are available for purchase on a subscription or ad hoc basis about 4 months after close of period (month or year). Also included in **U.S. Waterway Data** CD-ROM available from BTS and from the Corps of Engineers.

**Comments:** The Bureau of Census is prevented by law from publishing statistics at a level of detail that could be used to identify individual shipper's activity. The estimated low-value shipments may include a significant amount of air traffic. The Maritime Administration publishes summary data by trade route in United States Oceanborne Foreign Trade Routes.

#### Freight Demand Characteristics

**Commodity:** SITC (Revision 3) and 6-digit Harmonized Code

**O/D:** Foreign country of origin/destination; no domestic origin/destination.

**Routing:** U.S. Customs Port (USBOC Schedule D classifications) to foreign port (USBOC Schedule K classifications) flows

**Shipment:** Value and weight

**Transport:** Type of vessel service (liner, non-liner, tanker); import freight charges and containerized percentage.

**Other:** None

#### **Waterborne Commerce and Vessel Statistics**

**Mode:** Water

**Source:** U.S. Army Corps of Engineers

**Contact:** Mr. Thomas Mire and Mr. Roy Walsh, Data Managers, U.S. Army Corps of Engineers, (504) 862-1424, (504) 862-1423 (fax)

**Description:** Statistics on the commercial movement of domestic and foreign cargo for U.S. ports and waterways. The Corps of Engineers collects the domestic data directly from carriers who report vessel movements and cargo activity by port and dock. The foreign statistics are developed from Bureau of Census foreign trade statistics which are enhanced with detailed vessel movement information. The master file of individual dock-to-dock commodity flows is proprietary, but the following summarized extracts of the cargo and vessel activity are produced:  
 —Commodity tons by commodity, type (foreign/domestic, coastwise, internal, local),

and direction (inbound/outbound, upbound/downbound) for individual ports, harbors, and other waterways and components thereof (printed report and data tape)

—Vessel trips by draft, vessel type and direction for individual ports, harbors, and other waterways and components thereof (printed report and data tape)

—Commodity tons by commodity group and state of origin and destination (or foreign) (public domain database on diskette)

—State and principal ports tonnage summary

—*Transportation Lines of the United States* which lists the location, vessel characteristics, and area of operation for vessel operators.

**Structure:** The master file contains data for unique combinations of origin and destination channel dock locations, commodity, month of shipment, and carrier type. The public sources provide detail by year of shipment, commodity, and type and direction of movement for individual ports, harbors, and waterway segments.

**Data Source:** Vessel Operation Report—Statement of Freight and Passengers Carried (Corps of Engineers Form 3925) for domestic movements; Bureau of Census U.S. Waterborne Exports and General Imports revised to include channel codes.

**Scope:** All domestic and foreign waterborne movements of merchandise to or from U.S. ports including Puerto Rico and the Virgin Islands.

**Availability:** See description above for data products. Annual data are available about 18 months after the end of the year. Also included in **U.S. Waterway Data** CD-ROM available from BTS and from the Corps of Engineers.

**Comments:** In the past, there were problems with the accuracy and timeliness of reporting which the Corps is addressing through advanced processing of filings and estimating procedures. Calendar year 1991 estimated statistics were published in October 1992 showing domestic commodity traffic by general cargo type, waterway and direction.

#### Freight Demand Characteristics

**Commodity:** 4-digit Commodity Classification for Domestic Waterborne Commerce

**O/D:** Dock-to-dock flows (master tape); port/harbor/channel segment throughput (port summary); state-to-state (public domain database). Origin and destination of vessel may be inferred from flow type categories (e.g., internal, coastwise). No foreign country detail for international shipments

**Routing:** Data is provided for specific route elements; specific routing patterns are not available beyond inferred routing based on O/D combination

**Shipment:** Shipping weight (tons)

**Transport:** Number of vessels by direction, type and draft.

**Other:**

#### **Ship Movements Database**

**Mode:** Water

**Source:** Lloyd's Maritime Information Services (New York, New York)

**Contact:** Ms. Lorraine Parsons, Lloyd's Maritime Information Services, (800) 423-8672, (203) 358-0437 (fax)

**Description:** This database contains reported current movements of over 30,000 merchant vessels engaged in international waterborne trade covering over 2 million movements per year. The database is updated daily from information gathered by Lloyd's Agents located at principal ports around the world. This database can be used to develop vessel service patterns on international trade routes.

**Structure:** Vessel name and port of call

**Data Source:** Lloyd's Agents in over 5,000 worldwide ports

**Scope:** International movements of tankers and combination vessels over 6,000 DWT, dry bulk carriers over 10,000 DWT, and all other vessel types over 5,000 DWT.

**Availability:** Available on-line on a subscription basis or in extract form by request.

**Comments:** Can be correlated with vessel cargo activity (e.g., PIERS) to determine cargo routing patterns.

#### Freight Demand Characteristics

**Commodity:** Not available

**O/D:** Not available

**Routing:** Port-to-port vessel itineraries

**Shipment:** Total tons transported inferable from capacity (from same source) and assumed load factor (not provided)

**Transport:** Arrival and departure date plus vessel characteristics

**Other:**

#### **World Sea Trade Service**

**Mode:** Water

**Source:** DRI/McGraw-Hill (Lexington, Massachusetts)

**Contact:** Ms. Jill Thompson, DRI/McGraw-Hill, (617) 863-5100, (617) 860-6463 (fax)

**Description:** Historical and forecast ocean traffic for over 700 major trade routes by commodity group and vessel category (defined by cargo type, service type and size). Quarterly reports are provided in a variety of formats and forecasts include short-term quarterly estimates for a two-year period and long-term estimates.

**Structure:** Trade route (country/region pairs), vessel category, commodity group, and historical and forecast period.

**Data Source:** Country-based foreign trade statistics

**Scope:** All waterborne shipments covered in international data sources

**Availability:** Quarterly reports and data extracts are available.

**Comments:**

#### Freight Demand Characteristics

**Commodity:** 20 SITC-based commodity groups (additional detail available for certain countries)

**O/D:** Foreign country of origin and destination (based on ports of lading and discharge; transshipment activity not identified)

**Routing:** Trade routes as defined by coast/country/region pairs at various levels of detail; port detail is available for certain trade routes.

**Shipment:** Total weight and containerloads

**Transport:** Number of containerloads

**Other:**

#### **Lock Performance Monitoring System (PMS)**

**Mode:** Water

**Source:** U.S. Army Corps of Engineers

**Contact:** Ms. Donna Wood, Data Manager, U.S. Army Corps of Engineers, CEWRC, Navigation Data Center, (703) 355-0154, (703) 355-0047 (fax)

**Description:** Performance and flow statistics for all commercial and non-commercial lockages at Corps of Engineers-managed locks. The master file is summarized to produce traffic and performance summaries in quarterly reports. Lockage activity can be correlated with information on wind, weather and surface conditions collected in separate shift log.

**Structure:** Data records correspond to individual lockages identified by lock and chamber and the lockage start date and time.

**Data Source:** Individual lockage reports completed at time of lockage by lock personnel.

**Scope:** All activity at Corps-owned or operated locks.

**Availability:** Summary of Lock Statistics printed on quarterly basis within 6 months; "key" lock traffic data available within 2 months; detailed file available for special studies only. Also

included in **U.S. Waterway Data** CD-ROM available from BTS and from the Corps of Engineers.

**Comments:** Commodity categorization is done by lock personnel and may vary in detail and accuracy based on level of communications with the tow. This is a useful source for "closed" systems clearly defined by lock locations, but does not identify origin and destination points or inter-system movements.

#### Freight Demand Characteristics

**Commodity:** 2-digit commodity codes unique to PMS

**O/D:** Not available. (It may be possible to track distinctive tow movements from lock-to-lock within a single river system and infer O/D.)

**Routing:** See O/D

**Shipment:** Shipment weight

**Transport:** Barge type, dimensions, commodity type and weight (for each barge); lock processing characteristics for tow (type, direction, number of cuts, processing times, delay factors)

**Other:**

#### **St. Lawrence Seaway Annual Traffic Report**

**Mode:** Water

**Source:** The St. Lawrence Seaway Authority (SLSA) and the St. Lawrence Seaway Development Corporation (SLSDC)

**Contact:** Mr. Robert J. Lewis, Data Manager, USDOT, SLSDC (202) 366-0091, (202) 366-7147 (fax); and Mr. Don Kenny, Data Manager, Canadian Seaway Authority, (613) 932-5170

**Description:** Annual statistics on cargo and vessel activity on the Saint Lawrence Seaway segregated by section: Montreal-Lake Ontario and the Welland Canal. Activity data are provided in a variety of cross-references between groupings of commodities, toll classifications, origins and destinations, type of transit, and vessel type.

**Structure:** Individual tables provide cargo and vessel activity statistics for both sections, individually and combined.

**Data Source:** Filings with SLSA

**Scope:** All vessel activity transiting SLS locks including non-cargo activity.

**Availability:** Annual printed summary available within first quarter of following year.

**Comments:** 20-year historical summaries are available for certain characteristics; seasonal traffic statistics also shown.

#### Freight Demand Characteristics

**Commodity:** 53 commodity-based classifications grouped as agricultural products, animal products,

mine products, forest products and manufactures and miscellaneous; toll classification groups based on cargo type (bulk, grains, government-aid, containers, and general cargo).

O/D: U.S., Canada or foreign

Routing: Tabular summaries relate to two sections of waterway; also designates type of transit (inland, coastal, overseas, non-cargo)

Shipment: Cargo weight by vessel type, direction, and other characteristics.

Transport: Number and total gross registered tons (GRT) of vessel transits by class and type of vessel; distribution of transits and cargo by vessel size categories.

Other: Traffic revenue and flag of vessel.

#### **Annual Report—Lake Carriers' Association**

Mode: Water

Source: Lake Carriers' Association (LCA)

Contact: Mr. Glen Nekvasil, Director of Communications, LCA, (216) 621-1107, (216) 241-8262 (fax)

Description: Annual report contains traffic statistics for Great Lakes and included waterways.

Structure: Tabular summaries of seasonal traffic and vessel activity by commodity, origin/destination.

Data Source: Data collected by LCA members.

Scope: All commercial vessel activity on Great Lakes.

Availability: Printed annual report.

Comments: Statistics are geared toward monitoring bulk movements, canal utilization, and seasonal patterns of trade. The limited scope of operations on the Great Lakes and the specialized vessel fleet permits comprehensive coverage of activity.

#### **Freight Demand Characteristics**

Commodity: Five dry bulk groups plus petroleum and grains.

O/D: Not available

Routing: Origin port or lake; destination lake for some commodities

Shipment: Net tons and number of shipments; largest annual shipment by commodity group.

Transport: Number of vessel transits and commodity flows for canals; flag of carrier.

Other: Fleet description; lake draft levels.

#### **Exports from Manufacturing Establishments**

Mode: All modes combined

Source: U.S. Bureau of the Census

Contact: Mr. Richard Preuss, Assistant Division Chief, U.S. Bureau of the Census, (301) 457-2311, (301) 457-4615 (fax)

Description: This annual report includes estimates of export value and export-related employment for manufacturing industries by state of production. Both direct exports and indirect support for exporting industries are covered. Direct export activity is modified to match with foreign trade statistics, while indirect support (i.e., inputs to export manufacturers) is estimated based on BEA input/output relationships. Employment in auxiliary non-manufacturing industries related to transportation and shipment of exports is also estimated.

Structure: State of production and 3-digit SIC industry code

Data Source: Annual Survey of Manufacturers

Scope: All manufacturing establishments

Availability: Annual report is available within 3 years of period end.

Comments: This source differs from the foreign trade "State of Export" database which uses F.A.S. value at the port of export and a definition of "state of export origin" which is not restricted to production location.

#### **Freight Demand Characteristics**

Commodity: 3-digit SIC industry group (detail may be suppressed for confidentiality)

O/D: State of production

Routing: Not available

Shipment: Shipment value (F.O.B.) for direct and supporting exports.

Transport: Not available

Other: Employment for direct and supporting exports.

#### **Fresh Fruit and Vegetable Shipments by Commodities, States and Months**

Mode: Rail, truck, piggyback, air, water and total all modes.

Source: U.S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division, Market News Branch

Contact: Mr. Doug Edwards, U.S. Department of Agriculture, Section Head, Transportation Reports, (202) 720-3343, (202) 720-7502 (fax)

Description: This report provides detailed information for fresh fruits and vegetables including mode of transport, origin, and seasonal patterns.

Structure: The most detailed data covers commodity, origin, mode, market type (domestic or export), tonnage, and month of shipment.

Data Source: Domestic data is collected from various sources including Federal marketing order administrative committees, Federal-State inspection service, shippers and transporta-

tion agencies. Import data comes from the Bureau of Census, except imports from Mexico which are obtained from records of the Animal and Plant Health Inspection Service of USDA.

**Scope:** Domestic data covers all rail refrigerated and piggyback shipments, and available data from other modes and export. Truck data for Arizona and Florida represent interstate shipments only.

**Availability:** Annual report for calendar year available in March of next year.

**Comments:** Separate data collection by mode presents problems with aggregation and double counting. Partial coverage of non-rail shipments limits applicability to whole market. The coverage of mode of transport for multi-modal shipments is unclear.

#### Freight Demand Characteristics

**Commodity:** Individual fruits and vegetables with some grouping of minor commodities and mixed load shipments; domestic and export commodities are listed separately.

**O/D:** U.S. state (with 4-district detail for California) or foreign country of origin; domestic or export destination group.

**Routing:** Not available

**Shipment:** Cargo weight by month and year.

**Transport:** Mode of transport for domestic shipments (rail refrigerated cars, piggyback, truck, air and water).

**Other:**

#### **Fresh Fruit and Vegetable Arrival Totals for 23 Cities**

**Mode:** Rail, truck, air and water.

**Source:** U.S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division, Market News Branch

**Contact:** Mr. Doug Edwards, U.S. Department of Agriculture, Section Head, Transportation Reports, (202) 720-3343, (202) 720-7502 (fax)

**Description:** This report provides transport flow information for fresh fruits and vegetables for the top 23 U.S. and 4 Canadian city destinations including mode of transport, origin and seasonal patterns. Detailed information for Eastern and Western cities is available in separate reports (FVAS-1 and FVAS-2) or in summary form (FVAS-3).

**Structure:** The most detailed data for each city covers tonnage by commodity, origin, mode, market type (domestic or export), and month of shipment.

**Data Source:** Data is collected from various government and industry sources.

**Scope:** Domestic coverage based on completeness of various sources; imports include all shipments moving through regular market channels for each city.

**Availability:** Annual report for calendar year available in March of next year.

**Comments:** Partial coverage of shipments may limit applicability to whole market, although use of constant sources make time series comparisons consistent. The coverage of mode of transport for multi-modal shipments is unclear.

#### Freight Demand Characteristics

**Commodity:** Individual fruits and vegetables with some grouping of minor commodities and mixed load shipments.

**O/D:** U.S. state or foreign country origin; city of destination.

**Routing:** Not available

**Shipment:** Cargo weight by month and year.

**Transport:** Mode of transport (rail, truck, air and water).

**Other:**

#### **Quarterly Coal Report**

**Mode:** All modes

**Source:** U.S. Department of Energy, Energy Information Administration

**Contact:** Ms. Paulette Young, Coal Industry Information Specialist, Department of Energy/Energy Information Administration, (202) 254-5481, (202) 606-6223 (fax)

**Description:** Quarterly summary of U.S. coal production, distribution, foreign trade, receipts, consumption, and stocks. This description covers only the distribution statistics related to freight transportation.

**Structure:** Tabular summaries of quarterly tonnage for combinations of key characteristics.

**Data Source:** Form EIA-6 and Bureau of Census foreign trade statistics

**Scope:** All U.S. companies which own, or purchase and distribute more than 50,000 tons of coal per year; an estimated 99% of total U.S. production activity.

**Availability:** Printed report available within 5 months of quarter's end.

**Comments:** State-to-state flows are not included.

#### Freight Demand Characteristics

**Commodity:** Coal (with some data broken in categories defined by origin or physical properties such as BTU content)

**O/D:** U.S. state or foreign country of origin and (separately) destination country or U.S./Canadian sector (electric generation, coke plants, industrial plants, residential and commercial); no O/D pairs.

Routing: Customs District for imports and exports.  
 Shipment: Weight  
 Transport: Principal mode (rail, inland waterway, Great Lakes, ocean port, truck, slurry); no inter-modal designations.  
 Other:

#### **Natural Gas Monthly**

Mode: Pipeline and Water  
 Source: U.S. Department of Energy, Energy Information Administration  
 Contact: Ms. Sheila Darnell, Data Manager, U.S. Department of Energy, Energy Information Administration, Energy Information Center, (202) 586-6165, (202) 586-1076 (fax)  
 Description: Monthly statistics on production, consumption, pipeline flows, and prices.  
 Structure: Tabular summaries of monthly activity (measured in cubic feet) for combinations of key characteristics.  
 Data Source: Form EIA-759 and 857.  
 Scope: All activity for generating electric utilities (EIA-759) and a sample of companies delivering natural gas to consumers (EIA-857).  
 Availability: Monthly printed report available within 2 months.  
 Comments:

#### **Freight Demand Characteristics**

Commodity: Natural Gas  
 O/D: Foreign country for imports and exports; state of production; deliveries by state and type of use (residential, industrial, utility); no O/D pairs.  
 Routing: Volumes by pipeline company  
 Shipment: Monthly volume (cubic feet) and average price data  
 Transport: Mode (pipeline or LNG vessel) for imports and exports  
 Other: Financial information for pipeline companies.

#### **Natural Gas Annual**

Mode: Pipeline and water  
 Source: U.S. Department of Energy, Energy Information Administration  
 Contact: Ms. Sheila Darnell, Data Manager, Department of Energy/Energy Information Administration, Energy Information Center, (202) 586-6165, (202) 586-1076 (fax)  
 Description: Annual summary of state-based production, supply, disposition, consumption, and prices.  
 Structure: Tabular summaries of monthly activity (measured in cubic feet) for combinations of key characteristics.

Data Source: Form EIA-176 and FPC-14 (for transportation data)  
 Scope: All activity for companies that deliver natural gas to consumers or that transport gas across state lines (EIA-176); all import and export activity (FPC-14).  
 Availability: Monthly printed report available within 2 months.  
 Comments: The annual report provides state-level detail not available in quarterly reports.

#### **Freight Demand Characteristics**

Commodity: Natural gas  
 O/D: State or country of production or consumption; State-based receipts and deliveries at state borders of export, intransit, or interstate shipments.  
 Routing: Not available  
 Shipment: Volume (cubic feet) and prices  
 Transport: Mode (pipeline or LNG vessel) for imports and exports  
 Other:

#### **Petroleum Supply Monthly**

Mode: Pipeline, tanker, barge  
 Source: U.S. Department of Energy, Energy Information Administration  
 Contact: Mr. Sam Nealey, Data Manager, Department of Energy/Energy Information Administration, National Energy Information Center, (202) 586-9670, (202) 586-5846 (fax)  
 Description: Monthly report on U.S. petroleum supply and disposition, production, foreign trade, government shipments, and inventories.  
 Structure: Tabular summaries of monthly activity (barrels) for combinations of key characteristics.  
 Data Source: Form EIA-812, 813, 814 and 817.  
 Scope: All activity captured by survey of refiners, blenders, plant operators, transporters and importers.  
 Availability: Monthly printed report available within 2 months.  
 Comments:

#### **Freight Demand Characteristics**

Commodity: Separate statistics for crude oil and primary petroleum products  
 O/D: Foreign country for imports and exports; U.S. O/D inferable based on port routing.  
 Routing: Imports: traffic by country, multi-state Petroleum Administration for Defense (PAD) of entry and commodity. Exports: traffic by commodity and country or PAD of exit. Domestic PAD-to-PAD traffic flows by mode (may include foreign transshipments).

Shipment: Volume in barrels.  
 Transport: Mode (pipeline, tanker and barge)  
 Other:

### **Grain Transportation**

Mode: Highway, rail, water  
 Source: U.S. Department of Agriculture, Agricultural Marketing Service (AMS)  
 Contact: Mr. Bill Dunton, Data Manager, USDA-AMS-TMD, (202) 690-0331, (202) 690-3616 (fax); and Mr. Nick Marathon, Economist, USDA-AMS-TMD, (202) 690-0331, (202) 690-3616 (fax)  
 Description: Weekly report on grain transportation activity including U.S. export inspection volumes, U.S. rail car loadings, rail deliveries to port by coast, barge movements by commodity and river lock, major export sales by commodity, number of vessel calls, average commodity prices, and freight rate for ship charters. Data for latest and several prior weeks are shown.  
 Structure: Tabular summaries as described above.

Data Source: Various including Corps of Engineers, St. Lawrence Seaway Authority, shippers and ports.

Scope: Activity for grain commodities as reported to AMS.

Availability: 4-page weekly report available within 2 weeks

Comments:

### Freight Demand Characteristics

Commodity: Total grain; wheat, corn, and soybeans for export sales and barge movements.

O/D: Not available

Routing: U.S. coast for exports; inland river lock for barge traffic.

Shipment: Total volume (in bushels) inspected for export, tons of barge movements or export sales, carloads (total and delivered to port by coast); average prices

Transport: Modal volume (total rail carloadings and delivered to export ports, barge movement tons); Gulf Coast grain vessel call activity; ship charter rates.

Other:

## APPENDIX D

### FREIGHT TRANSPORTATION SURVEY PROCEDURES AND METHODS

Freight transportation is an integral part of economic activity. Evaluating current freight transportation capabilities and developing plans to meet future freight transportation demand is contingent on having the data and information necessary to make informed decisions. However, there are few, if any, procedures in place at the federal, state, or local level for the collection of the data and information needed. This appendix provides an overview of methods and procedures employed to collect data and information useful in the analysis and forecasting of freight demand. A further examination of data collection methodology is being conducted as part of a recently initiated NCHRP study, *Multimodal Transportation Planning Data* (Project 8-32(5)), being performed by Jack Faucett Associates.

As part of an early task of our study, an extensive survey/interview program was conducted by the study team with federal and state agencies, metropolitan planning organizations, ports, and airports. Among the questions asked was "What are the principal sources of freight data compiled and/or used by your agency?" The survey results revealed that states, MPOs, ports and airports utilize and, in large part, rely on data and information compiled and published by federal agencies and/or private and commercial sources for data related to freight movement and freight transportation. The principal state-level transportation databases are primarily truck-related and include vehicle registration, operating authority, fuel and other taxes, and safety. Data on commodity movements and origin/destination are limited as to the level of detail required or desired for forecasting and planning purposes. Of those agencies which do collect primary data, most do so sporadically or infrequently.

Gathering primary data on freight and traffic flows at the federal, state or local level is a costly and time-consuming process and data collection programs are rarely a funding priority. In addition, the dramatic regulatory, technological, and operating changes within the transportation industry have rendered many traditional and often modal-oriented data collection programs inappropriate for intermodal/multimodal planning purposes. While the freight movement and origin/destination data available from federal and commercial sources for the rail, water, and air modes are often adequate for planning purposes at the state and local level, comprehensive and detailed information on truck movements is inadequate in most cases. Because the vast majority of all

freight movements at some point move by truck, such information is critical to effectively planning and providing the infrastructure and facilities needed for efficient intermodal movement and transfer of freight. Accordingly, while the methods and procedures discussed herein could apply to all modes, there is particular focus on gathering data on truck movements.

A critical component of any data collection effort is survey sampling, since it would be virtually impossible and prohibitively expensive to collect data from every transportation carrier, facility, shipper, or location. It is much less expensive to gather data from a sample of the population, which, if drawn accurately, can provide reliable results. While there is no definitive way of selecting a sample size, generally the larger the sample, the more reliable the sample estimates.

In determining the optimal sample size, one must consider not only the survey design, but also logistics of implementing the survey. In the case of intercept, telephone surveys or personal interviews, this would include factors such as the number of interviewers, length of survey, traffic flow, time frame, location, etc. In the case of mail surveys, this would include reliability of mailing lists and points of contact, method of transmission and return (mail vs. fax or e-mail), etc.

A recent study prepared for the Metropolitan Transportation Commission (MTC) in Oakland, California<sup>1</sup> provides a comprehensive review of what has and is being done at the state and local level with regard to truck surveys and truck travel demand forecasting. While the methods and procedures discussed in the report related to actual truck travel surveys, most can also be applied to other modes of transport. The primary collection methods include:

- Telephone interviews generally yield a high response rate and facilitate follow-up; however, the survey must be conducted during normal business hours; the respondent may have limited time, data, or information available at the time of the initial contact and may be unwilling to return calls or accept follow-up calls; and may require mail or fax follow-up to verify data and infor-

<sup>1</sup> Samuel W. Lau, *Truck Travel Surveys: A Review of the Literature and State of the Art*, prepared for the Metropolitan Transportation Commission, Oakland, California, January 1995. This report includes an extensive bibliography as well as 13 sample forms used in truck surveys throughout the U.S. and Canada.



mation recorded by the interviewer. Depending on the sample size, time frame, and nature of the survey, the number and skills of the interviewers may make this method too costly.

- Mailout/mailback surveys are less costly, but generally have a lower response rate. The reliability and completeness of the response may depend on whether the survey form finds its way to the appropriate individual within an organization or company. This method also requires some type of tracking so that one can easily identify and follow up with non-responses. The follow-up may be done by telephone/fax, postcard reminders, or re-mail of the survey package.
- Combined telephone-mailout/mailback will generally yield a higher response rate than mailout/mailback; however, it is likely to be more expensive. One variation of this procedure involves contacting a company by telephone to advise that a survey form is being mailed and identify the appropriate department/individual to which the form should be addressed. In this manner, one can often determine whether a company is likely to respond and adjust the sample size accordingly. One can also utilize broadcast fax to distribute survey forms, although the quality of the transmission may affect the response.
- Roadside/intercept interviews are often used for truck surveys and generally yield a high response rate, offer better control over the sample, and enable the interviewer to respond to any questions the respondent may have when completing the form. The disadvantages of this method include potential disruption to traffic flow, safety hazards for the interviewers, less ability to follow up with respondents, the effect of factors such as weather, time of day, and lighting on implementation, and restricting the sample to a particular location rather than an entire region.
- Personal interviews are the most costly method of conducting surveys and generally involve a smaller, more select or targeted sample. This approach is particularly appropriate when assessing the feasibility of new or expanded facilities. Interviews with shippers to ascertain the demand for such facilities and interviews with carriers to determine whether they would consider providing/expanding service to/from the facility are critical to the decision-making process.

A paper presented at the 1995 Transportation Research Board (TRB) Annual Meeting<sup>2</sup> provides a comprehensive blueprint for gathering truck movement data and information on a statewide basis. The paper describes the methodology and procedures employed to interview a total of 30,000 truck drivers at 28 weigh stations located throughout the State of Washington. The interviews were conducted in each of four seasons to take into account seasonal differences in truck

movements. The researchers established a goal of conducting 300 surveys over a 24-hour period at each survey site, and ultimately interviewed approximately 7500 drivers during each of the survey periods. The following summarize the significant aspects of the methodology and procedures:

- The survey gathered information on vehicle configuration, origin and destination, highway route, cargo type, vehicle and cargo weight, and the use of intermodal facilities. Identification of routes was accomplished with the aid of a map attached to each questionnaire. The primary data collection sites included permanent weigh stations, ports of entry, and border crossings along major interstate and state highway corridors. The questionnaire was designed so that it could be completed within three minutes, with about half the questions answered by the interviewer through direct observation of the vehicle. Terms (such as "payload weight") that were not readily understood by truck drivers were identified during a pretest and replaced by simpler language (e.g., "the weight of the cargo being carried").
- Interview teams, totaling up to 90 people on any given day, were recruited from community service clubs, comprised of individuals with personal knowledge of local roads, industries, and transportation facilities. They were trained, supervised, and periodically evaluated by members of the project management team. Training included instruction in personal interviewing techniques, how to accurately identify different truck and trailer configurations, and safety procedures and requirements. Each team was provided with equipment ranging from clipboards and pens to reflective safety vests, headlamps, and hats. Each site was equipped with a survey crew sign and traffic cones. Cooperation and assistance was provided by uniformed Commercial Vehicle Enforcement Officers and Customs officials, helping to ensure the safety of the interviewers and, by directing selected trucks to the interview site, creating an atmosphere that produced a high response rate. Trucks were selected, on the basis of the sequence in which they were weighed, at a rate that made it possible for the interview to begin without delay.
- At each site, a member of the project management team was available to check completed questionnaires for accuracy and to address any problem areas with interview personnel. Weather and other unforeseen events also had an effect on the quality of data gathered, with some interviews conducted inside the scale house during particularly inclement weather. In addition, during high-volume traffic periods, there were occasions when enforcement and interviewing activities had to be suspended to enable traffic to clear. There were a few instances where interview activities were suspended for a period of time as a result of nearby construction activity or, in one case, a hazardous material spill.

<sup>2</sup> William R. Gillis, Kenneth L. Casavant, and Charles Howard, Jr., *Survey Methodology for Collecting Freight Truck Origin and Destination Data*, presented at the TRB Annual Meeting, Washington, D.C., January 1995.

## Exhibit D.1. Survey form for evaluating demand for a rail/truck intermodal facility.

NORTHERN EXPRESS TRANSPORTATION AUTHORITY (NETA)  
 Shelby Intermodal Exchange Feasibility Study  
 Market Survey Form - Shipper/Consignees

1. Interviewer \_\_\_\_\_ Interview Date \_\_\_\_\_
2. Interviewee \_\_\_\_\_ Title \_\_\_\_\_
3. Company Name \_\_\_\_\_
4. Address (Street) \_\_\_\_\_  
 City/State/Province \_\_\_\_\_  
 Phone: \_\_\_\_\_
5. Products: \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_
6. Use or interest in Toole County:
  - a. \_\_\_\_\_ TOFC/COFC transfer
  - b. \_\_\_\_\_ Container stuffing/unstuffing (CTS)
  - c. \_\_\_\_\_ Container bulk loading/unloading
  - d. \_\_\_\_\_ Warehouse storage \_\_\_\_\_ regular \_\_\_\_\_ refrig.
  - e. \_\_\_\_\_ Warehouse distribution \_\_\_\_\_ regular \_\_\_\_\_ refrig.
  - f. \_\_\_\_\_ Bulk storage and distribution \_\_\_\_\_ (specify)
  - g. \_\_\_\_\_ Forest products storage & distribution \_\_\_\_\_ (specify)
  - h. \_\_\_\_\_ Other storage, distribution \_\_\_\_\_ (specify)
  - i. \_\_\_\_\_ Manufacturing \_\_\_\_\_ (specify)
  - j. \_\_\_\_\_ other office activity \_\_\_\_\_ (specify)
7. Explain potential use: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Exhibit D.1. (Continued)

8. What products and routings might benefit from transshipment in the Toole County?

<u>Product</u>	<u>Tons</u>	<u>To</u>	<u>From</u>	<u>Conveyance</u>	<u>Point-to-Point Cost</u>
_____	_____	_____	_____	_____	\$ _____
_____	_____	_____	_____	_____	\$ _____
_____	_____	_____	_____	_____	\$ _____
_____	_____	_____	_____	_____	\$ _____
_____	_____	_____	_____	_____	\$ _____
_____	_____	_____	_____	_____	\$ _____

9. Specifically what facilities, costs, conditions, incentives, etc. would cause you to transship through Toole County?

\_\_\_\_\_

\_\_\_\_\_

10. What products, processes or services might benefit from manufacturing, manipulating, administering distributing or marketing in Toole County.

<u>Product</u>	<u>Storage Cost Per Sq. Ft.</u>	<u>Principal Market</u>	<u>Labor Cost Per Hour</u>	<u>Energy Cost</u>
_____	\$ _____	_____	\$ _____	\$ _____
_____	\$ _____	_____	\$ _____	\$ _____
_____	\$ _____	_____	\$ _____	\$ _____
_____	\$ _____	_____	\$ _____	\$ _____

11. Specifically what facilities, costs, conditions, incentives would cause you to locate a facility in Toole County.

\_\_\_\_\_

\_\_\_\_\_

12. Has your organization ever used or considered using a foreign trade zone in the U.S.? \_\_\_\_\_ Yes \_\_\_\_\_ No

Explain: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Exhibit D.1. (Continued)

13. Are any of the raw materials, subassemblies or finished products associated with your operation subject to any of the following in either the U.S. or Canada.

	<u>U.S.</u>		<u>Canada</u>	
Import Quotas	Yes _____	No _____	Yes _____	No _____
Customs duties	Yes _____	No _____	Yes _____	No _____
Assembly with U.S. Components	Yes _____	No _____	Yes _____	No _____
Assembly with Canada components	Yes _____	No _____	Yes _____	No _____
Assembly with components other than from U.S./Canada	Yes _____	No _____	Yes _____	No _____
Display, re-label, re-package or destroy	Yes _____	No _____	Yes _____	No _____

14. Which of your products are subject to highest Customs duties (regardless of the origin)

<u>Product</u>	<u>Annual Tonnage</u>	<u>Custom Duty</u>	<u>Origin</u>	<u>Ultimate Destination</u>
_____	_____	\$ _____ per _____	_____	_____
_____	_____	\$ _____ per _____	_____	_____
_____	_____	\$ _____ per _____	_____	_____
_____	_____	\$ _____ per _____	_____	_____

15. If a foreign trade zone were to be proposed for Toole County, would you provide a non-binding letter of intent to use for the application process? \_\_\_\_\_ Yes \_\_\_\_\_ No
16. If you were to establish an office or operation in Toole County for \_\_\_\_\_, what types of positions or jobs would be established?

	<u>Full Time</u>	<u>Part Time</u>	<u>Contract Full-Time</u>	<u>Contract Part-Time</u>
Officers/Executives	_____	_____	_____	_____
Supervisors	_____	_____	_____	_____
Skilled	_____	_____	_____	_____
Semi-Skilled	_____	_____	_____	_____
Clerical	_____	_____	_____	_____
Labor	_____	_____	_____	_____

**Exhibit D.1. (Continued)**

17. In general, how would you improve facilities and stimulate shipper services in Toole County?

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18. Action items for NETA:

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Return this questionnaire to:

Overall, the effort was highly successful, with a 95% response rate providing data and information for an extensive database of statewide freight and goods movement in Washington.

Exhibit D.1 contains a copy of an interview-survey form used by Leeper, Cambridge and Campbell in a study of demand for a possible rail/truck intermodal facility in Shelby, Montana.<sup>3</sup>

An additional area being addressed by some state and local transportation agencies is the effort to improve and support

data collection programs. Many public agencies have followed the lead of private sector/commercial data providers and are seeking input from the current and potential users ("customers") of the data they collect. For example, the Minnesota DOT recently conducted a "Customer Survey" to determine whether the agency's current data products were adequate to meet the needs of users, whether and to what extent elimination of a particular data product would affect the customer, how current and frequent the data product must be to be useful, and how much historical data is necessary. The goal is to improve existing programs and products to better meet user needs, develop and seek ways for funding new programs and products, and eliminate those which are redundant or no longer useful.

<sup>3</sup> The Northern Express Transportation Authority—Port of Shelby, Leeper, Cambridge & Campbell, Inc., and Thomas, Dean and Hoskins, Inc., *Shelby Intermodal Exchange Facility—A Feasibility Study*, Shelby, Montana, July 1991.

## APPENDIX E

### STATISTICAL FORECASTING TECHNIQUES

Frequently, transportation planners need forecasts of freight data as a basis for a whole range of short-term investment decisions. Indeed, starting a new highway construction project versus a project for the construction of a new intermodal freight terminal may depend upon whether the planner projects truck or rail traffic to growth at a faster pace during the next 5 years. The problem confronting planners is to take available time-series data on the freight traffic in question and develop projections of future volumes or flows. Indeed, the solution to a whole class of practical transportation planning problems involves assessment of future freight traffic demand based on time-series data. Since time-series freight data exist for a number of different types of freight movements, a number of specific transportation planning issues can be answered by using that data.

For example, there are time-series data on the volume of traffic (by commodity) moving on the inland waterway system. These data can be disaggregated to show traffic volumes on particular segments of the system. Planners are frequently confronted with the problem of projecting future traffic volumes on each segment in order to determine whether existing facilities need to be expanded or whether new facilities are, in fact, required in order to meet demand. Planners also have time-series data for truck traffic by highway segment. Again, the issue confronting the planner is to project that traffic into the future in order to decide whether or not existing facilities need expansion or whether new facilities are needed. Airport planners are faced with critical decisions regarding the mix of air freight versus air passenger facilities on their property. In order to assist in making that decision, they need to use time-series data on air freight shipments in order to project future needs. Planners may confront a decision regarding a need for an expansion of an urban intermodal freight terminal. They could use time-series data from the rail waybill database to project future intermodal shipments in their metropolitan area. These represent selected examples of the type of problems facing transportation planners at the state, local, and even national level whose solution can benefit from projections generated from the use of available time-series freight data.

#### E.1 REGRESSION ANALYSIS

Regression analysis is widely used by analysts for empirical estimation and forecasting. Regression analysis involves

identifying one or more independent variables (the explanatory variables) which are believed to influence or determine the value of the dependent variable (the variable to be explained) and calculating a set of parameters which characterize the relationship between the independent and dependent variables.

Assume a variable,  $y$ , is linearly dependent upon three independent variables,  $x^1$ ,  $x^2$ , and  $x^3$  plus some unknown, unmeasurable influence,  $\epsilon$ :

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon$$

Given a sufficient number of observations<sup>1</sup> of  $y$ ,  $x_1$ ,  $x_2$ , and  $x_3$ , the regression will use ordinary least squares (OLS) to estimate values of the true parameters  $\beta_0$ ,  $\beta_1$ ,  $\beta_2$ , and  $\beta_3$  and use these estimates,  $b_0$ ,  $b_1$ ,  $b_2$ , and  $b_3$ , to calculate an estimated value of each observation of  $y$ . This estimate is denoted as  $\hat{y}$ :

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3$$

The regression assumes the unknown term,  $\epsilon$ , has a mean value of zero. The true value of  $\epsilon$  may be non-zero for any given observation. The difference between the observed  $y$  and its estimate,  $\hat{y}$ , is the "error" or "residual" of the estimate. The regression chooses the values of the parameter estimates to minimize the sum of the squared errors<sup>2</sup> of the estimate to produce the "best" fit.

It must be emphasized that, although regression analysis provides the best fit between the independent and dependent variables, this does not mean that the estimated  $\hat{y}$  will be a good estimate of  $y$ . Regression simply guarantees that there is no better estimate of  $y$  based on the given independent variables. If different independent variables are used, the estimate of  $y$  may change significantly. Regression analysis

<sup>1</sup> Observations of dependent and independent variables may be time-series or cross sectional in nature. Time-series data contain a single observation for each variable for each of several time periods or points in time. Examples might be annual volume of freight shipments, annual output per employee, and annual real gross domestic product (GDP). If twenty years' worth of data are collected, there would be twenty observations of shipments, output per employee and GDP. Cross sectional data contain observations across the population at a point in time or during a single time interval. Examples include volume of shipments by state, industry, or firm, in a given year.

<sup>2</sup> The sum of the squared errors =  $\sum_{i=1}^n (\hat{y}_i - y_i)^2$  for  $n$  observations.

provides little guidance as to which variable or variables should be used to estimate  $y$ .<sup>3</sup>

### Ordinary Least Squares Regression

The simplest and most commonly used form of regression analysis is the “Ordinary Least Squares” (OLS) approach. OLS is a single equation estimation technique in which each observation is given equal “weight” or importance in estimating the parameters described above. Advanced forms of regression analysis include weighted least squares, two-stage least squares, and step wise regression.<sup>4</sup> Most packages provide capabilities for one or more of these advanced regression techniques.

OLS is based on several key assumptions. If one or more of these assumptions is violated, it may be necessary to use an advanced estimation procedure to obtain a satisfactory model. OLS assumes:

1. A “one-way causality” exists between the independent and dependent variables;
2. The regression includes all relevant independent variables and excludes irrelevant ones (i.e., the “right regressors” are chosen);
3. The dependent variable can be calculated as a linear function of a specific set of independent variables plus an error term;
4. The expected value of the error term is zero;
5. The error terms have the same variance and are independent of each other (uncorrelated errors);
6. Observations of independent variables do not depend on the sample chosen;
7. No independent variables are linear combinations of other independent variables (no perfect multicollinearity); and
8. The number of observations exceeds the number of independent variables.

Some of these assumptions are essential for using OLS, either because of the implied underlying theoretical relationships (e.g., Assumption 1) or because of the pure mathematical properties involved in minimizing the sum of squared errors (e.g., Assumption 7). Others represent nice, desirable, properties but may be set aside without invalidating the regression results. Methods for identifying violations of these assumptions in an OLS model and the consequences of these violations are discussed in the second subsection below.

<sup>3</sup> There are statistical tests available to assist in determining the “significance” of an independent variable in explaining variation in the dependent variable (the  $t$ -test is most commonly used). However, these tests do not ascertain whether there is a meaningful relationship between the variables or a coincidental correlation. If it is the latter, the model is unlikely to be a reliable forecasting tool, even if it shows a good statistical “fit.”

<sup>4</sup> For further discussion of these and other advanced regression techniques the reader may consult any standard text on econometrics. Particularly good intuitive discussions are contained in Peter Kennedy, *A Guide to Econometrics*, Third Edition, MIT Press, Cambridge, Mass., 1992. For more technical specifications see J. Johnston, *Econometric Methods*, Third Edition, McGraw-Hill, New York, 1984.

### Model Specification and Testing

The key to a good OLS model lies in the theoretical relationship between independent and dependent variables, as described in assumptions one and two above. Johnston<sup>5</sup> provides a very useful description of the process of building and evaluating a regression model. He emphasizes the following steps:

1. Talk with experts to become knowledgeable about the problem being modeled;
2. Become familiar with the relevant institutions and the constraints they impose on the problem;
3. Look at the data to gain a better understanding of the problem or process being modeled and the limitations of the data;
4. Base the model on sound economic theory;
5. Avoid “data mining” in which models are selected on the basis of high  $R^2$  or high  $t$ -values while ignoring other, more fundamental, relationships; and
6. Use the judgment of an “experienced critic” to shape the model.

Building a good regression model requires good data, a thorough understanding of the expected relationships among variables, and the time to test the various outcomes against a range of criteria. Among the most commonly used tests are:

1. The  $t$ -test which assesses the likelihood that the estimated parameter,  $b_n$ , is significantly different from zero. If the parameter equals zero, the corresponding independent variable,  $x_n$ , provides no information in the given specification; i.e., it does not explain any of the variation of the dependent variable. Most software packages provide the  $t$ -value for each independent variable. The  $t$ -value can then be compared with the critical value of the Student’s  $t$  Distribution table, found in statistics books.<sup>6</sup> If the absolute value of the computed  $t$  exceeds the table value for the appropriate number of degrees of freedom<sup>7</sup> at the desired confidence level, the parameter estimate is considered to be significantly different from zero. To be significant at the five percent level,<sup>8</sup> for example, the  $t$ -value generally must exceed a value close to two. It is often possible to test the significance of the  $t$ -value without referring to the table of values; absolute values of  $t$  above three will always be considered significant while those below one will always be considered insignificant. The  $t$ -test is not valid, however, when autocorrelated errors are present (see discussion below).

<sup>5</sup> *Op. cit.*, pp. 498–510.

<sup>6</sup> E.g., see Stephen Kokoska and Christopher Nevison, *Statistical Tables and Formulae*, Springer-Verlag, Inc., New York, 1989.

<sup>7</sup> The degrees of freedom for a particular equation equal the number of observations (sample size) minus the number of parameters estimated.

<sup>8</sup> Significance testing must be based on a level of confidence. The five percent level represents 95 percent confidence that the result is true.

2.  $R^2$ , the *coefficient of determination*, measures the “goodness of fit,” i.e., the amount of the variation in the dependent variable explained by the independent variables.<sup>9</sup> Many researchers search for the highest possible value of  $R^2$ , regardless of the sensibility of the model they have developed. This is the wrong approach to model building. One glaring problem with this approach is that the mathematical nature of the  $R^2$  is such that  $R^2$  cannot fall when an additional variable is added to a regression and may rise, regardless of the quality of the variable. The analyst who wants a high  $R^2$  needs only to add more variables, whether they are sensible or not. A further problem with  $R^2$  is that time-series regressions typically produce high values of  $R^2$  because the time trend is a strong determinant of both independent and dependent variables.
3. The adjusted<sup>10</sup> measure of  $R^2$  corrects for the number of observations and the number of independent variables and may fall when a new, meaningless variable is added to the regression. Although a better measure than  $R^2$ , the adjusted  $R^2$  still cannot distinguish between a model that fortuitously fits the data well and one which has identified the true underlying relationships. Analysts are advised to ignore the  $R^2$ , adjusted or not, when building their models.
4. The *standard error of the estimate* (SEE), which provides a better indication of how well the independent variables explain the variation in the dependent variable. Adding more variables may reduce or increase the SEE.

For a more detailed discussion of the range of tests and how to interpret their results, consult any econometrics textbook.<sup>11</sup>

### Violating the OLS Assumptions

The assumptions identified at the beginning of this section are often violated in practice, and the tests identified above are often inadequate to identify the problem. Exhibit E.1 summarizes the effect(s) of each violation on the ability of OLS to calculate parameter estimates and the usefulness of the model's results.

<sup>9</sup>  $R^2$ , also known as the “coefficient of determination,” is calculated as the ratio of the regression sum of squares to the total sum of squares and its value ranges between zero and one. The total sum of squares is the total variation of the dependent variable around its mean,  $\sum (y - \bar{y})^2$ ; the regression sum of squares is the variation of the dependent

variable “explained” by the regression,  $\sum (y - \hat{y})^2$ .

<sup>10</sup> Adjusted  $R^2$ , also known as “ $\bar{R}^2$ ,” is calculated as:

$$R^2 - \frac{K-1}{T-K} (1 - R^2)$$

where  $K$  is the number of independent variables and  $T$  is the number of observations.

<sup>11</sup> One of the less technical textbooks is Harry H. Kelejian and Wallace E. Oates, *Introduction to Econometrics: Principles and Applications*, Third Edition, Harper & Row, New York, 1989.

Although Exhibit E.1 shows that only two violations interfere with OLS' ability to perform the calculations, there are several situations in which the parameter estimates or the estimate of the dependent variable (or both) are less than ideal. If the parameter estimates are questionable, the analyst would have little confidence in describing the influence that a change in a particular independent variable's value would have on the value of the dependent variable. However, the estimate of the dependent variable may still be adequate, allowing for the interactions among the independent variables and the error term. The model may be a good forecasting tool. If the model does a poor job of estimating the dependent variable but is adequate in its parameter estimation, the model may be useful for simulation studies. It is important, therefore, to know the intended purpose of the model before deciding whether a violation of the basic assumptions renders the model unfit for that purpose.

Perhaps the most difficult assumptions to satisfy are the first two, namely that the model is using the “right” independent variables to explain the variation in the dependent variable. One can never be sure that there are no other pertinent influences on the dependent variable. Furthermore, even if statistical testing points to the need for an additional variable, there is no standard procedure for identifying the missing variable. It is easier to reject potential existing variables than to find and incorporate new ones. The model builder is advised to choose independent variables that are consistent with economic or other appropriate theory as a first step.

Regression analysis assumes a “one-way causality” among the variables: the independent variables must affect the value of the dependent variable but the dependent variable cannot affect the values of the independent variables. In some situations this is clearly the case, but in other situations the relationships may be tangled. Consider the following examples:

1. The number of umbrellas carried in a city on a given day depends on the region's population and the expected probability of rain. Population does not depend upon the number of people carrying umbrellas nor does the probability of rain. One-way causality is well established in this case.
2. The demand for a new car depends in part on the vehicle's price, but the vehicle's price is determined in part by the aggregate demand for cars. In this case, there is a simultaneity between demand and price. OLS would not provide a good basis for forecasting demand if vehicle price is used as an independent variable. More advanced techniques<sup>12</sup> might be used in this case.

OLS is a linear estimator and assumes that the variables are linearly related. OLS will still calculate parameter estimates if the true relationship is nonlinear but the estimates

<sup>12</sup> See Kennedy (*op. cit.*, pp. 157–163) for a good discussion of indirect least squares, instrumental variables, two-stage least squares, and limited information, maximum likelihood techniques which might be used to overcome a simultaneous equation problem.



**Exhibit E.1. Consequences of violating the basic OLS assumptions.**

<b>Assumption</b>	<b>Effect on Ability to Calculate Parameters</b>	<b>Effect on Quality of Parameter Estimates</b>	<b>Effect on Quality of the Estimate of the Dependent Variable</b>
1. One-way causality	None	None	Not suitable for forecasting because no meaningful relationship has been identified
2. The "right" regressors are used	None	May cause bias	May produce larger errors; less reliable
3. The dependent variable is a linear function of the independent variables	None	Biased	Poor estimate unless the particular sample used for estimation is nearly linear; unsuitable for forecasting
4. The expected value of the error is zero	None	Estimate of the intercept is biased; other parameter estimates may be biased or unbiased	May be adequate for estimation and forecasting
5a. Error terms have some variances (homoscedasticity)	None	Parameter estimates unbiased but no longer have minimum variance	May be adequate but can be distorted by the undue influence of some of the observations
5b. Errors are uncorrelated with each other	None	Parameter estimates unbiased but <i>t</i> -test invalid to determine parameter significance	May be adequate for estimation and forecasting but using an autocorrelation correction technique is advised
6. Observations of the independent variable are fixed even with repeated sampling	None	Biased, especially if autoregressive model	May still provide good estimation and forecasts
7a. No variables are linear combinations of other independent variables	OLS cannot perform calculation; matrix cannot be inverted		
7b. No collinearity	None	Parameter estimates unbiased but large variances make them unreliable	Estimation and forecasting may be reliable
8. Number of observations	OLS cannot perform calculation		

will not be useful for forecasting. It is critical that the model builder using OLS specify a linear relationship.

The linearity of the relationship can often be examined through simple scatter plots of the data and a nonlinear relationship can sometimes be “linearized” by transforming the variables in a specific manner. The logarithmic transformation is probably the most commonly used. It is appropriate when the growth rates of the variables are related in a linear manner. When Assumption 4 is violated and the expected value of the error term is not zero, the estimation of the intercept,  $b_0$ , will be biased. Omitting a key, relevant independent variable from the regression is often responsible for violating Assumption 4. The error term will reflect the variation in this missing variable and the mean of the error term will likely not be zero. This is, however, more properly viewed as a violation of Assumption 2.

Assumption 4 can also be violated if the dependent variable is restricted to a limited range of values, thereby limiting the potential size of the error. The nature of the study may make this truncation unavoidable. For example, a study of low-volume roads would exclude observations of average annual daily traffic (AADT) above a cutoff value. This truncation ensures that the error terms would not be large enough to cause the dependent variable to be less than the AADT cutoff, leading to a truncation of the upper end of the error distribution. The expected value of the truncated error distribution is negative, not zero.

The two major problems resulting from violating Assumption 5 are heteroscedasticity (errors with different variances) and autocorrelated errors. Heteroscedasticity often occurs when higher values of the independent variable are associated with larger variances of the error. This may be an entirely logical outcome. For example, if personal VMT depends on income, at higher levels of income there is more opportunity for spontaneous discretionary travel. This spontaneity would produce a larger variability in observed VMT, and, consequently, a greater variability in the error of the estimate. Several large values of the independent variable could shift the regression line, weakening its predictive value. A weighted least squares approach (“generalized least squares”) is often used instead of OLS when heteroscedasticity is present to reduce the influence of the observations that are expected to have large errors.

Autocorrelated errors exist when the errors are not independent of each other. The Durbin-Watson test is commonly used to detect the presence of autocorrelated errors although the test is not reliable when lagged values of the dependent variable are used as independent variables. The presence of autocorrelated errors reduces the reliability of the OLS estimate.

Autocorrelated errors are often found in time-series data because the effect of a disturbance usually persists beyond the period in which it occurs. For example, the Mississippi River flooding affected travel when it occurred and in the months following. If a model overestimated barge traffic dur-

ing the flood (i.e., its error was positive), it likely would have underestimated barge traffic during the several months following. The errors would all be related to the flood and would be correlated with each other. More generally, there are almost always some exogenous influences that have been omitted from a model which tend to increase (or decrease) the dependent variable for several consecutive time periods, thus producing a series of negative (or positive) errors for these time periods.

Autocorrelated errors may also result from model misspecification, especially the omission of a relevant variable, a violation of Assumption 2. If the model appears to be specified correctly, techniques such as the Cochrane-Orcutt method can be used to reduce or eliminate the autocorrelation.

Assumption 6 specifies that observations of the independent variable are fixed even when the sampling is repeated. This assures that the independent variables are uncorrelated with the error terms. When this assumption is violated, the OLS estimate will be biased. Assumption 6 will be violated when the independent variables are improperly measured or when a model is autoregressive. In the latter case, the current value of the dependent variable is influenced by its own past values which were, in part, determined by the error term in those periods. Despite their bias, autoregressive models can still be useful for estimation.

Although not technically a violation of Assumption 7, strong collinearity among the independent variables may still weaken a model. If there is an approximate linear relationship among the independent variables (strong but not perfect multicollinearity), OLS will run but the variances of the parameter estimates will be large, reducing the confidence one should place in the resulting estimates of the dependent variable. Various tests exist to determine whether multicollinearity is present.<sup>13</sup> Even if multicollinearity is found, the analyst may choose to do nothing if the model appears to be satisfactory.<sup>14</sup> Other approaches to multicollinearity include obtaining more observations since a larger sample size helps to reduce variance by providing additional information to the regression. The analyst may also want to consider dropping one of the collinear variables although this may result in a specification error and biased estimates of the remaining parameters if, in fact, the true coefficient of the dropped variable is not zero.

## Forecasting with an OLS Model

Although much of the emphasis in this discussion has been on building a satisfactory model to explain the variation in a variable of interest, the purpose of many models is to provide decision-makers with useful forecasts. A well-built econo-

<sup>13</sup> These include an analysis of the correlation matrix and the use of condition indices.

<sup>14</sup> Kennedy (*op. cit.*, p. 181) discusses two “rules of thumb” which suggest doing nothing: all  $t$  statistics greater than 2; or, the  $R^2$  from the regression exceeds the  $R^2$  of any independent variable regressed on the other independent variables.

metric model may or may not produce “good” forecasts. This section discusses some of the pitfalls of forecasting.

In order to use an OLS model for forecasting, it is necessary to provide future values (forecasts) of each independent variable. Developing good forecasts of the independent variables may require additional model building, extrapolating past trends, or acquiring forecasts from outside firms or agencies. When the data are trendless, the “naïve” forecast that the next period’s value will equal the current period’s value, may prove satisfactory. To the extent that estimated or forecasted future values of the independent variables contain errors, the forecast of the dependent variable will be weakened.

A second problem in forecasting involves the stability of the parameter estimates. If the parameter estimates are extremely sensitive to the data sample used in the regression, the model’s structure may change over time. Forecasting models implicitly assume that the parameter estimates identified by OLS will be invariant over time. This is rarely true. Statistical tests, such as the Chow test, are helpful in analyzing the structural stability of a model. Validation techniques such as estimating the regression over a portion of the sample and allowing it to “forecast” the remaining values of the dependent variable are also helpful in assessing the usefulness of the model for forecasting.

A third problem in forecasting involves the unforeseen disturbances which can cause any forecast to miss its mark. Examples are found in natural disasters (earthquakes, fires, floods), supply shocks (e.g., petroleum), international disturbances, and significant policy changes. The estimated parameters have no knowledge of these events and the manner in which they alter the relationship between independent and dependent variables.

A fourth problem in forecasting involves the range of the independent variables’ future values. If the values of the independent variables move outside the range from which the model established its parameter estimates, there is an increasing likelihood that the forecast will have a large error.

Forecasts which fail to predict the level of the dependent variable can still be useful if they forecast the direction of change. Regression models are more likely to forecast “turning points” than the simple ARIMA models which extrapolate past trends.

Regression models can also be used to assess the sensitivity of the dependent variable to possible changes in one or more independent variables. These simulations, sometimes called “what if?” analyses, are not true forecasts but provide a range of outcomes to consider under different input assumptions. By assigning probabilities to the potential values of the independent variables, an expected future value can be derived.

## E.2 EXPONENTIAL SMOOTHING

Time-series data frequently involve some short-term fluctuations, or up and down movements in the data, that seem to deviate from an established pattern. One type of time-series forecasting technique involves the “smoothing” out of these

short-term fluctuations by identifying the underlying pattern in the data and extrapolating the underlying “smooth” pattern into the future. These exponential smoothing techniques remove random fluctuations and establish the underlying pattern in the time-series. All “exponential smoothing” techniques use some form of weighted average of past observations to smooth out data fluctuations. The differences in methods involve how much weight should be given to the most recent observation versus the more distant data in generating the smoothing effect.

Specifically, “exponential smoothing” methods answer the following questions: (1) what weight should be given to the most recent value in the series (in most time-series data, each value is positively correlated with its preceding value—i.e., positive autocorrelation)?; (2) do the data lack any pattern such that the best value to use in developing projections is the overall average of the entire series with no special consideration given to the more recent data?; (3) what is the general trend in the data?; and (4) do the data reflect any seasonal pattern?

The “exponential smoothing” procedure in SPSS Trends<sup>15</sup> estimates four parameters to control for the relative importance of recent observations in developing predictions. One parameter is used in all applications of the procedure, while the researcher selects among the other three parameters depending upon whether the data shows evidence of trends or seasonality. The four parameters are:

1. The alpha parameter—controls the weight given to the most recent observation in determining the overall level and is used in all time-series estimations. (When alpha is one, the single most recent observations is used exclusively in the smoothing process; when alpha is zero, old observations count just as heavily as more recent ones in the process.) This parameter is referred to as the smoothing constant.
2. The gamma or trend parameter—used only when the series shows a trend. (When the gamma is high, forecasts are based on trends estimated from most recent points in the series; when the gamma is low, forecast uses trend based on entire series with all points counting equally.)
3. The delta parameter—used when the data show a seasonal pattern. (When delta is high, the seasonality adjustment is based on the more recent time periods; when delta is low, the seasonality adjustment is based on the entire series with all time periods counting equally.)
4. The phi parameter—used in place of gamma when the series shows a trend and that trend is damped, or dying out. (High values of phi provide rapid response in projections when any indication that the trend is dying out

<sup>15</sup> “An Inventory Problem: Exponential Smoothing,” Chapter 4 of *SPSS for Windows, Trends*, Release 6.0, SPSS, Inc., Chicago, IL., 1993. See also “Smoothing and Extrapolation of Times Series,” Chapter 14 of Robert S. Pindyck and Daniel L. Rubinfeld, *Econometric Models and Economic Forecasts*, McGraw-Hill, New York, NY, 1991.

is given, while low values of phi estimate damping of the trend from the entire data series.)

In the “exponential smoothing” procedure within SPSS Trends, the researcher can initially generate a simple data smoothing operation through the application of a smoothing constant—i.e., the alpha parameter. SPSS Trends will evaluate the range of alpha values and recommend a value for the model with the lowest “sum of squared errors.”

In most applications, however, the researcher is confronted with a more complicated problem that would benefit from a specification of one or more additional parameters. The underlying data might have either a growth or trend component or, alternatively, a seasonal component. In SPSS Trends, the exponential smoothing procedure provides the flexibility to handle each of these situations. The routine can estimate both an alpha and a gamma parameter to achieve minimum error and generate a corresponding smooth curve and projections based on the estimated parameters. This procedure is based on Holt’s exponential smoothing routine. If, however, the researcher suspects the data involve both a trend and a seasonal component, the routine can estimate three parameters—alpha (the smoothing constant); gamma (the trend parameter); and delta (the seasonal parameter). Again, the model will evaluate a range of values for each of the parameters and recommend values for each based on the achievement of a minimum sum of squared errors.

The “exponential smoothing” procedure establishes the underlying pattern of the data based on the combination of parameters specified by the researcher and uses that pattern to make projections of the time-series data into the future. The exponential smoothing procedure in SPSS Trends includes a number of features to facilitate its use by planners. It adds two new series to the existing time-series data for each application. The first additional series contains the predicted values resulting from the exponential smoothing and the second contains the error terms. These data can be plotted against the actual time-series data to show how the smoothed data compare to the original.

In addition, the package enables the researcher to develop a plot of the residuals for examination in order to establish whether a pattern exists in the residuals. Indeed, the residuals should be randomly distributed. If they display a pattern, then the model is, indeed, inadequate.

Finally, the procedure can provide either one-step or n-step ahead forecasts based on projection of the “smoothed” underlying pattern into the future. The researcher can specify the number of time periods beyond the data for which a projection is requested. Of course, the “exponential smoothing” routine is most appropriate for the short-range forecasting situation.

### E.3 LEADING INDICATOR REGRESSION

The curve fitting procedure does not make any assumptions about why the time-series curve has the particular modeled shape. Indeed, the curve fitting procedure may indicate that the time-series data best conform to a linear model and that, indeed, the linear model provides very close predictions of the time-series in the validation period. However, there are many instances in which researchers believe that the time-series data, i.e., the modeled variable, is closely related to another time-series variable. In fact, the related data series may lead or provide a good prediction of the time-series variable, i.e., the modeled variable. Thus, if researchers know the value of the lead or indicator variables at the current moment, they will be able to develop predictors for the “modeled variable” at some specified point in the future as indicated by the lead time. In fact, the indicator variables will be of most value if they lead or predict values of the “modeled variable” in the future.

#### Selecting a Lead Variable

The following example of relevance to a transportation planner will illustrate the point. A need might arise to predict the level of household goods shipments on a national or regional basis. The future levels of such shipments might establish the need for additional drivers or, perhaps, new facilities. While curve fitting procedures might provide future estimates of household goods shipments, there may be reason to believe that other independent variables will provide “leading indications” of household goods shipments in the future. Indeed, a recent investigation showed that sales of existing homes and retail sales of new automobiles lead by four months the number of individual household goods shipments. Thus, the model can predict household goods shipments four months into the future based on sales of existing homes and retail sales of automobiles in the current month.

SPSS Trends provides the researcher the means to evaluate the appropriateness of independent explanatory variables, determine an appropriate lead time for each variable and provide the actual estimation of the variable’s effect on the dependent variable—i.e., determine the statistical coefficients specifying the relationship between auto sales, new home sales and household goods movements.

#### Determining Lead Time

The leading indicator regression depends critically on determining an appropriate leading indicator variable and establishing the appropriate lead time. The leading indicator regression procedure within SPSS Trends provides all the necessary tools to make an appropriate analysis. The establishment of an appropriate lead time between an indicator variable and the time-series variable of interest, the depen-

dent variable, requires an examination of a cross-correlation function—i.e., the correlation between two time-series at the same time and also with each series leading by one or more lags. By analyzing a cross-correlation function between two series, researchers can see the lag at which they are most highly correlated.

However, the use of the cross-correlation procedure requires that the two time-series variables, the dependent modeled variable and the indicator variable, are stationary—i.e., each variable's mean and variance stay at about the same over length of the series. For variables with a gradually increasing value over the time-series, an effective way to make the series stationary is to difference it. Taking differences means replacing the original time-series by the differences between adjacent values in the series. The leading indicator regression procedure provides for differencing of time-series data (for one or more differences) and the calculation of a cross-correlation function between the differenced variables.

Once the cross-correlation function is examined to select an appropriate lead time indicator, the SPSS routine can automatically alter the database so that each value of the selected lead time indicator variable is matched with the appropriate value of the dependent or modeled variable during both the historical and validation periods. Thus, if the indicator variable leads the dependent variable by three months, then a new variable is created in which the first value of the indicator variable is matched with the fourth value of the dependent variable.

The procedure then enables the researcher to calculate a regression between the dependent time-series variable, the “modeled variable,” and the lead-indicator independent variable. The regression establishes a coefficient of impact of the lead variable on the value of the dependent variable. The entire regression equation is used to produce predicted values of the dependent variable during the historical period, the validation period, and a future period as well.

### Adjusting for Autocorrelation

One of the assumptions made in regression analysis is that the residuals or errors from regression are uncorrelated among themselves. When important explanatory variables are omitted from a regression analysis, autocorrelated residuals commonly occur. When residuals are strongly autocorrelated, the significance levels reported for the regression coefficients are wrong and the R-squared value does not accurately summarize the explanatory power of the independent variables. Time-series regression frequently violates the assumption of uncorrelated errors, since it is difficult to include all the important explanatory variables in the regression.

One way to explain the problem is to note that the time-series regression involves use of dependent and independent variables that most probably have trends, either up or down. The two time-series variables with trends will correlate simply because of the trends regardless of whether the two vari-

ables are casually related or not. What the researcher wants to know is whether the two variables are related apart from a similarity due to autocorrelation. Thus, it becomes necessary to remove the autocorrelation prior to model estimation.

The leading indicator regression package within SPSS Trends provides information researchers can use to determine the presence of autocorrelated errors in the time-series regression and procedures to correct for these errors. Autocorrelation among errors is most frequently determined by reference to a residual analysis statistic, labeled the Durbin-Watson Statistic, produced as part of the regression output. Values of this statistic range from zero to four, with values less than two indicating positively correlated residuals and values greater than two indicating negatively correlated residuals. Statistical tables indicate whether a given Durbin-Watson statistic is statistically significant given the sample size. Statisticians recommend that researchers review not only a Durbin-Watson statistic and determine its statistical significance, but also examine statistical plots of residuals from a regression against the predicted values and also against each of the predictor variables.

The SPSS procedure provides the researcher with three approaches to removing autocorrelation: two algorithms (Prais-Winsten and Cochrane-Orcutt) transform the regression equation to remove the autocorrelation. The third method uses a maximum likelihood method for removing autocorrelation. Regardless of the removal procedure, the program provides a new estimated model with autocorrelation removed. The new model includes estimates of the impact of each of the predictor variables on the “modeled” or dependent variable as well as predicted values of the dependent variable in the historical and validation period. Finally, the coefficients from the equation can be used to make projections into the future for the “modeled variable.”

## E.4 ARIMA MODELING

In developing regression forecasts based on indicator variables, the planner must have a very clear idea regarding the variables that might be causally linked with the “modeled” variable of interest. However, in many practical situations, the planner lacks such information or, in some instances, does not have adequate time-series data for the indicator variables. While such circumstances might dictate the use of an exponential smoothing procedure or a curve estimation regression, there is a technically sophisticated time-series modeling approach that builds forecasts from more inclusive and simultaneous analysis of complex past patterns in the time-series than is achievable with application of either the exponential smoothing or curve estimation regression approach. This class of models is called the Box-Jenkins ARIMA Models.<sup>16</sup>

<sup>16</sup> “A Quality-Control Chart: Introduction to ARIMA,” Chapter 6 of *SPSS for Windows, Trends*, op. cit. See also “Box-Jenkins ARIMA Type Forecasting Models,” Chapter 7 of J. Holton Wilson and Barry Keating, *Business Forecasting*, Richard D. Irwin, Inc., Boston, MA., 1994, pp. 305–361.

ARIMA models process a great deal of information from time-series data, but require the researcher to specify only a minimum number of parameters. ARIMA models are highly flexible and compare a wide variety of alternative models in developing the “best” or “correct” model for the time-series data. Indeed, the Box-Jenkins ARIMA models have come to be quite highly regarded and results from them carry a greater degree of acceptability than do models based on either exponential smoothing or curve estimation procedures.

The *SPSS Trends* routine provides the researcher with the tools to specify and evaluate the ARIMA model. Based on the results provided, the researcher can choose the model with the “best fit” and use it to develop projections of the modeled time-series data into the future.

### ARIMA Parameters

ARIMA stands for AutoRegressive Integrated Moving Average based on the model’s three components. The general model (not considering seasonality) is written as ARIMA ( $p, d, q$ ), where  $p$  is the order of autoregression,  $d$  is the degree of differencing, and  $q$  is the order of moving average involved. Researchers specify levels for each of these parameters according to the guidelines established in the ARIMA module of *SPSS Trends*. The following paragraphs discuss in turn each of the parameters and their specification process.

The  $p$  parameter is the order of autoregression. In any autoregressive process, each value is a linear function of the preceding value or values. In a first-order autoregressive time-series model, only the single preceding value is used in model building; in a second-order process the two preceding values are used in building a model; and so on. The coefficient for the autoregressive parameter usually is greater than  $a-1$  and less than  $a+1$ , indicating that the influence of earlier observations dies out exponentially. In a first-order autoregressive process, the current value is a function of the preceding value, which is in turn a function of its preceding value. Thus, “each shock or disturbance to the system has a diminishing effect on all subsequent time periods.”

The  $d$  parameter is the differencing parameter, providing adjustments needed to make the time-series data stationary. Time-series data are stationary when two consecutive values in the series depend only on the time interval between them and not on time itself. A time-series with a constant mean value over time is consistent with this notion. However, “real-world time-series are most often nonstationary; that is, the mean value of the time-series changes over time, usually because there is some trend in the series so that the mean value is either rising or falling over time.” The nonstationary properties need to be removed from time-series data prior to an attempt at specifying the model.

Indeed, time-series data often reflect the cumulative effect of some process. “The process is responsible for changes in

the observed level of the series, but is not responsible for the level itself. Inventory levels, for example, are not determined by receipts and sales in a single period. Those activities cause changes in inventory levels. The levels themselves are the cumulative sum of the changes in each period. A series that measures the cumulative effect of something is called integrated series. You study an integrated series by looking at the changes or differences from one observation to the next. The differences of even a wandering series often remain fairly constant.”

As noted in the discussion of the cross-correlation between a dependent variable and a leading indicator variable, differencing is a common approach to bringing about stationarity to a data series. The researcher can specify a differencing parameter of either 1, for first-differences, or 2, for second-differences.

The third ARIMA parameter is  $q$ , the order of the moving average. In a moving average process, each value is determined by the average of the current disturbance (i.e., error term) and one or more previous disturbances. The order of the moving average process specifies how many previous disturbances are averaged into the new value.

It is important to differentiate between the autoregressive parameter and the moving average one. “Each value in a moving-average series is a weighted average of the most recent random disturbances (i.e., error terms), while each value in an autoregression is a weighted average of the recent values of the series. Since these values in turn are weighted averages of the previous ones, the effect of a given disturbance in an autoregressive process dwindles as time passes. In a moving-average process, a disturbance affects the system for a finite number of periods (the order of the moving average) and then abruptly ceases to affect it.”

### Steps in Using ARIMA

ARIMA modeling involves three distinct phases: identification of the underlying processes of the time-series data through specification of the three parameters; model estimation based on the specified parameters; and model diagnosis. The researcher can use the diagnosis to re-specify the parameters and re-estimate the model until the model is satisfactory. The ARIMA process is iterative and highly flexible.

The identification of the values of the three parameters involves a systematic procedure. Since the identification process for both the autoregression and the moving average parameters requires stationarity, a researcher must transform the data series, if necessary, in order to obtain a stationary series. The most frequent method of obtaining a stationary series for time-series data is differencing. The selection of a first or second-order differencing results in the determination of the  $d$  parameter in the ARIMA identification process. This parameter is most frequently either a zero or a one. It should be noted that while differencing is the most common method of data transformation, the ARIMA routine in *SPSS Trends*

provides for logarithmic and square-root transformations—useful in the situation in which there is more short-term variation where the actual values are large than where they are small.

Once the differencing parameter is identified, the researcher must select the autoregressive and moving average parameters. The ARIMA package provides the researcher with autocorrelation functions between the time-series variable of interest and its lagged value at 1, 2, 3, . . . lags. In addition, the researcher is provided with the partial autocorrelation function, controlling for autocorrelations at intervening lags. Based on these functions and their plots, researchers are guided in their selection of both the AR and the MA parameters.

The Trends ARIMA procedure then estimates the model and its coefficients based on the parameters specified. The researcher supplies the three parameters  $p$ ,  $d$ , and  $q$  from the analysis of autocorrelation and partial autocorrelation functions, while ARIMA performs the iterative calculations needed to determine the maximum-likelihood coefficients associated with each of the parameters. The ARIMA software also adds new series to the data file representing the fitted or predicted values, the error (residual), and the confidence limits for the fit.

The diagnosis of the ARIMA results requires an investigation of whether the model's residuals are correlated and/or whether the residuals show a pattern. If either the residuals are correlated or they show some time of pattern, then the researcher needs to return to the identification process and re-evaluate the parameters entered into the model.

The model provides the researcher with the ability to calculate the autocorrelation and partial autocorrelation function among the error terms or residuals. If the first or second-order correlations are large, the researcher has probably misspecified the model.

The residuals should be without pattern. That is, they should be white noise. The ARIMA package provides a test for whether the residuals have a pattern. The test is called the Box-Ljung Q Statistic, also called the modified Box-Pierce statistic.

The focus on determining the appropriateness of a Box-Jenkins ARIMA model is on the error terms—to insure no autocorrelation and no residual pattern. It is not on whether each of the model's coefficients is statistically significant.

Once the researcher is satisfied with the model's coefficients, its results can be used to predict future values of the time-series variable of interest. It is expected that projections resulting from the ARIMA method will benefit from its enhanced features and its simultaneous treatment of the order of autoregression, the degree of differencing, and the order of the moving average.

## E.5 INTERVENTION ANALYSIS

In the transportation field, events will frequently occur that result in major changes in an established time-series pattern.

For example, major deregulation legislation, passed in the late 1970s and 1980, significantly altered the competitive relationship among transportation modes. In addition, major changes in fuel prices during the 1970s and 1980s resulted in major disruptions and shifts in modal patterns. Transportation planners are frequently called upon to estimate the impacts of major events on, for example, levels of truck traffic or, alternatively, levels of rail traffic. The Box-Jenkins ARIMA models can be adapted to include a specific assessment of the impact of an intervention (e.g., passage of a major piece of transportation legislation or major fuel price increase) on a time-series data. The following pages explain the process through a technique called intervention analysis. Again, the *SPSS Trends* program provides an option to incorporate intervention analysis in the ARIMA model.

Researchers initially estimate an ARIMA model for the data without regard to the intervention event or its corresponding impact. Thus, the researcher follows the procedure detailed in the preceding section to specify the three required parameters of the ARIMA model—i.e., the autoregressive parameter ( $p$ ); the difference parameter ( $d$ ); and the moving average parameter ( $q$ ). As noted, initial specification of the parameters is based on determination of whether the time-series data is stationary; the transformation of data through differencing; and an examination of the autocorrelation and partial autocorrelation plots of the time-series data at various lags.

Assessment of the impact of the intervention on the time-series requires that an intervention variable be added to the analysis. The coefficient of this intervention variable will represent its impact on the change in the time-series variable of interest at a particular time controlling for the impact of the other three parameters in the model.

The intervention variable is what econometricians label as a “dummy” variable, taking on a value of “1” from the time of the intervention on to the present time and a value of “0” prior to the intervention. Thus, if a transportation planner had a time-series data of motor carrier market share and wanted to assess the impact of the Motor Carrier Act of 1980 on that traffic, the planner would create a new variable to include in the ARIMA model. This intervention dummy variable would equal zero for all time-series data points prior to 1980 and a value of one from 1980 to the present.

The *SPSS Trends* ARIMA program gives the researcher the ability, once the  $p$ ,  $d$ , and  $q$  parameters have been specified, to specify one or more predictor variables (also called regressors) for the time-series data being modeled. The ARIMA program treats these predictors much like predictor variables in regression analysis. It estimates coefficients for them that best fit the data. The coefficients, indeed, are interpreted just like regression coefficients. Positive signs indicate that the intervention event adds positively to the change in the modeled variable, while negative signs indicate the opposite.

The specified ARIMA model with regressors must be diagnosed in a fashion similar to the ARIMA model without

regressors. The autocorrelation of the residuals must be evaluated as well as their pattern. If autocorrelation is found or a distinct pattern emerges, then the researcher must return to the model identification phase and reevaluate the situation.

## **E.6 SEASONAL DECOMPOSITION AND WEIGHTED LEAST SQUARES REGRESSION**

Frequently, planners work with transportation data having distinct seasonal trends. For example, small package shipments peak during the holiday season; auto traffic peaks during the summer months; truck traffic slows during the winter months; household goods shipments peak in the spring and summer and fall off rapidly in the winter.

The *SPSS Trends* package includes a Seasonal Decomposition routine to “decompose” or break down a time-series variable into the following components: a long-term trend component, a seasonal adjustment factor, a cyclical component, and a random or irregular component. Indeed, the Seasonal Decomposition routine takes the original time-series data and adds the following information: (a) a seasonal adjustment factor for each season; (b) a seasonally adjusted data series (i.e., the original data with the seasonal component removed); (c) a deseasoned trend and cycle component; and (d) an error component.

In the Seasonal Decomposition routine, the time-series dependent variable is treated as a linear function of the following independent components: trend, seasonal, cyclical, and irregular or random. This multiplicative model is appropriate when seasonal variation is greater at higher levels of the series. If seasonality does not increase with the level of the series, an alternative additive model is available. Each of the model’s components are estimated separately by the methods discussed below. The components are re-assembled and used to generate forecasts of the time-series variable from either the multiplicative or additive models.

### **Estimation of Seasonal, Trend, Cyclical, and Error Components**

The Seasonal Decomposition routine initially removes the seasonality effect, i.e., it deseasonalizes the data, and calculates a seasonal adjustment factor for each season (e.g., each quarter). By removing the seasonal variations in the data, the long-term trend and cyclical components can be more easily identified.

The Seasonal Decomposition routine removes the seasonal variance by calculating moving averages whose number of terms equals the periodicity of the time-series (four quarters in our example). This removes the seasonality by averaging the high and low points of each quarter for every period in the time-series. A ratio is established between each quarter’s value of the time-series data and the average value for the four quarters in the period (that quarter and the subsequent three quarters). If this ratio is greater than one, the

quarter has a positive seasonal impact on the value of the series. The specific seasonality index for each quarter is based on the average of this ratio for each quarter throughout the entire time-series. This seasonal index is the first component of the four needed to develop a time-series decomposition forecast.

The second component needed for the decomposition forecast is the trend component. The trend component is developed from a regression between the seasonally-adjusted time-series and a time variable that increments one unit for each quarter or time period in the database. A positive coefficient for the trend variable would indicate growth in the series over time, while a negative coefficient would suggest decline over time. The trend coefficient in the regression is used to estimate a moving average trend for each quarter in the time-series. This moving average trend value is the second component of four required to generate a forecast by the decomposition method.

The cyclical factor, the third component, needed for a decomposition forecast is the ratio of the seasonally-adjusted moving average and the moving-average trend. If this ratio is greater than one, there is an indication that the deseasonalized value for that period is above the long-term trend in the data. If the cyclic factor is less than one, the reverse is true.

By combining the trend, seasonal, cyclic, and error terms together, the Seasonal Decomposition routine can be used to predict values of the time-series data for both the historical and evaluation periods as well as for forecasting in the future. As shown, here, however, the Seasonal Decomposition routine requires separate estimates be developed for each component of the equation. After developing each component’s estimates, they can be re-assembled to develop estimates of the time-series data for forecasting purposes.

### **Seasonal Adjustments with Dummy Variables**

If, however, the seasonal factors are treated as dummy variables in a larger regression model, the seasonal effects and the trend can be evaluated simultaneously. The simultaneous evaluation of the trend and seasonal factors simultaneously make the use of the Seasonal Decomposition routine somewhat less cumbersome. Positive coefficients for a dummy seasonal variable would be indicative of a positive seasonal impact, while a negative coefficient would suggest the opposite.

### **Use of Weighted-Least Squares to Adjust for Heteroscedasticity**

When the seasonal effects are estimated simultaneously with other independent factors, such as the trend component, researchers must be aware of and make adjustments for heteroscedasticity—violations of the assumption that regression



residuals have constant variance. It is often the case that there are differences in variance of a time-series variable depending upon the specific time period. For example, while truck traffic has a seasonal component (with declines in the winter months), the variance of truck traffic in the winter will depend greatly on the severity of the winter. Since there are fluctuations in winter's severity, a researcher should expect greater variation in truck traffic in the winter months.

Thus, when using seasonal dummy variables in a regression analysis, the transportation planner needs to evaluate a scatterplot of residuals against the values predicted from the regression. If this scatterplot indicates greater dispersion in residuals depending on the predicted value of the time-series variable, then heteroscedasticity adjustments should be made.

The *SPSS Trends* routine provides for the use of weighted least squares as an adjustment for heteroscedasticity. One approach would be to weight each time-series observation by the standard deviation of its residual. However, the package evaluates a number of different weighting approaches and selects the best "weighting" factor and, then, uses that factor in re-estimating the regression equation with heteroscedasticity removed.

### Advanced Methods for Seasonal Adjustments

While the discussion in the previous section focused on the use of the Seasonal Decomposition routine for handling time-series data with seasonal patterns, the *SPSS Trends* package includes other methods for handling seasonal adjustments as well. In fact, the procedures for making seasonal adjustments in the Seasonal Decomposition routine are based on procedures developed by the U.S. Bureau of the Census in the 1950s for seasonally adjusting census data. New methods have been developed that constitute refinements over the originally approaches. The *SPSS Trends* package includes, for example, a seasonal adjustment method, labeled the X-11 ARIMA approach, adopted by researchers at Statistics Canada. These researchers noted that when new data were added to a time-series, the seasonal adjustment factors estimated with the Seasonal Decomposition method often were different. Forecasts resulting from the method changed every time new data became available. While some changes in the seasonal adjustment factors are inevitable with the addition of new data, researchers felt that the level of change was too great in factors with the Seasonal Decomposition method.

The X-11 ARIMA method attempts to reduce the size of changes in seasonal forecasting when new data is added to the series. The approach adds forecasts and backcasts (obtained through ARIMA modeling) to the ends of the original time-series data and then calculates seasonal adjustment factors on the extended series with ARIMA modeling.

As discussed, the ARIMA procedure requires the researcher to specify three parameters in modeling a

time-series with no seasonal pattern. The process of specifying the  $p$ ,  $d$ , and  $q$  parameters was presented above. When a seasonal pattern exists in the data, the ARIMA model requires the researcher to specify three additional parameters for the  $p$ ,  $d$ , and  $q$  parameters to reflect the seasonal factor. The *SPSS Trends* package fully supports the specification of an ARIMA model with a seasonal component. Thus, the ARIMA model can be used to develop backcasts and forecasts for the original time-series data under the assumption of seasonality. These values are subsequently added to the original time-series and the X-11 ARIMA procedure is used to develop a new model with seasonal adjustment factors and better forecasts.

This section will not go into detail regarding the modifications in the ARIMA procedure needed to incorporate the seasonality factor. Suffice it to say that the SPSS package fully supports this process and provides the researcher the flexibility to evaluate each specified model and to re-estimate the model based on intermediate results. Like the Seasonal Decomposition procedure, X-11 ARIMA produces four new series and adds them to the original time-series file. These new series are the seasonally adjusted series, the seasonal factors, the trend-cycle component, and the error component.

### E.7 OTHER SOFTWARE PACKAGES

The previous discussion has shown the *SPSS Trends* software to be very extensive and supportive of the entire range of time-series techniques available. Its use requires user knowledge and interface with the program. Frequently, the researcher needs to examine output, determine, for example, whether error terms are correlated or whether they show some distinct pattern. Based on this examination, the researcher must modify parameters and re-estimate models. This required interaction and feedback has many desirable characteristics. It gives the researcher maximum control over the process and allows for modifications based on the unique characteristics of the time-series. To many, this type of control and input is a necessary condition for an effective tool.

However, there are in the market place some time-series packages<sup>17</sup> that provide an "expert" system component for selecting the "best" model from among the range of alternatives—i.e., exponential smoothing, curve estimation, ARIMA, etc. These programs make decisions about the parameters that have to be specified—e.g., the  $p$ ,  $d$ , and  $q$  parameters in the ARIMA model and make decisions about what adjustments need to be made in those parameters based on an analysis of the initial results. For the regression with leading indicators, these programs will examine up to 50 leading indicator variables to determine which, if any, are appropriate indicators of the time-series data. Furthermore, the techniques determine the appropriate time lag for any

<sup>17</sup> Some other statistical packages are AutoBox, from Automatic Forecasting Systems, Inc., Hatboro, PA.; Forecast Plus, from StatPac, Inc., Minneapolis, MN., and Smart-Forecasts, from Smart Software, Inc., Belmont, MA.

selected variable. In short, these “expert system” software packages automate many of the decisions that the *SPSS Trends* routine requires researchers to make on their own.

The advantage of the “expert system” software packages is that the planner has the benefit of “expert” statistical advice on the most appropriate method for establishing a time-series estimate and using that estimation for forecasting purposes. Certainly, the planner without any detailed background and training would be in a position to produce better forecasts than would be possible in the absence of the software. On the other hand, planners with some knowledge would prefer the control

over the process that is afforded by the *SPSS Trends* routine. Indeed, these planners would object to the “cookbook” aspect of the “expert system” software.

Certainly, planners would benefit from a combination of approaches. That is, they should analyze the time-series data to the best of their ability with the *SPSS Trends* package and then compare their projections with projections generated from an expert system package. Indeed, the expert system software packages have features that allow the planner to override the “expert’s” choice and to substitute their own evaluation in place of that of the computer.

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## APPENDIX F

### ESTIMATING TRANSPORT COSTS

There are a variety of measures commonly used for expressing the transport costs of a shipment or set of shipments. Shippers are most interested in measures, such as cost per shipment or cost per ton, that summarize the total costs they incur. However, transport costs vary with shipment size and length of haul. Accordingly, analysts find measures that reflect shipment size and/or length of haul to be more useful. These include cost per ton-mile, cost per shipment-mile, cost per container-mile, etc.

This appendix discusses sources of cost estimates for the truck, rail, water, and air modes.

#### TRUCK COSTS

In general, truck costs rise with distance at a somewhat less than linear rate. However, for lengths of haul above 50 or 100 miles, truck costs increase only slightly more slowly than length of haul. Accordingly, cost per vehicle-mile is a particularly useful measure for analyzing truck costs.

Although the cost per mile of haul for intercity truck transport is relatively independent of length of haul, there are a number of other factors that influence this cost. These factors include

- trailer type;
- configuration (number and sizes of trailers, number of axles, etc.);
- annual mileage of tractors and trailers;
- percentage of miles operated empty;
- payload;
- driver costs;
- fuel efficiency;
- type of vehicle ownership;
- truckload vs. less-than-truckload operation; and
- local conditions (taxes, terrain, congestion, etc.).

Exhibit F.1 shows Jack Faucett Associates (JFA) estimates of typical truck transport costs.<sup>1</sup> These costs were developed in 1991 using forecasts of 1995 conditions and expressed in 1988 dollars. The exhibit shows how costs vary by vehicle configuration, gross vehicle weight (GVW), and trailer type. For each trailer type, the exhibit shows a typical percentage of miles that

vehicles operate empty and how this percentage affects the cost per loaded mile. Also, for each GVW, the exhibit shows payload carried and cost per ton-mile. For a given configuration and trailer type, costs per mile rise slowly with GVW and payload, but costs per ton-mile drop appreciably.

All costs shown in Exhibit F.1 are for truckload operation. Taking into consideration the increased handling required for less-than-truckload (LTL) operation, JFA estimated costs for intercity LTL shipments to average about 15 cents per ton-mile (in 1988 dollars)—equivalent to \$2.40 per vehicle-mile of operation for a five-axle, twin 28-ft configuration.

A factor of 1.16 for converting the JFA cost estimates from 1988 dollars to 1995 dollars is developed in the first subsection below. Applying this factor to the Exhibit F.1 estimates for the operation of 48-ft dry vans produces an estimate of \$1.19 to \$1.25 per vehicle-mile in 1995 dollars. As indicated in Exhibit F.1, costs per mile for longer and heavier configurations are somewhat higher, as are costs per mile for conventional length refrigerated vans and tank trailers.

The issues of how to estimate truck costs and the effect that a change in the highway system or in public policy might have on truck transport costs are complex and, when accurate estimates are needed, the development of such estimates requires quite detailed analyses. Such analyses may be performed using an updated version of the JFA spreadsheet or any of several proprietary models developed by consulting firms and software vendors. Two such models are described in the second subsection below. For those purposes for which an order-of-magnitude estimate will suffice, an estimate of \$1.25 per vehicle-mile may be used.

#### Adjustment for Inflation

Exhibit F.2 documents the development of an inflation factor for converting the JFA cost estimates from 1988 dollars to 1995 dollars. For the purpose of the conversion, truck costs were decomposed into six components, corresponding to the six components considered in the original JFA analysis, and separate adjustments were developed for each of these components.

For all components except fuel, the adjustment was performed using an appropriate price index or, in the case of driver costs, average driver wage rates. The price indexes and wage-rate series used are identified in Column 2 of the exhibit. These series were used to obtain an annual compound rate of

<sup>1</sup> Herbert Weinblatt, *The Effect of Size and Weight Limits on Truck Costs*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, Revised October 1991, Appendix A.

**Exhibit F.1. Estimates of 1995 costs for truckload operations (1988 dollars).**

Configuration	GVW (lbs)	Cost per Vehicle Mile	Percent Miles Empty	Cost per Loaded Mile	Payload (lbs)	Density (lbs/ft <sup>3</sup> )	Cost per Ton-Mile (cents)
<b>Dry Vans</b>							
5 Axle 48'	52,000	\$1.03	15%	\$1.20	24,500	7.0	9.78
	61,000	1.04	15%	1.21	33,000	9.4	7.36
	78,000	1.08	15%	1.25	50,000	14.3	5.01
5 Axle 53'	56,000	1.04	15%	1.21	27,100	7.0	8.94
	78,000	1.09	15%	1.26	49,100	12.7	5.13
6 Axle 48'	54,000	1.06	15%	1.24	24,500	7.0	10.13
	80,000	1.11	15%	1.29	50,500	14.4	5.12
	86,500	1.13	15%	1.31	57,000	16.3	4.59
5 Axle Twin 28'	59,800	1.07	15%	1.25	28,600	7.0	8.76
	80,000	1.12	15%	1.30	48,800	12.0	5.32
9 Axle Twin 28'	66,300	1.21	15%	1.41	28,600	7.0	9.86
	108,000	1.29	15%	1.49	70,300	17.2	4.24
7 Axle 40' + 28'	105,500	1.16	15%	1.35	69,200	14.0	4.13
9 Axle Twin 48'	95,200	1.27	15%	1.49	49,000	7.0	8.80
	127,400	1.37	15%	1.59	81,200	11.6	3.91
7 Axle Triple 28'	83,400	1.26	15%	1.47	42,900	7.0	7.43
	116,000	1.34	15%	1.55	75,500	12.3	4.10
<b>Other Trailer Types</b>							
Refrigerated Van (5 Axle 48')	78,000	1.17	15%	1.36	48,100		5.65
Flatbed (5 Axle 48')	78,000	1.08	25%	1.40	50,400		5.56
Tank (5 Axle 42')	78,000	1.35	45%	2.36	53,400		8.85
Hopper (5 Axle 42')	78,000	1.04	40%	1.67	53,400		6.21
Dump (5 Axle 36')	70,000	1.02	40%	1.64	43,600		7.53

Source: Herbert Weinblatt, *The Effect of Size and Weight Limits on Trucks Costs*, Working Paper, Jack Faucett Associates, Revised October 1991, Appendix A.

change for each cost component, generally using 1988 and 1994 values, and this inflation rate was extrapolated to 1995. The ratios of the extrapolated 1995 values to the 1988 values are shown in Column 5 of the exhibit.

The adjustment for fuel costs was handled somewhat differently. JFA fuel costs were based on a forecast 1995 diesel-fuel price of \$1.25 per gallon (in 1988 dollars). The actual average price of diesel fuel is only \$1.126 per gallon, a price that is about ten percent lower than the price assumed by JFA. The ratio of \$1.126 to \$1.25 is shown in Column 5 of the exhibit.

The sixth column of Exhibit F.2 shows the approximate percentage of JFA's forecast of total costs contributed by each of the six cost components. Multiplying each of these percentages by the corresponding Column 5 growth ratios

and adding produces the overall inflation adjustment factor, 1.156, developed in Column 7.

It may be noted that the above adjustment procedure excludes the effects of changes in technology between 1988 and 1995. This exclusion is appropriate since the JFA cost estimates were intended to reflect forecasts of 1995 technology. However, additional use of this procedure to adjust the cost estimates to current dollars in some future year is not recommended. Such use of this procedure would not reflect the effects of future improvements in technology, and so it would tend to overstate the effects of inflation.

For the purpose of future price adjustments, it is recommended that the Producer Price Index (PPI) for nonlocal trucking or one of its subcomponents be used. This price

Exhibit F.2. Estimating effects of inflation.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cost Component	Data Source	1988 Value	1994 Value	Growth Ratio 1988-1995 <sup>1</sup>	Weight <sup>1</sup>	Contribution to Cost Change (5) x (6)
Drivers	U.S. Bureau of Labor Statistics (BLS), Occupational Earnings in all Metropolitan Areas, mean hourly pay for all drivers of tractor-trailers.	\$12.24	\$13.48 <sup>2</sup>	1.145	28%	0.321
Vehicle	BLS Producer Price Index (PPI) for trucks over 10,000 lbs. GVW (Series 1106).	112.4	138.7	1.278	19%	0.243
Fuel	U.S. Department of Energy, Energy Information Administration, U.S. average retail diesel fuel price per gallon.	\$1.25 <sup>3</sup>	\$1.126 <sup>4</sup>	0.901	20%	0.180
Tires	BLS PPI for tires (Series 1201).	93.6	97.8	1.053	3%	0.032
Repair	BLS Consumer Price Index for automotive maintenance and repair (SE 49).	119.7	150.2	1.303	9%	0.117
Overhead	U.S. Bureau of Economic Analysis, Implicit GDP deflator (current dollar GDP divided by constant dollar GDP).	1.039	1.261	1.254	21%	0.263
					100%	
Overall Adjustment Factors						1.156

<sup>1</sup> See text.

<sup>2</sup> 1993 value.

<sup>3</sup> Model's forecast of 1995 fuel price in 1988 dollars.

<sup>4</sup> Average fuel price, week of May 8, 1995.

index (PCU4213) was initiated by the Bureau of Labor Statistics in June 1992. Its subcomponents include indexes corresponding to agricultural trucking (#1), LTL general freight (#311), and truckload general freight (#312).

### Software Packages

This subsection discusses software packages for performing detailed analyses of truck costs. Packages from two vendors are discussed below.<sup>2</sup> The first package, MicroTOCS (produced by Snavely, King & Associates of Washington, D.C.) is primarily designed to provide detailed cost estimates for individual truckload (and multi-truckload) shipments. The second package, the Truckload Cost Information System (TL/CIS) (produced by the Transportation Consulting Group of Bethesda, Maryland), has a more carrier-oriented focus, producing less cost detail for individual shipments but a substantial amount of aggregate information describing the overall costs incurred by truckload carriers. Both vendors also have corresponding packages for analyzing costs for LTL shipments and operations.

The prices of the software packages vary with: the specific configuration (PC versus mainframe version); amount of technical support needed; whether any consulting services are required in preparing data for input into the models and in interpreting results; and the number of work stations and sites involved. The Transportation Consulting Group charges \$3,900 for a site license for TL/CIS and \$250 per update.

#### *MicroTOCS*

MicroTOCS is a package produced by Snavely, King & Associates for estimating the costs of truckload movements. In MicroTOCS, the basic costing unit is a truckload shipment from a particular origin to a particular destination. The shipment costs can be reported in a variety of ways, including: total operating cost per mile; total cost per mile; total cost per ton; and total cost per ton-mile. Total cost includes equipment capital cost, while operating cost does not. All costs exclude loading and unloading costs and the cost of any associated waiting time. However, empty return ratios are reflected in the cost estimates.

Linehaul operating costs are estimated as consisting of: driver costs; fuel costs; miscellaneous costs; tires; maintenance; user taxes; and administrative and overhead. The estimates of tire and maintenance costs distinguish the tractor and trailer components; and insurance costs and licensing and permit charges are also distinguished. Total costs include all operating costs plus capital costs for tractors and trailers.

The operation of the system requires the user to move through a series of menus specifying model inputs. The first menu requires specification of shipment characteristics: total tons; tons per trailerload; trip distance; and estimated empty

return mileage. The remaining menus provide default settings for various costs required by the model and provide the user with the opportunity to modify these settings.

#### *Truckload Cost Information System*

The Transportation Consulting Group's Truckload Cost Information System (TL/CIS) is designed primarily for use by truckload carriers for analyzing the costs of various aspects of their operations. Accordingly, TL/CIS provides less detail than MicroTOCS about costs relating to individual shipments, though, unlike MicroTOCS, it does reflect data on pickup, delivery, and unloading costs. With its broader focus, TL/CIS makes greater demands on the user in terms of data gathering and information collection and provides correspondingly more detail.

The underlying basis for TL/CIS is the activity-based accounting system required by the Interstate Commerce Commission in its annual report process. This accounting system requires Class I and II carriers to break down all cost categories by activity. For example, driver wages are broken down into wages paid for pickup and delivery activities versus those paid in linehaul activities. Accordingly, the TL/CIS model requires carriers to break down all of their costs into individual components and then account for the cost components by activity. The major activity categories for a truckload carrier are linehaul, loading, unloading, stopoff, claims, and billing and collecting.

At the most disaggregate level, the program produces output in terms of costs for a particular shipment (with origin and destination specified) or a round-trip movement. In contrast to MicroTOCS, however, TL/CIS reports not only the total linehaul costs for a shipment, but also includes costs for pickup, delivery, unloading and any stopoff costs. In TL/CIS, the basic unit of costing analysis is costs per mile. There is no information on type of commodity, nor is there any effort to determine load capacity, cargo weight, cost per ton, or cost per ton-mile. Instead, the program is designed to operate in batch processor mode to summarize and report on shipments from a particular terminal, on a specific traffic lane, from a particular customer, or by a particular salesperson, during any given time period. These summary reports form the backbone of the costing system. It allows the carrier to determine how specific terminals, traffic lanes, accounts, and salespeople are doing and where trouble spots exist within the entire system.

TL/CIS has a module designed to provide the interactive costing of specific loads and trips by means of an on-screen "input log" which the user completes to describe a particular move. This input log gives the user the flexibility to select from a choice of over 100 different driver and equipment configurations.

### RAILROAD RATES AND COSTS

Average 1992 railroad rates per ton-mile are summarized in Exhibit F.3 for selected major commodity groups. The

<sup>2</sup> Some other firms that have developed proprietary models for estimating truck costs are IBI Group (Toronto), Peat Marwick Stephenson & Kellogg (Toronto), and Trimac Consulting Services (Calgary, Alberta).

**Exhibit F.3. Average rail rates per ton-mile for selected commodity groups.**

<b>STCC Code and Commodity Group</b>		<b>Cents per Ton-Mile (1992 Dollars)</b>
01	Farm Products	2.19¢
11	Coal	2.10
14	Nonmetallic Minerals	2.98
20	Food Products	2.92
24	Lumber and Wood Products	2.89
26	Pulp and Paper Products	3.93
28	Chemical Products	3.90
29	Petroleum and Coal Products	4.03
32	Clay, Concrete, Glass, and Stone Products	3.59
33	Primary Metal Products	3.18
37	Transportation Equipment	9.01
40	Waste and Scrap Materials	3.83
42	Empty Shipping Containers	3.83
46	Miscellaneous Mixed Freight	2.91
<b>All Commodities</b>		<b>3.03¢</b>

Source: Interstate Commerce Commission, 1992 *Carload Waybill Sample*, CD-ROM.

commodity groups shown in the exhibit account for about 87 percent of rail tonnage and 88 percent of rail revenue.

The average railroad rate in 1992 was 3.03 cents per ton-mile. The average rate in 1994 can be estimated by multiplying by 1.017 (from the U.S. Bureau of Labor Statistics, PPI for railroad line haul operations) to produce a rate of 3.08 cents per ton-mile. Extrapolating an additional year produces an adjustment factor of 1.026 and an average rate of 3.11 cents per ton-mile for 1995.

Rates per ton-mile tend to vary inversely with length of haul, size of shipment, and commodity density. If rate and cost estimates are required that reflect the effects of these influences on actual transport costs, estimates can be obtained using the ICC's Uniform Rail Costing System (URCS). Computer implementations of this system are available from several commercial sources. One such implementation, MicroURCS (produced by Snavely, King & Associates of Washington, D.C.) is discussed in the subsection below.

For many purposes, less precise rate estimates should suffice and data presented in Exhibit F.3 should prove adequate. The average rates for the commodities shown in this exhibit are all between two and four cents per ton-mile with one very significant exception: the average rate for transportation equipment is 9.01 cents per ton-mile. This high rate occurs primarily because of the low density of assembled motor vehicles (which average only 22 tons per carload as compared to an average of 66 tons per carload for all commodities). The lowest average rates are for coal and farm products (particularly grain), both of which are frequently shipped by unit train, qualifying for significant volume discounts.

### **A Software Package**

This section discusses a software implementation of the ICC's URCS. The package, MicroURCS, was developed by Snavely, King & Associates (of Washington, D.C.). Its price varies with the specific configuration (PC versus mainframe version); amount of railroad-specific cost data purchased; amount of technical support needed; whether any consulting services are required to prepare data for input into the model or to interpret results; and the number of work stations and sites involved.

For each shipment, the minimum information required of the user by MicroURCS consists of commodity, tonnage shipped, railroads used, and mileage on each railroad. With just this information, the program will set a number of default values to estimate railroad costs for the shipment. Alternatively, users can provide additional data, overriding the defaults, and enabling the program to produce better cost estimates.

The ICC's URCS is a three-phased process. Phase 1 involves an exhaustive regression analysis based on data supplied by the railroads. Phase 2 involves the conversion of the regression results into unit costs and operating parameters. The third phase uses unit costs and operating parameters, along with the detailed shipment characteristics supplied by the user, to determine shipment costs.

Within the structure of MicroURCS, users can change parameters and assess the impact of these changes on shipment costs. The sensitivity analysis, making individual changes and assessing impacts, is straightforward and a strong point of this software package.

MicroURCS develops cost estimates for specific, individual railroad shipments from data supplied by the individual

railroads and analyzed through the URCS. If the user of MicroURCS purchases costing data from all the individual railroads, then cost estimates for a given movement will be based on data from the actual railroads participating in the movement. Otherwise, the cost estimates will be derived from data from all the railroads operating in the appropriate region.

The user begins the input process by specifying information about the commodity being moved and its specific requirements. The user specifies the commodity; whether a TOFC/COFC movement is involved; the net tons in the shipment; whether any protective services, accessorial services, or refrigeration services are needed; and whether the shipment involves movement of motor vehicles.

Users are then directed to provide information on the equipment used, routing, and handling requirements for the shipment. If the shipment is a TOFC/COFC shipment, the user is asked whether the railroad or the shipper is supplying the trailer/container and the number of units involved. The program requests information on the number of cars, car type (with default car types selected on the basis of commodity specification), and whether the cars are supplied by the railroad or by the shipper. The program also requests information on the specific railroads in the route, the mileage on each railroad, the origin and destination, and any special handling required at the origin or destination. As previously observed, default values can be used for all inputs except commodity, tons, and mileage by railroad.

The program next moves into a costing section based on the line-haul characteristics of the shipment. This involves determination of whether the specific shipment is part of a multi-car shipment. Switching costs at origin and destination are reduced by 75 percent for unit-train movements and by 50 percent for computes car-miles, gross tons, gross ton-miles, number of intra-/inter-train switches, and interchange switches. These inputs and intermediate results are used to develop detailed cost data for the individual shipment. The program calculates total variable costs per car, per net ton-mile, and per net ton, and also fully allocated cost per net ton-mile.

## WATER TRANSPORTATION

Cost and time analysis for water transport facilities can either be based on the marginal impact on existing rate and service characteristics or the development of fully-allocated system costs and service parameters for representative cargo flows. The virtual elimination of meaningful tariff rates for most water transportation limits the ability to use rate analysis for public use facilities with a mixture of commodities. The more common method is to estimate the underlying cost and transit-time structure, calibrated against available rate and service data. This section examines the specific elements used in water transport costing, provides some representative sources, and also identifies critical issues which affect the results.

## Types of Operation

The structure for the cost analysis depends on the operating and market patterns specific to various vessel and service types. The various types of water transportation can be categorized:

- inland barge;
- intercoastal tug-barge;
- deep-sea bulk carriers (liquid, dry, and mixed);
- deep-sea breakbulk carriers (liner and tramp); and
- deep-sea container carriers (liner).

Inland barge and intercoastal tug-barge operations generally are limited to the carriage of bulk commodities. Barge transport includes the dedicated transport of single commodities between two points, as well as common carrier distribution of common barge types between river systems. As with other bulk operations, the shipper often owns and operates dedicated equipment, particularly for coastal operations. Inland barges typically are moved in multi-barge tows which may combine barges for several shippers. For example, an upper Mississippi tow operator may pick up grain, fertilizer and chemical barges at various points on the upper river for transfer to operators on the lower Mississippi at an interchange point. On the other hand, dedicated services will shuttle between a limited number of river points, with the towboat often waiting with the barge for the return.

Deep-sea operations are primarily distinguished by the combination of vessel type and operating pattern. "Tramp" operations are based on single voyages moving one or more commodities, often on a single charter basis. Bulk and high-volume or seasonal breakbulk commodities typically move in this fashion. Tramp operations generally include full shipload lots and empty deadhaul legs between discharge and load ports. Some vessels may be dedicated to a particular cargo flow (e.g., Alaskan oil carriers), or may shift between trade routes and commodities on a seasonal or market-driven basis (e.g., tramp refrigerated vessels).

"Liner" operations are based on multi-commodity markets using multiple vessels in fixed port rotations and schedules. These services are designed for containerized and general breakbulk cargoes, and typically make multiple port calls over a coastal range. For example, a North Atlantic carrier might operate four vessels with weekly calls at Charleston, Baltimore and New York in the U.S. and Felixstowe and Rotterdam in Europe. A single voyage for each vessel would take 28 days. Container operators also maintain inland distribution systems for their containers, which must also be considered in a costing analysis.

## Cost Elements

Total transport costs can be estimated from a combination of physical characteristics, operating and productivity factors, and unit cost elements. The physical characteristics relate to items such as vessel type, cargo handling equipment, and commodity density. Operating and productivity factors



include vessel and cargo processing time, fuel efficiency, and vessel speed. The unit costs are typically based on volume or time and are combined with operating estimates to generate total system costs.

Inputs for water transportation costing can be categorized:

- vessel;
- voyage and port;
- cargo-related; and
- inland and other.

Vessel-related inputs encompass physical and cost characteristics which apply regardless of the voyage or service patterns (with some exceptions). The physical characteristics of the vessel affecting costs include:

- type and utilization (e.g., tramp bulk vessel);
- physical dimensions (for accessibility and port charges);
- capacity (cargo load and design speed);
- operating efficiency (fuel consumption and maneuverability);
- manning requirements;
- safety characteristics (for annual repair and insurance estimates); and
- annual operating availability (for allocating annual costs).

The cost inputs associated with the vessel include:

- capital or lease cost (on annual or other basis);
- annual insurance (hull and machinery, personnel and injury);
- maintenance and repair (periodic and overhaul);
- supplies and stores;
- crew costs;
- fuel; and
- administrative/overhead.

Annual costs for capital/lease, maintenance and insurance are generally specific to a particular type of vessel, but may vary with the type of utilization (e.g., high risk voyages). Supplies and stores and crew costs can be estimated on an annual or daily basis. Unit fuel costs vary with fuel type and the point of purchase. Administrative and overhead costs typically are estimated as a percentage of all other costs (perhaps excepting capital costs).

Sources for vessel data include: Lloyd's Registry of Shipping (and an associated on-line database); the U.S. Maritime Administration; special industry reports by Drewry Shipping Consultants of London; and various industry journals (such as *Containerization International*, *Lloyd's Shipping Economist*, *Marine Log*, *Maritime Reporter and Engineering News*, and *Waterways Journal*). As with other costs, costing for international operations considers the effect of currency exchange rates when appropriate.

Voyage and port inputs are specific to a particular use of a vessel, varying by trade route and commodity market. The vessel itinerary dictates many of the cost and time factors and

is defined by the specific port calls, the voyage length, and the time or distance under low-speed operations (e.g., canal transit). Vessel itineraries frequently change, sometimes requiring a definition of a prototypical voyage for analysis.

A tramp operation will typically assume a direct route between the load and discharge ports at full operating speed unless a lower speed is appropriate based on fuel economy. In many cases, tramp operations will include a deadhaul (e.g., empty) leg from the discharge port to the next voyage's load port, some portion of which may be allocated to the previous voyage.

Costing for liner operations is typically based on the entire itinerary rather than specific port pairs. A liner operation following a fixed schedule may operate at a lower-than-maximum speed which can be calculated based on available sea time (i.e., round-trip voyage time minus port and other delays).

Transit time for inland barge operations may include delays for lock processing which often represents a large portion of total transit time. Lock delays can be measured from historical data or approximated using models which combine lock-processing efficiency with traffic-flow and tow-arrival patterns.

Port characteristics may be estimated for each port or within general categories (e.g., domestic and foreign). Operating factors include berthing delays (in fixed hours or days per voyage), vessel berthing time (based on vessel size and berth type), and cargo handling time (based on load characteristics, equipment type and stevedoring practices). The term "port delay" is typically used to denote an unusual circumstance (e.g., berth congestion) which extends the port time, but may be applied to the entire port time in some cases.

Costs which are specific to a voyage itinerary include vessel tolls and port-related charges applied to the vessel (often based on size) and the cargo transferred (mostly based on type and volume). Vessel-related port costs include dockage and pilotage, while cargo-related costs include wharfage and cargo handling costs. Some port costs are fees assessed by the port as reimbursement for use of public facilities. Most cargo handling costs in deep-sea trades are charged by private stevedores based on the required manpower and equipment to load and discharge the vessel. Typical charges include stevedoring, terminal handling, equipment rental, and container stuffing and stripping. Practices for port charges may vary by U.S. coast and for foreign countries. Bulk and domestic barge operations typically utilize private terminals, often with no public port involved. Costs for these operations must be estimated from private sources.

Sources for voyage itineraries include Lloyd's on-line databases, the Journal of Commerce Shipcards and other service listings. Port operating characteristics and non-public cargo handling costs must typically be developed through private interviews; although, in most cases, costs and operating factors will be common by general cargo type over a particular port range. Fees charged by ports usually are available from port tariffs, although tariff rates may not apply to high-volume users. Worldwide port directories (e.g., *Lloyd's*

*Ports of the World*) often include summary information on port tariffs, facilities and rules.

Cargo-specific inputs affecting cost and time factors include physical, market and packaging characteristics. The physical stowage and load characteristics determine the utilization of vessel and container capacity, while the handling and storage requirements dictate the type and cost of port facilities and equipment. The market characteristics include the balance of flow which determines port handling time and costs, as well as load factors for liner operations and required vessel size for tramp operations (including backhaul opportunities). When cargo is palletized or containerized, the cargo weight/unit relationship affects cargo handling factors.

The cost of container and pallet systems may also be included in the cost analysis. Pallet costs are based on an allocated share of the unit cost for reusable units and the total costs for one-way pallets. Container system costs can be estimated by calculating capital and operating costs for a fixed ratio of containers to available vessel capacity ("slots"). For example, a service of four vessels with a capacity of 800 twenty-foot equivalent container units (TEUs) might require three containers for every TEU of capacity or a total of 7,200 TEUs. The "additional" containers are either resting in a port or involved in the inland transit.

A final cargo-related cost which may be considered is the inventory cost which measures the financial cost of "holding" the commodity during the transit period. While this cost is not included in the transport rate or typically calculated at all, it provides a basis for measuring the impact of delays and changes in transit time, including changes resulting from changes in mode and/or route. Inventory costs can be calculated based on the average value per weight or container unit, combined with interest rate which reflects the cost of the capital required to hold the commodity for the period of transport.

Sources for cargo-related physical inputs include *Thomas' Stowage* (which provides weight-to-volume ratios on a commodity basis) and cargo flow statistics which cover both weight and volume data (e.g., PIERS and Census sources described in Appendix C). Data for major commodity flows may also be available through Drewry and other industry sources. Flow patterns can be measured from traffic statistics (available from PIERS, Census and individual ports). Other data must be generated from interviews or general commodity or water transportation sources.

The final category of costs is for inland transport which can be estimated using the appropriate modal costing methodology or assumed at a fixed unit cost if not influenced by the new facility. A key consideration for many general cargoes is the split between rail and truck flows. This information is not generally available but may be collected through a survey or interview process or approximated from a disaggregation by geographical region (i.e., rail vs. truck hinterlands).

### Cost-Estimating Methods

Total and unit transport costs can be estimated by generating total capital and operating costs for an annual operation

or single voyage, and then appropriately allocating the costs over the traffic flow. The first step is typically to calculate the total voyage time for use in generating time-based costs. Other cost factors are combined with the appropriate "use" factor (e.g., crew man-days or tons loaded and discharged). The allocation of annual costs on a voyage-basis requires the following steps:

- calculate total annual costs;
- estimate projected annual operating days (excluding maintenance and other downtime);
- calculate daily cost by dividing annual costs by operating days; and
- calculate voyage costs by multiplying daily costs by voyage days.

Fully allocated unit costs for bulk and breakbulk commodities are usually stated on a "per ton" basis, while containerized cargoes may be either per ton or per container or TEU. Costs may also be stated on a ton-mile basis, particularly if port and voyage costs are insignificant or measured separately. The unit costs can be calibrated against rate data if available.

Some key issues which often apply to water transport costing include:

- *Capital Costs: Accounting or Economic*—The estimation of capital costs on an accounting basis (i.e., depreciation, principal and interest) may skew results when comparing services with different fleet compositions. The true "economic" costs can be estimated based on an amortization of the current sale value over the expected lifetime minus scrap value.
- *Allocation of Fixed Costs*—The volatility of water transportation markets often creates a disparity between rates and fully allocated costs due to the method for allocating fixed costs. It is often useful to segregate marginal and fixed costs in the analysis, and also to consider current industry conditions.
- *Definition of Cargo Capacity*—While most capacities are stated in weight terms, volume-based restrictions apply for many breakbulk and containerized commodities. It is critical that vessel loading reasonably reflect the cargo mix, particularly when comparing different vessel types.
- *Allocation to Backhaul Flows*—Many waterborne services are designed for one-way movements of specific commodities (e.g., vehicles or bananas) or may have a natural imbalance in one direction. The backhaul leg is often considered secondary to the main cargo flow and is often sold on a marginal cost basis. In such cases, an equal allocation of fixed costs among all traffic understates the costs in the headhaul direction. (The service would probably exist with no backhaul traffic, in which case, the headhaul traffic would be assigned all fixed costs). Various adjustments include assigning only the marginal costs of cargo handling to the backhaul or calibrating the assignment of fixed costs based on the relative market rates in each direction.

**Exhibit F.4. Deep-draft vessel costs (1995 dollars).**

Capacity (DWT Tons)	Speed (Knots)	U.S. Flag		Foreign Flag	
		Dollars per Hour	Cents per Ton-Mile <sup>1</sup>	Dollars per Hour	Cents per Ton-Mile <sup>1</sup>
Tanker – Non-Double Hull					
20,000	14	\$1,592	1.184¢	\$639	0.475¢
50,000	14	1,953	0.581	815	0.243
90,000	14	2,270	0.375	975	0.161
150,000	14	2,625	0.260	1,162	0.115
265,000	14	3,128	0.176	1,440	0.081
Tanker – Double Hull					
20,000	14	\$1,452	1.080¢	\$583	0.434¢
50,000	14	1,981	0.589	826	0.246
90,000	14	2,519	0.417	1,075	0.178
150,000	14	3,185	0.316	1,386	0.138
265,000	14	4,228	0.237	1,880	0.106
Dry Bulk					
15,000	14	\$1,093	1.084¢	\$393	0.390¢
40,000	14	1,430	0.532	561	0.209
80,000	14	1,820	0.339	759	0.141
120,000	14	2,136	0.265	820	0.114
200,000	14	NA	NA	1,204	0.090
General Cargo					
11,000	17	\$1,059	1.259¢	\$412	0.490¢
20,000	17	1,393	0.910	542	0.354
30,000	17	1,721	0.750	667	0.291
Container					
Capacity (TEUs)	Speed (Knots)	Dollars per Hour	Cents per TEU-Mile	Dollars per Hour	Cents per TEU-Mile
600	17	\$909	14.85¢	\$544	8.88¢
1,200	17	1,154	9.43	768	6.28
2,000	18	1,517	7.02	1,101	5.10
2,800	19	1,984	6.22	1,527	4.78
4,000	20	2,293	4.78	1,811	3.77

<sup>1</sup> Excludes port fees and tolls.

Source: Study team estimates and data from U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Planning Guidance: Deep Draft Vessel Costs*, Fort Belvoir, Virginia, December 1994.

## Typical Costs

### Deep-Draft Vessels

Exhibit F.4 shows some typical costs for deep-draft vessels by type and vessel size. The costs per hour are a weighted average of fiscal year 1995 Corps of Engineers estimates for vessel costs at sea and in port and exclude port fees and tolls.<sup>3</sup> (The only difference between at-sea and in-port costs is fuel consumption, which represent less than ten percent of total costs.)

For tankers and dry-bulk vessels, costs per ton-mile were estimated by assuming an average load factor (ratio of cargo weight to deadweight tons) of 60 percent and that 20 percent of time is spent in port. For general cargo vessels, the corre-

sponding assumptions were an average load factor of 75 percent and 40 percent of time in port. For containerhips, costs per 20-foot equivalent container unit (TEU) mile were estimated assuming an 80 percent load factor (relative to TEU capacity) and 20 percent of time in port.

The cost estimates in Exhibit F.4 show very large cost advantages for foreign-flag vessels relative to U.S.-flag vessels and substantial economies of scale for the larger vessels (though large vessels, of course, are limited to routes generating high traffic volumes and serving harbors with adequate channel depth).

### Inland Barges

Exhibit F.5 shows some typical costs for operating inland barges. The costs per hour for barges and towboats are fiscal

<sup>3</sup> U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Planning Guidance: Deep Draft Vessel Costs*, Fort Belvoir, Virginia, December 1994.

Exhibit F.5. Inland barge costs for waterways without locks.

Barge Type	Commodity	Dimensions (L x W x D) (Feet)	Capacity (Tons)	Operating Cost Per Day	Tow Characteristics				
					Horsepower	Operating Cost per Day	Barges per Tow	Load Factor	Cents per Ton-Mile <sup>1</sup>
Standard Dry Barge									
Deck Barge	General Cargo	130x35x10	750	\$58.07	1,200	\$2,717	1	62.5%	3.08¢
					1,500	3,109	4	62.5	0.93
Open Hopper	General Bulk	195x35x12	1,500	\$89.66	1,200	\$2,717	1	62.5%	1.56
					1,500	3,109	4	62.5	0.48
					1,500	\$3,109	4	62.5%	0.48
					5,600	7,677	15	62.5	0.38
Covered Hopper	General Bulk	195x35x12	1,500	\$91.52	1,500	\$3,109	4	62.5%	0.48
					5,600	7,677	15	62.5	0.34
Standard Liquid Barge									
Tank – Double Hull – with Coils	Petroleum Products	195x35x12	1,425	\$256.70	1,500	\$3,109	4	55%	0.69¢
					5,600	7,677	15	55	0.51
Single Skin Tank	Liquid Bulk	195x35x12	1,425	\$210.86	1,500	\$3,109	4	55%	0.66
					5,600	7,677	15	55	0.48
Chemical Tank (II) – Coils and Lined	Liquid Bulk	195x35x12	1,425	\$323.90	1,500	\$3,109	4	55%	0.73
					5,600	7,677	15	55	0.56
Specialized Barge									
Self-Unloader	Cement	195x35x12	1,410	\$337.60	2,300	\$4,077	2	50%	1.76¢
		290x50x12	3,300	770.20	4,200	6,152	2	50	1.21
Tank – Double Hull – with Coils	Petroleum Products	290x50x12	3,000	\$524.51	4,200	\$6,152	2	50%	1.25
		278x50x12	2,500	\$1,736.99	4,200	\$6,152	2	50%	2.01
Pressure Tank	Ammonia	210x44x12	1,500	\$1,129.96	2,300	\$4,077	2	50%	2.20
Pressure Tank	LPG	210x44x12	1,500	\$1,129.96	2,300	\$4,077	2	50%	2.20
Pressure Tank	Chlorine	195x35x12	1,000	\$745.61	2,300	\$4,077	2	50%	2.90

<sup>1</sup> Excludes port fees and the effects of lock delays and transit times.

Source: Study team estimates and data from U.S. Army Corps of Engineers, Institute of Water Resources, FY 1995 *Estimated Towboat and Barge Costs*, Draft, Fort Belvoir, Virginia, no date.

year 1995 Corps of Engineers estimates.<sup>4</sup> The costs per ton-mile are derived assuming an overall average operating speed of 10 knots (upstream and downstream) and tows underway 80 percent of the time. This last assumption is appropriate only for waterways without locks. For waterways with locks, an additional (waterway dependent) adjustment is necessary to reflect lock transit and delay times (decreasing the percentage of time underway and increasing costs per mile and per ton-mile). These delays can result in a substantial increase in costs per mile and per ton-mile.

Exhibit F.5 indicates that costs per ton-mile vary significantly with tow size and, to a more moderate extent, with barge type and commodity (which affects barge capacity) and with load factor. The load factors shown in the exhibit reflect assumed backhaul loads of 25 percent for dry barges, 10 percent for standard liquid barges, and zero percent for specialized barges. Four-barge tows are operated on several waterways, and 15-barge tows are operated on the Illinois and Ohio Rivers and on the upper Mississippi (and 30-barge tows are used on the lower Mississippi). Specialized barges usually are operated in dedicated service using small tow sizes.

For most commodities and tow sizes, the barge costs per ton-mile estimated in Exhibit F.5 are appreciably lower than the corresponding rail rates shown in Exhibit F.3—in some cases by a factor of ten. However, as observed above, for most waterways, the barge costs require a further adjustment to reflect the effects of lock delay and transit times. Furthermore, if comparisons are to be made with rail rates, an additional adjustment is required to reflect the greater circuitry of waterways. (Barge circuitry is estimated to average about 17 percent more than rail circuitry.<sup>5</sup>)

## AIR TRANSPORTATION

The secondary status of air freight in the air transport industry is indicated by the lack of data and techniques for cost analysis. While detailed unit costs are available for passenger transport, freight costs are typically stated as general “per pound” rates which are applied to entire markets (e.g., U.S. to North Europe). Although integrated air carriers have detailed internal costing methods, they do not file data that is comparable to that filed by passenger carriers and they use general tariff rates that are not easily correlated with specific traffic flows.

The following discussion addresses general cost elements used in air passenger costing as applied to air freight operations for a combination or charter carrier. (The dedicated closed systems of integrated carriers are not included in this

analysis.) Air freight costs can be estimated based on the following categories of inputs:

- flight and airport operating characteristics;
- operating expenses (fuel and other);
- airport/station costs; and
- administrative costs.

Similar to water transport, air freight operations can be separated between scheduled round-trip services (“liner”) and one-way charter flights (“tramp”) often requiring an empty backhaul leg. In either case, the round trip distance and average operating speed for a particular aircraft can be used to calculate the round trip “block” hours which designate the period from when the blocks are removed prior to takeoff and when they are replaced after landing. (Flight distances between airports are available from a variety of sources including the U.S. DOT.)

Costing methodologies for air passenger transport utilize detailed periodic costs for specific carriers, aircraft types and operating divisions as designated in the Department of Transportation Form 41 filings and reports. For example, Carrier A may file a report for all DC-8 aircraft for its Pacific Division. Unit costs per block hour can be estimated for personnel, equipment, insurance, taxes and other non-fuel operating expenses. Aircraft-related unit costs include maintenance and capital cost (depreciation, amortization and leases) also state per block hour. Fuel costs could also use Form 41 consumption rates per block hour, combined with the appropriate unit fuel cost for the airports involved. Total flight operating costs per round trip would combine the unit costs with estimated block hours.

Ground or “station” costs can be calculated on a trip basis, as most carriers use contract operators at non-hub airports (due to the limited number of daily flights). Ground costs include landing fees, aircraft and cargo handling, crew overnight costs, and miscellaneous airport charges. Landing fees are usually published rates available directly from the airports, although reductions and exemptions may apply. Aircraft and cargo handling costs depend on rates with the contract operator, but could be estimated from charter rate quotes. No published source is available for other ground costs.

Administrative overhead and profit estimates are also not available from public sources, but could be estimated based on general industry conditions or calibrated using current rate levels. These cost items are often stated as a percentage of all other costs.

The allocated unit cost per ton depends highly on the assumed load factor in both directions. Aircraft freight capacity for combination vessels can vary based on the service area (affecting fuel requirements) and passenger load (e.g., baggage load). Operating capacities are available from various aviation industry sources, as well as from the manufacturer. As with vessel operations, it is critical that the impact of volume-measured commodities on available capacity be considered.

<sup>4</sup> U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Estimated Towboat and Barge Costs*, Draft, Fort Belvoir, Virginia, no date.

<sup>5</sup> Herbert Weinblatt, *Goods-Movement Energy Efficiency: Overview*, prepared by Jack Faucett Associates for the California Energy Commission, Sacramento, November 1982, p. 51.

## APPENDIX G

### RAIL/TRUCK MODAL DIVERSION

Modal choice generally is determined by minimizing perceived total logistics costs (TLC) for using the various modes or modal combinations that are practical for a given set of shipments. TLC consists of actual transport costs (or carrier charges) incurred by the shipper plus a variety of other logistics costs (including inventory costs, stock-out costs, etc.) incurred by the shipper or receiver. Any increase in TLC for use of a particular mode can result in diverting some traffic from that mode to competing modes, and any decrease in TLC can result in diverting some traffic from competing modes to the mode in question.

Potential modal diversion can be estimated using either disaggregate data for a sample of potentially affected movements or more aggregate data in which the total volume of such movements has been summarized by one or more key variables, such as by commodity. The diversion estimates can be derived from estimates of before and after TLC, from absolute or percentage change in TLC, or, for situations in which other logistics costs are essentially unaffected, from changes in transport costs (or carrier charges) incurred by the shipper.

Computer models that have been developed for performing disaggregate analyses of rail/truck diversion include: the proprietary Intermodal Competition Model (ICM) developed by the Association of American Railroads (AAR);<sup>1</sup> and the recently developed Truck-Rail, Rail-Truck (T-R/R-T) Diversion Model developed by Transmode Consultants under contract to the Federal Railroad Administration.<sup>2</sup> Brief reviews of both models are presented in Appendix H. Although concerns about both models exist, the ICM has been used to estimate modal diversion in several public and proprietary studies. The T-R/R-T Model, on the other hand, is essentially untested and, in its current form, apparently contains a significant number of questionable parameter values that are likely to affect its results.

The first two sections of this appendix present some sources of aggregate data that can be used for performing modal diversion analyses when acceptable diversion models are not available. The data are presented as elasticities of

modal demand (in tons or ton-miles) relative to changes in rail rates or truck costs. Truck costs are used (instead of rates) because they are more easily estimated (see Appendix F) and because the highly competitive nature of the trucking industry causes trucking companies to pass both upward and downward cost changes through to shippers in a reasonably direct manner.

The concluding section of this appendix contains a more technical discussion of the development of elasticities.

#### G.1 EFFECTS OF CHANGES IN TRUCK COSTS

##### Cross Elasticities from the ICM

One source of aggregate data for diversion analyses consists of a set of cross elasticities developed, by commodity group, by Jones, Nix and Schwier,<sup>3</sup> using results obtained from the ICM. These cross elasticities are presented in Exhibit G.1. Each cross elasticity represents the percentage change in rail ton-miles that would result from a one percent change in truck costs. For example, a one percent decrease in truck costs would result in diverting to truck 2.0 to 2.2 percent of the ton-miles of food products currently carried by rail.

Exhibit G.1 shows high elasticities (generally above 2.0) for most categories of finished or highly processed goods and much lower elasticities (below 1.0) for all categories of bulk materials and for automobiles. Since rail traffic now consists disproportionately of the latter categories of commodities, the overall effect of changes in transport costs would be somewhat less than a glance at Exhibit G.1 might suggest.

It is reasonable to presume that the cross elasticities shown in Exhibit G.1 represent the effects of a reasonably uniform change in truck costs;<sup>4</sup> and they also can be used to analyze the effects of a reasonably uniform change in rail rates (by estimating the equivalent change in truck costs that would have the same effect on the difference in costs for using the two modes). However, somewhat different effects may be

<sup>1</sup> Scott M. Dennis, *The Intermodal Competition Model*, Association of American Railroads, Washington, D.C., September 1988.

<sup>2</sup> Transmode Consultants, Inc., *Truck-Rail, Rail-Truck Diversion Model*, Users Manual, Draft, Washington, D.C., December 1994.

<sup>3</sup> J. Jones, F. Nix, and C. Schwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, Table 4.2.

<sup>4</sup> The actual assumption used in the ICM analysis are not stated in the report and are no longer readily available (Joseph Jones, Boon, Jones and Associates, personal communication, November 1994).

**Exhibit G.1. Implicit cross elasticities by commodity group derived from ICM results.**

Commodity	Rail Ton-Mile Cross Elasticities
Bulk Farm Products	0.02 - 0.03
Finished Farm Products	3.5 - 3.7
Bulk Food Products	0.62 - 0.83
Finished Food Products	2.0 - 2.2
Lumber and Wood	0.57 - 0.73
Furniture	4.0 - 4.7
Pulp and Paper	0.71 - 0.93
Bulk Chemicals	0.49 - 0.67
Finished Chemicals	3.2 - 3.5
Primary Metals	1.2 - 1.5
Fabricated Metals	5.2 - 7.3
Machinery	3.7 - 4.8
Electrical Machinery	4.1 - 4.8
Motor Vehicles	0.21 - 0.28
Motor Vehicle Parts	1.1 - 1.4
Waste and Scrap	0.17 - 0.22
Bulk All Else	0.14 - 0.19
Finished All Else	3.9 - 4.5

Source: J. Jones, F. Nix and C. Schwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, Table 4.2.

expected if a change in costs is not uniform (e.g., it affects long-haul traffic differently than short-haul traffic or tank trucks differently than vans).

An alternative to the use of elasticities by individual commodity group is the use of overall elasticities. Exhibit G.2 presents six sets of overall cross elasticities developed from published results using ICM data. For each source, the elasticities show the effects of a one percent change in truck costs on rail ton-miles and, for all but one of the sources, on rail revenue. The estimated effects on rail revenue include revenue lost both as a result of losing traffic and as a result of rate reductions adopted in order to avoid additional traffic losses.

Exhibit G.2 indicates that the effects on rail revenue are always somewhat greater than the effects on rail ton-miles. This is the case for two reasons: the most readily diverted traffic (as indicated in Exhibit G.1) tends to be more highly rated (cost more per ton-mile) than average; and some rail revenue is lost on traffic that is retained by rail as a result of rate reductions.

The first set of elasticities shown in Exhibit G.2 were developed by Scott Dennis, of the AAR,<sup>5</sup> by using the ICM to analyze the effects of a uniform ten percent reduction in costs for all rail-competitive trucks.

The "Canadian Tax Policy" elasticity was developed from results published by Jones, Nix, and Schwier. In this analysis, the Exhibit G.1 elasticities were used to estimate the effects of potential changes in Canadian truck-tax policy that would decrease overall truck costs by four percent or increase them by 9 or 17 percent. The Exhibit G.1 elasticities were applied, by commodity group, to traffic and revenue data for the Canadian National (CN) and Canadian Pacific (CP) railways. The elasticity shown in Exhibit G.2 was derived by dividing the resulting estimate of the percentage increase in rail ton-miles for the first policy alternative by the assumed four percent decrease in truck costs. Some internal inconsistencies in the Jones, Nix, and Schwier results<sup>6</sup> leave us with somewhat less confidence in this elasticity than in the preceding set of elasticities.

The final four sets of cross elasticities were developed from the results of three ICM analyses of potential changes in U.S. truck size and weight regulations.<sup>7,8</sup> All four sets of cross elasticities relate the percentage change in rail ton-miles and rail revenue to the *average* percentage change in costs for all shipments carried by combination trucks.

The principal distinction between the four sets of size-and-weight analyses are the assumptions relating to truck lengths. The first analysis (labeled "Bridge Formula B") would allow some increase in truck weights but would have very little effect on lengths; the second analysis would also allow the use of twin 33-foot trailer combinations on a relatively extensive set of major roads; and the last two would also allow the use of twin 48-foot trailer combinations on the Interstate System and on some additional roads. The last two analyses differ in their estimates of the amount of traffic that can be carried efficiently on twin 48s. These two sets of diversion estimates also were adjusted downward by Sydec to minimize the effects of some limitations in the ICM's ability to represent the network on which twin 48s would be allowed to operate.<sup>9</sup>

The Exhibit G.2 cross elasticities show substantial variation between the results obtained from different analyses. The first two analyses assume a uniform change in costs for all use of combination trucks, while the last four assume the changes in truck costs are relatively concentrated on longer haul truck movements that tend to be more competitive with the rail industry. For example, in the "Bridge Formula B" case, the average cost savings for all combination trucks was estimated to be about one percent, but the savings for ship-

<sup>6</sup> Jones, Nix, and Schwier data actually can be used to derive both a rail ton-mile elasticity (1.00, as shown in Exhibit G.2) and a rail revenue elasticity (0.95). For reasons discussed above, these elasticities are inconsistent with each other. Accordingly, to avoid misleading the casual reader, the second elasticity has been omitted from Exhibit G.2.

<sup>7</sup> Herbert Weinblatt, *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, July 1990, Exhibit 5.

<sup>8</sup> Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles*, Final Report, prepared for the U.S. Department of Transportation, November 1993, Exhibits IV-4 and IV-11.

<sup>9</sup> *Ibid.*, pp. V-4-V-5. Also discussed briefly in Section H.1 of this report.

<sup>5</sup> Scott M. Dennis, *op. cit.*, pp. 7-9.

## Exhibit G.2. Implicit overall cross elasticities from the ICM.

	Cross Elasticities	
	Rail Ton-Miles	Rail Revenue
1. Uniform Change in Truck Costs <sup>1</sup>	0.52	0.81
2. Canadian Tax Policy <sup>2</sup>	1.00	—
Size and Weight Analyses		
3. Bridge Formula B <sup>3</sup>	0.99	1.43
4. Twin 33s <sup>3</sup>	1.50	2.30
Twin 48s <sup>4</sup>		
5. Low Usage	2.09	2.43
6. High Usage	2.30	2.91

Elasticities derived from:

<sup>1</sup> Scott M. Dennis, *The Intermodal Competition Model*, Association of American Railroads, September 1988, pp. 7-9.

<sup>2</sup> J. Jones, F. Nix and C. Schwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, p. 27.

<sup>3</sup> Herbert Weinblatt, *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, July 1990, Exhibit 5.

<sup>4</sup> Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles*, Final Report, prepared for the U.S. Department of Transportation, November 1993, Exhibits IV-4 and IV-11.

ments that actually benefited from the higher limits was estimated to average 3.6 percent and to be as high as 14 percent for some movements. The concentration of the cost savings on relatively competitive operations results in greater diversion than would be produced by a more uniform distribution of the cost savings.

The above discussion leads us to conclude that uniform changes in the cost of operating combination trucks are likely to produce cross elasticities of about 0.5 for rail ton-miles and 0.8 for rail revenue, and that changes that are more focused on rail-competitive segments of the truck industry are likely to produce cross elasticities that are two to three times as large.

### Cross Elasticities from the CN and CP

Another source of cross elasticities is a set of modal diversion estimates developed by the CN and CP railroads as part of a 1987 study sponsored by the Roads and Transportation Association of Canada.<sup>10</sup> In that study, the two railroads provided estimated ranges for the expected effects of three possible changes in truck size and weight limits on their traffic volume and revenue. Using estimates of the average reduc-

tion in truck costs for the three scenarios (which ranged from 8 to 14 percent), Jones, Nix, and Schwier<sup>11</sup> derived the implicit cross elasticities shown in Exhibit G.3.

The CP diversion estimates tended to produce slightly larger cross elasticities than the CN estimates. More significantly, both sets of cross elasticities are appreciably smaller than those produced by the ICM for the effects of changes in truck size and weight limits. At least part of the reason for the lower cross elasticities is that the Canadian railroads have relatively large volumes of long-haul movements of low-value natural resources—commodities that, as indicated in Exhibit G.1, have relatively low cross elasticities and are relatively resistant to diversion to truck. Other possible contributors to the difference in cross elasticities could include tendencies for the CN and CP analysts to have underestimated diversion or for the ICM to have overestimated it.

### Conclusions

On the basis of the above discussion, we conclude that, for *uniform* changes in truck costs, it is appropriate to assume cross elasticities of about 0.5 for rail ton-miles and 0.8 for rail revenue.

Separate cross elasticities were not obtained for rail tons. However, most rail traffic diverted to truck is likely to be intermodal traffic, frequently moving long distances, or single carload traffic, most typically being shipped more moderate distances. (Most short distance single carload shipments have already been diverted to truck while the longest haul movements are more insulated from truck competition than more moderate-haul movements.) Therefore, the length of haul of newly diverted rail traffic is likely to be slightly higher than average, and the cross elasticity of rail tons is likely to be slightly smaller than that of rail ton-miles. Hence, it would appear appropriate to assume that for a *uniform* change in truck costs, the cross elasticity of rail tons is likely to be about 0.4.

For changes in truck costs that are concentrated on the more rail-competitive truck operations, when expressed relative to the *average* change in costs for combination trucks, the cross elasticities are higher. In the case of the truck size and weight studies reviewed, the cross elasticities ranged from 1.0 to 2.3 for rail ton-miles and from 1.4 to 2.9 for rail revenue. Accordingly, for nonuniform changes in the cost of operating combination trucks, some judgment is necessary to determine the extent to which the changes are focused on rail-competitive truck operations, and so the extent to which the cross elasticities suggested in the preceding paragraph should be increased.

Since rail routes usually are more circuitous than truck routes, the change in truck ton-miles generally will be smaller than the change in rail ton-miles. Estimates of the

<sup>10</sup> N.A. Irwin and R.A. Barton, *Economics of Truck Sizes and Weights in Canada*, Final Report, Council on Highway and Transportation Research and Development and the Roads and Transportation Association of Canada, Ottawa, July 1987.

<sup>11</sup> Jones, Nix, and Schwier, *op. cit.*, Table 4.3.



### Exhibit G.3. Implicit cross elasticities from CN and CP analyses.

	Cross Elasticities	
	Rail Ton-Miles	Rail Revenue
Canadian National	0.39 – 0.51	0.54– 0.71
Canadian Pacific	0.35 – 0.59	0.59– 0.92

Source: J. Jones, F. Nix, and C. Scwier, *The Impact of Changes in Road User Charges on Canadian Railways*, prepared for Transport Canada by the Canadian Institute of Guided Ground Transport, Kingston, Ontario, September 1990, Table 4.3.

change in truck ton-miles can be obtained by multiplying the rail estimate by  $-0.85$ .<sup>12</sup>

### G.2 EFFECTS OF CHANGES IN RAIL RATES AND RAIL COSTS

Information about the modal-diversion effects of changes in rail rates and costs is less readily available than the information presented above about the effects of changes in truck costs.

Much traffic currently carried by rail is fairly well insulated from intermodal competition, though the portion of rail traffic that is not well insulated is somewhat larger than the corresponding portion of traffic in combination trucks (which includes substantial amounts of local and short-distance movements). Railroads usually have a substantial advantage in efficiency for transporting multi-carload shipments, and such shipments constitute about 62 percent of rail tonnage.<sup>13</sup> Because rail traffic is somewhat less well insulated from intermodal competition than truck traffic, *uniform* percentage changes in rail rates are likely to result in diverting somewhat more traffic between modes than would the same uniform percentage change in truck costs and rates.

In the preceding section it was suggested that a uniform one percent change in truck costs would result in diversion amounting to about 0.5 percent of rail ton-miles and 0.4 percent of rail tons. The above discussion implies that a uniform one percent change in rail rates might result in diversion amounting to about 0.75 percent of rail ton-miles and 0.6 percent of rail tons; i.e., that the *own elasticities* of rail ton-miles and rail tons to changes in rail rates are about  $-0.75$  and  $-0.6$  respectively. (These elasticities are negative since an increase in rail rates will result in a *decrease* in rail traffic.)

The elasticities suggested in the preceding paragraph are appropriate when changes in rail costs and rates are reason-

ably uniform across all categories of traffic. Changes in rail costs that apply primarily to truck-competitive traffic (most of which provides relatively low operating margins) are likely to produce rate changes that are concentrated on this traffic. As in the case of changes in truck costs, rate changes that are concentrated on modally competitive traffic are likely to produce substantially higher elasticities than uniform changes in rates, with the highest elasticities (perhaps in the two to four range) likely for doublestack and trailer-on-flatcar traffic.

As suggested in the preceding section, changes in truck ton-miles can be derived by multiplying estimated changes in rail ton-miles by  $-0.85$ .

### G.3 FREIGHT DEMAND ELASTICITY STUDIES: TECHNICAL CONSIDERATIONS

Three different methods are commonly used in the transportation literature for computing elasticities:<sup>14</sup>

- A *point elasticity* is calculated by expressing the quantity demanded as a function of price and then calculating

$$e_p = \frac{dQ}{dP} \frac{P}{Q}$$

If the functional relationship between quantity and price is not available, then it is generally not possible to calculate a point elasticity.

- An *arc elasticity* is calculated from information on price and quantity before and after a price change

$$e_a = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

This measure most nearly approximates a point elasticity.

- A *shrinkage factor* also is calculated from information on price and quantity before and after a price change

$$e_s = \frac{(Q_2 - Q_1) / Q_1}{(P_2 - P_1) / P_1}$$

The problem with calculating elasticities as shrinkage factors is that if the price is reduced by a given amount and then increased by the same amount, the shrinkage factor does not predict that demand will return to its original level. For small changes in price, however, the shrinkage factor will not differ significantly from the arc elasticity.

Elasticities can be short-run or long-run in nature, depending on the time period over which changes in demand are

<sup>12</sup> The results of two ICM analyses indicate that, on average, rail routings are 16 to 18 percent more circuitous than truck routings. (Herbert Weinblatt, *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, July 1990, Exhibit 4.)

<sup>13</sup> Derived from 1992 waybill data from Bureau of Transportation Statistics, *Rail Waybill Data: 1988–1992*, CD-ROM, Washington, D.C., 1994.

<sup>14</sup> Barton-Aschman Associates Inc. and R.H. Pratt, *Traveler Response to Transportation System Changes*, prepared for the U.S. Department of Transportation, Federal Highway Administration, July 1981.

observed. Differences between short-run and long-run elasticities can be substantial. For example, the short-run price elasticity for gasoline is about  $-0.20$ , while the long run elasticity is close to  $-1.00$ . This is because in the short-term, the only way to reduce gasoline consumption is to reduce vehicle miles of travel, while in the long term, more fuel-efficient vehicles can be used.

The focus of this section is on using price elasticities of demand to measure the responsiveness of demand to a change in price. Analysts employ elasticities to evaluate how proposed policies will impact freight demand. Ordinary price elasticities of freight demand include the scale or output effect associated with a change in price—i.e., they assume a carrier might adjust output levels as part of an overall response to changes in prices. In contrast, conditional or compensated elasticities measure the substitution effects of a price change and hold output constant. In their study of freight demand elasticity models, Oum, et. al., found that many of the existing empirical models do not treat output as an endogenous variable and, as a result, may report biased elasticities.<sup>15</sup>

Since compensated elasticities are the only elasticity measures available, they are used by policy analysts in assessing impacts of proposed policies. Fortunately, in most applied planning situations, the analyst is most critically interested in the modal substitution issues—i.e., an estimate of how much traffic will be shifted from one mode to another as a result of a given price change in one of the modes. The compensated elasticity models provide estimates of the specific measures of interest to the analysts.

There have been two major approaches in collecting the data needed for developing estimates of freight demand elasticities. One involves the collection of aggregate data to develop elasticity estimates. Specifically, these studies rely on data collected in the aggregate for a particular geographic corridor (state-to-state freight shipments, for example) on average freight rates, shipment volumes, shipment times, and delivery reliability by mode. Depending upon the particular analytic model used to develop elasticity measures, the dependent variable will vary to some degree. If a logit model is used to develop elasticity measures from the aggregate data, the dependent variable is a ratio of the modal volumes. If the translog model is used, the dependent variable is average freight rate on the geographic corridor for all modes. Oum analyzed a variety of functional forms for developing elasticities from aggregate data and concluded that the translog model performed the best in all aspects.<sup>16</sup> When the policy analyst is focusing on total traffic volumes and modal shifts occurring as a result of the implementation of a partic-

ular policy, then elasticities from aggregate models seem most appropriate.

The second class of models requires researchers to collect data from a representative sample of individual shipments. For each shipment, information is collected on freight rates for the mode used as well as alternatives. Data are also accumulated on time and variability of the shipment by the mode used and the alternative. In most instances, some form of logit or probit model is employed to develop freight demand elasticities from the disaggregate data.<sup>17</sup> The disaggregate models have intuitively appealing features. For example, the decision to shift traffic from one mode to another as a result of shifts in price is, in essence, an individual, disaggregate decision. It is more logical to use disaggregated data from individual shippers to develop elasticity measures designed to capture such individual decisions. Winston concludes: “(disaggregate models) offer a much richer econometric specification than any of the previous freight demand models. In addition, disaggregate models yield more precise estimates of market elasticities than the aggregate or inventory models. Finally, and perhaps most important, the disaggregate models are grounded in a behavioral theory of the actual decision-maker’s behavior thereby adding considerable substance to any policy implications.”<sup>18</sup>

However, despite these advantages, the development of a disaggregated data base is problematic. For one, it is time consuming and expensive to develop. Second, many of the data items required are not easy to obtain because of the confidentiality of private information.<sup>19</sup> Third, there is always the issue of whether the selected sample is representative of all major groups in the universe as well as the issue of expanding the sample results to the universe. If there are any biases in sampled shippers, these biases will be reflected in the developed elasticity measures. Use of the disaggregate data require the analyst to spend a great deal of time developing a systematic approach for its expandability to the population.

The issue here, however, is not so much on whether the disaggregate or aggregate approach is the most time and cost efficient, rather the issue here is to find a set of elasticities that can be employed when an analyst wishes to estimate the demand impact of modal cost/price increases resulting from the initiation of a new policy. As Oum has argued, the disaggregate and aggregate approaches should be viewed as complementary, not competing.<sup>20</sup>

The analyst must be aware of the limitations in the entire set of freight demand elasticities that have been developed

<sup>15</sup> Tae Hoon Oum, W.G. Waters II, and Jong-Say Yong, “Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates,” *Journal of Transport Economics and Policy*, May 1992, p. 142.

<sup>16</sup> Tae Hoon Oum, “Alternative Demand Models and Their Elasticity Estimates,” *Journal of Transport Economics and Policy*, May 1989, p. 185.

<sup>17</sup> Clifford Winston, “A Disaggregate Model of the Demand for Intercity Freight Transportation,” *Econometrica*, Vol. 49, No. 4 (July 1981), p. 981.

<sup>18</sup> Clifford Winston, “A Disaggregate Model of the Demand for Intercity Freight Transportation,” *Econometrica*, Vol. 49, No. 4 (July 1981), p. 998.

<sup>19</sup> Both Oum in “Alternative Demand Models and Their Elasticity Estimates,” and Winston in “A Disaggregate Model of the Demand for Intercity Freight Transportation” discuss the advantages and disadvantages of the disaggregate models.

<sup>20</sup> Tae Hoon Oum, “Alternative Demand Models and Their Elasticity Estimates,” *op. cit.*, p. 164.

in the literature. This section discusses some of these limitations.

For one, the most careful and thorough freight demand elasticities developed to date do not reflect all the changes that have occurred in the freight transport sector since deregulation. There were a flurry of very impressive freight demand elasticity studies conducted in the mid to late 1970s. However, there has been a dearth of such studies in the deregulated environment.

The absence of such investigations reflects a number of factors. Deregulation has shifted the focus in rate-making from the collective group to the individual carrier and shipper. More and more rates are being negotiated between carriers and shippers and kept out of the public domain. For example, more and more of the records from the Railroad Waybill Data do not include rate information because the rates are negotiated between the parties and filed as "contract rates." There is no question that the transport sector has changed dramatically since passage of the Motor Carrier Act of 1980 and the Staggers Rail Act of 1980. As a consequence, reference to elasticities based on pre-1980 data must be subjected to careful scrutiny.

There are, for example, solid data supporting the growth of intermodal transportation in the new deregulated environment. Railroads have experienced unprecedented growth in intermodal traffic throughout the 1980s and into the 1990s. All indications point toward higher and higher levels of intermodal movements on this nation's railroads. Certainly, the development of the intermodal option is now much more

prominent in the marketplace than it was prior to deregulation. Demand elasticities not reflecting these changes must be carefully interpreted.

As noted above, there are limitations inherent in both the aggregate and disaggregate approach to the development of demand elasticities. The aggregate studies suffer from their inability to model the actual modal decision process. All individual decisions are lumped together and the unit of analysis becomes modal market shares or freight rates on particular corridors. The disaggregate studies are based on a limited set of individual decisions which may be taken out of context from a shipper's overall modal assessment process. Thus, shippers might make modal decisions based on their entire set of shipment needs over a particular time period—quarter, half-year, or year. It may not be very effective to base demand elasticities on an individual shipment from a particular shipper rather than from that shipper's entire set of shipments.

Despite these very significant limitations, the policy analyst still must address the issue of how to estimate freight demand impacts associated with the implementation of a policy with a quantifiable impact on modal costs. The next section will present freight demand elasticity estimates that represent the best available estimates. There will be strong caution that these estimates have some very significant limitations. Nevertheless, the policy analyst may need to evaluate them as the best available evidence, albeit evidence that must be carefully screened, evaluated, and subjected to sensitivity analysis based on additional available evidence.

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## APPENDIX H

### THREE MODAL-DIVERSION MODELS

This appendix contains brief descriptions of two computer models that are designed to estimate modal diversion between rail and truck using disaggregate data on individual shipments and a third model designed to estimate diversion using more aggregate data.

#### H.1 INTERMODAL COMPETITION MODEL

The most commonly used tool for estimating rail/truck modal diversion from disaggregate data is the AAR's proprietary Intermodal Competition Model (ICM).<sup>1</sup> This model is designed to analyze a sample of actual rail movements, taken from the ICC Carload Waybill Sample,<sup>2</sup> and, for these movements, to estimate which will be diverted to truck, which will be retained as a result of competitive railroad rate reductions, and which will be unaffected by the reductions in truck transport costs. The most recent version of this model also is capable of analyzing the effects of increased truck costs on railroad rates charged on existing truck-competitive rail movements and on diversion from truck to rail (using a sample of truck movements from the North American Trucking Survey).<sup>3</sup>

The proprietary nature of the ICM makes a careful evaluation of the accuracy of its estimates difficult. We have reviewed output produced by the previous version of the model and concluded that the cross-elasticities of rail demand relative to changes in truck costs that are implicit in these results appear to be reasonable.<sup>4</sup> However, the comparison of cross-elasticities produced by the ICM to those produced by a CN/CP analysis discussed in Appendix G suggests that the ICM may tend to overestimate diversion moderately. For this reason, caution should be applied when using results produced by the model.

An important concern about the use of the ICM relates to the truck cost analysis performed by the model. This analysis presumes that the utilization rates of larger and heavier vehicles generally would be the same as current utilization of 48-foot semis; i.e., that all loads carried would be loads for

which the vehicles are designed and that there would be no increase in empty mileage and no decrease in annual mileage. These assumptions about utilization are optimistic, especially with respect to non-door-to-door configurations such as twin 48s. The ICM's estimates of cost savings resulting from the use of larger and heavier trucks are overstated, and, accordingly, modal-diversion estimates derived using these cost estimates are too high. This problem is not insurmountable. The model has been run in the past using exogenously specified estimates of the effects of regulatory changes on truck transport costs;<sup>5</sup> and adjustments also can be made to ICM results (with some loss of accuracy) to compensate for any known tendency of the model to over or underestimate diversion.

Several other factors have affected ICM results that have been produced in the past, although some of these may have been corrected in the latest version of the model. These factors are listed below, along with estimates of the effect of these factors on the model's estimates of overall diversion to twin 48s.<sup>6</sup>

- Fuel taxes were assumed to be zero on all truck movements originating in Canada, increasing overall diversion by an estimated 8.0 percent in the twin-48 analysis and to an unknown extent in other model runs.
- The costs of reconfiguring twin 48s and the costs of access hauls to the twin-48 network were not adequately reflected for short hauls (particularly those under 800 miles) while they were overestimated for long hauls (particularly those over 1,800 miles), increasing overall diversion by about 23 percent.
- Because the ICC waybill sample does not identify the true origin and true destination of intermodal movements (but only the rail origin and rail destination), the ICM underestimates the cost of intermodal movements and significantly underestimates diversion of these movements. Overall diversion was estimated to be reduced by 3 percent, but the magnitude of this underestimate can be expected to grow as intermodal traffic grows.

<sup>1</sup> Scott M. Dennis, *The Intermodal Competition Model*, Association of American Railroads, Washington, D.C., September 1988.

<sup>2</sup> The ICC Carload Waybill Sample consists of a systematic sample of waybills for railroad shipments terminating on Class I railroads in the United States.

<sup>3</sup> The North American Trucking Survey is a survey of truck drivers conducted during 1993 and 1994 at 46 truck stops by Arthur D. Little, Inc., under contract to the Association of American Railroads.

<sup>4</sup> Herbert Weinblatt, *Modal Diversion Effects of Changes in Truck Size and Weight Limits*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, Washington, D.C., July 1990.

<sup>5</sup> *Ibid.*; and Sydec, Inc., Jack Faucett Associates, and Transportation Consulting Group, Inc., *Truck Size and Weight and User Fee Policy Analysis Study, Part One: Productivity Effects of Policy Options*, Final Report, prepared for the Federal Highway Administration, Washington, D.C., March 1991.

<sup>6</sup> Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles*, Final Report, prepared for the Federal Highway Administration, Washington, D.C., November 1993, pp. V-4 and V-5.

- The use of waybill data for a recent historic year tends to understate the portion of rail traffic that is intermodal or will be in the future. Since intermodal traffic is the traffic most readily divertible to twin 48s, this understatement tends to reduce overall diversion to twin 48s.
- The ICM estimates of other logistics costs (OLCs) (which have been printed in the past but are no longer printed) do not appear to represent realistic relationships between OLCs for rail movements and OLCs for truck movements. (However, the model appears to have been calibrated to compensate for this effect.)

It should be emphasized that some of these problems may have been corrected in the latest version of this model.

Also, a slight bias toward understating diversion occurs because this model, and most diversion models, estimate only the direct effects of an exogenous change in costs. Some additional effects, not measured by the model, may result as traffic is diverted from one mode to another, decreasing the economies of density and increasing costs for the first mode, and having the opposite effect on the second mode.

Finally, no review has been conducted of the construction of the North American Trucking Survey (NATS) or of the way the ICM uses this data to represent the universe of rail-competitive truck shipments. However, the National Motor Truck Data Base (the predecessor to the NATS) had an inherent, but easily correctable, bias toward overrepresenting long-haul movements.<sup>7</sup> If the ICM is used with NATS for estimating diversion from truck to rail resulting from policy changes that increase truck costs or reduce rail costs, a failure to adjust for this bias will result in significantly overrepresenting long-haul truck movements, which are relatively divertible, and so in overestimating diversion from truck to rail.

## H.2 THE T-R/R-T DIVERSION MODEL

The Truck-Rail, Rail-Truck (T-R/R-T) Diversion Model is a new model currently being developed by Transmode Consultants under contract to the Federal Railroad Administration (FRA). A preliminary description of this model is contained in a Draft Users Manual<sup>8</sup> released in December 1994. The actual model and a somewhat revised Users Manual are scheduled for release in the next few months.

The T-R/R-T Model is based on much of the same research as the ICM. It distinguishes four types of truck transport (truckload (TL), less than truckload (LTL), longer-combination vehicle (LCV), and private); three types of intermodal transport (trailer-on-flatcar, doublestack, and Road Railer); and conventional rail carload transport.

The T-R/R-T Model represents nearly all movements as originating and terminating at county seats. The actual origins and destinations of shipments currently being made by truck or conventional rail are contained in the data sources

used, but those of intermodal shipments are not. The model creates assumed origins and destinations for these shipments from their intermodal origins and destinations, County Business Pattern data, and a gravity model.

The T-R/R-T Model estimates origin/destination (O/D) distances for conventional truck movements as great-circle miles (GCMs) between county seats, adjusted for circuitry. For LCV movements, the model estimates mileages of LCV operation from a node-link representation of an LCV network and from mileages of access hauls using GCMs between origins and destinations and nearby LCV network nodes (assumed to represent staging areas). The model currently assumes that LCVs can operate on all ramps connecting LCV network links.

For shipments that currently are not handled by conventional rail, railroad O/D distances are estimated by applying a rail/truck circuitry factor to GCMs. It is not clear what assumptions are made about the availability of rail service at the origin and destination. The use of a rail/truck circuitry factor results in consistent estimates of rail and truck O/D distances (both of which apparently are underestimated as a result of omitting any adjustment for truck/GCM circuitry).

For shipments that are currently handled by conventional rail, railroad O/D distances are set to actual distances obtained from the railroad waybill. The use of actual distances for rail and GCMs with no circuitry factor for truck results in overestimating the difference in length of haul between the two modes and biases the analysis toward rail-to-truck diversion.

All intermodal shipments are assumed to be made through one of 32 major intermodal rail terminals at each end of their rail haul. Rail distances between each pair of these terminals are maintained in a matrix used by the model and are actual rail distances between terminals. The use of a restricted set of intermodal terminals most likely results in overestimating highway access miles to intermodal terminals for some shipments.

A major advantage of the T-R/R-T Model relative to the ICM is that the T-R/R-T Model is nonproprietary. The Users Manual<sup>9</sup> provides a better description of the model and its construction than available documentation for the ICM. However, no definitions or derivations for the many parameters incorporated in the model are provided (though some of the parameter values can be inferred from three pages of output reproduced in an appendix); and the Users Manual provides no information about how to modify any of these parameters.

A second advantage of the T-R/R-T Model is its ability to create initial origins and final destinations for current intermodal movements. This capability enables the model to develop much better estimates of the potential for diverting current intermodal movements to alternate modes than the ICM was able to do the last time we were exposed to its use for this purpose (as discussed in the preceding subsection).

<sup>7</sup> *Ibid.*, p. C-7.

<sup>8</sup> Transmode Consultants, Inc., *Truck-Rail, Rail-Truck Diversion Model*, User Manual, Draft, Washington, D.C., December 1994.

<sup>9</sup> *Ibid.*

Despite these advantages, several concerns exist about the current version of the T-R/R-T Model as a result of a brief review of the draft model description and of the three pages of output produced in an appendix for a single shipment (of a weight-limited sodium compound).

The most significant concerns relate to the analysis of LCVs. Data contained in the appendix indicates that transit times for LCVs are assumed to be one-third shorter than those of for-hire TL transport, and that reliability is assumed to be 20 percent better. Although not discussed anywhere in the Users Manual, the shorter transit times reflect an assumption that around-the-clock relay operation would be used for LCVs but not for conventional trucks. However, the cost structures used for LCVs and for conventional trucks apparently do not reflect any cost difference between relay operation and the single-driver operation assumed for conventional trucks. (If the costs actually are similar, conventional TL operators would choose to provide the better service attainable with relay operation.)

The transit time assumption for LCVs apparently also ignores the delays that can be expected at staging areas in order to match pairs of trailers moving in the same general direction. Also, because of the need for such delays (without which the economies of LCV operation are unattainable), it seems that, for most shippers, transit-time reliability of LCVs would be *poorer* than that of conventional truckload service (though some shippers might be willing to pay a premium to guarantee expedited handling of their trailers).

Other concerns include:

- The procedures used for estimating length of haul for shipments currently handled by rail (discussed above) apparently overstate somewhat the lower circuitry of truck, thus biasing the analysis somewhat toward diversion to truck.
- A load ratio (loaded miles per total mile) of 1.0 is assumed for all modes except rail (for which it is 0.6) and private truck (for which it is 0.5). An overall load ratio of 1.0 is unattainable for any mode. (There might be some analytic justification for treating loaded backhauls as if they had load ratios of 1.0, or even higher; but the movement in question—from Barstow, California to Swansea, Illinois—is unlikely to represent a backhaul.)
- The assumptions used for LCV access costs (roughly half to two-thirds of those for intermodal access costs) may be somewhat optimistic.
- Rail costs appear to be modeled as being directly proportional to distance, with no additional costs for pickup and delivery.
- A negative charge for pickup and delivery appears to be incorporated into the rate structure of truckload carriers (actually, a \$162 charge per shipment for pickup and a \$332 credit for delivery).
- The costs for LCVs appear either to exclude or to underrepresent the cost of reconfiguring LCVs en route and the inefficiency resulting from an inability to pair all trailers operating on the LCV network. Also, the apparent assumption that efficient interconnections will exist between all intersecting LCV roads without any added circuitry will result in underestimating the lengths of LCV hauls.

It is likely that some of these concerns will be addressed prior to public release of the model. However, addressing other concerns will require a larger effort than the one that is currently underway. Accordingly, we are not confident that the first version of the model will be appropriate for analyzing modal diversion.

### H.3 THE 1,000-MILE STRATEGIC CHOICE MODEL

The 1,000-Mile Strategic Choice (TMSC) Model currently is being used by Mercer Management Consulting (MMC) to perform truck/rail modal diversion analyses as a part of a study being conducted for the Southern California Association of Governments (SCAG). The model is proprietary and very little information is currently available. However, because of its current use in an important public-policy study, it warrants some brief discussion based on the limited published description that is available.<sup>10</sup>

Unlike the models described in the two preceding sections, the TMSC Model apparently does not contain a representation of either the rail or highway systems. Instead, the model focuses its analysis on the effect on modal choice of changes in four modal characteristics. The modal characteristics considered are: transport costs, transit time, service reliability, and accuracy of freight bills. The modes analyzed are truck, rail intermodal, and rail carload. The effects of any policy change on any of the modal characteristics apparently must be specified exogenously.

The model's estimates of the diversion effects of changes in modal characteristics are derived from 117 responses to a survey of major shippers conducted in 1991 by Temple, Barker, and Sloane (MMC's predecessor). Most or all respondents appear to be manufacturers, and the relevant survey questions all focused entirely on shipments moving about 1,000 miles (hence, the name of the model).

The survey used a very small sample. More importantly, the information collected appears to be too narrow to be used as the basis for estimating overall modal diversion. In particular, it is not clear what assumptions the model makes about shipments of natural resources or about hauls that fall outside of the 800 to 1,200-mile range.

<sup>10</sup> Mercer Management Consulting, *Interregional Goods Movement Study*, Task 2C Report: Evaluation of Key Methodologies, prepared for the Southern California Association of Governments, Los Angeles, April 1995.

## APPENDIX I

### CASE STUDIES

This appendix presents two case studies demonstrating the practical application of some of the procedures presented in this Guidebook.

The first case study presents the development of forecasts of freight traffic for North Carolina's two existing freight airports and for a third proposed freight airport. These forecasts make use of the comparison and proximity/level-of-service procedures presented in Chapter 4 under Evaluating Proximity and Level of Service, and Analyzing Total Logistics Costs of Individual Shipments.

The second case study presents an analysis of the effects of a possible change in federal truck size and weight policy. This case study demonstrates some of the cost estimation and modal-diversion procedures presented in Appendices F–H.

#### I.1 CASE STUDY: NORTH CAROLINA FREIGHT AIRPORTS

In 1991, the State of North Carolina's Department of Transportation commissioned a study to evaluate short and long term needs for the state's air cargo infrastructure.<sup>1</sup> The study included an inventory of the state's air cargo facilities and intermodal linkages, an analysis of system capacity, and traffic forecasts to 2010 for state airports. The study also evaluated the technical and market feasibility of the Global Air Cargo Industrial Complex (GACIC) concept which is currently being developed as the Global Transpark in Kinston, North Carolina. The GACIC analysis included a projection of new industrial activity attracted to the facility and the development of a forecasting model which allocates future demand among the state's primary cargo airports including various locations for the GACIC. This case study examines the demand forecasting techniques used for both the current airport system and one that included the GACIC.

##### Problem Definition and Research Objectives

The forecasting elements of this study required long-term forecasts for existing cargo airports in the state with an emphasis on the primary facilities at Charlotte (CLT),

Raleigh-Durham (RDU), and Greensboro (GSO). These forecasts were required to determine the adequacy of existing and projected infrastructure. The GACIC portion of the study required the ability to define a new cargo airport with an indefinite location and capacity, also identifying new industrial activity to be attracted to the airport.

Air cargo demand forecasts for airports have traditionally been based on trend analysis, projecting future growth based on national trends and a continuation of historical growth. A primary reason for this strategy has been the limited availability of data beyond airport traffic statistics. This approach treats individual airports as independent of the larger markets in which they actually compete. This study incorporated a more detailed representation of the air cargo market, incorporating regional demand and market share analysis. The reasons for this more detailed analysis included:

- a requirement to forecast flows among multiple airports which share a common hinterland;
- a requirement to test various scenarios for the location and service profile for the GACIC; and
- a requirement to identify specific industries which might be attracted to a GACIC facility.

The following sections discuss the techniques utilized in generating the demand forecasts.

##### Market Characteristics

The process for forecasting demand in this case included measuring baseline activity and relationships and projecting them into the future under various development scenarios. The North Carolina air cargo market analysis isolated four primary areas of data and activity:

- Market Demand;
- Airport Traffic and Aircraft Activity;
- Cargo Routing Patterns; and
- New Industrial Activity for GACIC.

The characteristics, sources, and techniques used to describe these market elements are discussed in the following sections.

<sup>1</sup> *North Carolina Air Cargo System Plan and a Global Air Cargo Industrial Complex*, by Transportation Management Group, Inc., Leeper, Cambridge & Campbell, Inc., and COMSIS Corporation, February 1992.

## Market Demand

Market demand was defined by the volume, location, and type of air cargo shipments and receipts without regard for airport routing. The characteristics of market demand are shown in Exhibit I.1.

The geographic market definitions were determined by:

- a requirement to identify sub-state cargo flows;
- the ability of cargo airports to attract traffic from local, regional and national markets with closer origins and destinations more susceptible to capture; and
- the levels of detail available for various data sources.

Since all of the state's airports were included, the "local" market was defined as the entire State of North Carolina at the county level. A primary data source for cargo demand was the Colography Group's estimates of domestic and export air shipments generated by the top 73 manufacturing industries (defined at the four-digit SIC level) by U.S. county.<sup>2</sup> The "regional" market was defined as an aggregation of various "airport market areas" which are county groupings surrounding primary airports as defined by Colography. The "All Other U.S." market was defined as the rest of the national market as measured for all airports.

The primary technique required for the geographical-based data was associating the detailed county-based data with more aggregated data at the state or other levels. For example, the employment forecasts of the Bureau of Economic Analysis (BEA) are only available at the two-digit SIC industry level by state with more aggregate data available for BEA regions (larger county groups associated with major metropolitan regions) which did not match the Colography regions. In most cases, detailed county-based characteristics were assumed to mirror the average of data available for the larger regions.

As market proximity is a key factor in determining air cargo routings, the location of market origins and destinations relative to the study's airports was incorporated as highway distances between the airport and the "centroid" of the local and regional market areas. This geographical structure easily allowed the introduction of "new" airport locations as required in the GACIC analysis.

The total outbound market was estimated from the 73 industry totals using expansion factors provided by Colography as determined from national traffic totals. Inbound traffic was estimated based on flow characteristics for the state's airports and assumptions based on outbound distributions. The "All Other U.S." demand totals were calculated as the residual of national totals minus the regional market estimates.

The forecasting methodology utilized for market demand was designed to reflect the following characteristics of air cargo markets:

- Air cargo traffic represents a segment of larger manufacturing, trade and transportation markets. Market growth will incorporate national, regional and local economic trends. Employment growth trends were used to represent the general growth in regional outbound shipments. BEA employment forecasts for state industry groups and BEA county regions<sup>3</sup> were combined and modified for this purpose.
- The use of air cargo services relative to other modes has increased significantly due to the implementation of advanced distribution systems for both manufacturing and consumer markets (e.g., just-in-time) and the trend toward more globalized markets. The shift of the U.S. industrial base away from traditional heavy industry toward high technology manufacturing and service industries has also resulted in a trend toward more air service use. Historical Colography data for average air cargo production per employee (in pounds) was compared for 1983 and 1990, generating average productivity growth rates used in the forecasts for regional outbound shipments.
- Regional growth for outbound shipments was compared with national growth as projected in the Boeing Company's *World Air Cargo Forecasts*<sup>4</sup> resulting in traffic projections for the "All Other U.S." category.
- Inbound traffic estimates assumed the baseline distribution by market region to national totals based on the Boeing growth trends.

## Airport Traffic and Aircraft Activity

The most common form of transportation data involves facility statistics for ports, airports or border points. The major drawback with most facility data is the lack of detail regarding the origin and destination of traffic and through routing information. This study attempted to correlate airport traffic volumes with the underlying demand and supply markets in order to produce more results which represented the underlying market relationships.

Baseline activity for North Carolina airports was derived from published carrier statistics modified and supplemented with information gathered in an interview program with airports, carriers and other air cargo firms. State airport traffic was then compared with national traffic totals (as estimated from the market demand totals). Exhibit I.2 summarizes the characteristics measured.

Total state traffic combines airport statistics published by the Federal Aviation Administration<sup>5</sup> (for U.S. carriers), the Airport Operators Council International<sup>6</sup> (AOCI), and the

<sup>3</sup> U.S. Department of Commerce, Bureau of Economic Analysis, *BEA Regional Projections to 2040*, U.S. Government Printing Office, October 1990.

<sup>4</sup> Boeing Commercial Airplane Group, *World Air Cargo Forecast*, Seattle, annual.

<sup>5</sup> Federal Aviation Administration, *Airport Activity Status of Certificated Air Carriers*, annual.

<sup>6</sup> Airport Operators Council International, *Worldwide Airport Traffic Report*, annual.

<sup>2</sup> The Colography Group, *U.S. Air Freight Origin Traffic Statistics*, Marietta, Georgia, annual.



Exhibit I.1. Market demand characteristics.

Data Item	Source	Techniques/Comments
Geographic Regions	Study Team	North Carolina counties (NC), airport-based county groups for parts of surrounding 5-state region ("regional market areas" – RMA), and "All Other U.S."
Airport-Market Distances	Household Goods Carriers' Highway Mileage Tables	Distances based on published highway mileage tables between airports and county/RMA centroids.
Outbound Air Shipments by Industry Group and Origin Market Area	Colography Group	Data source only includes top 70+ industries (at 4-digit SIC level). Expansion to all industries based on Colography-supplied expansion factors modified based on aggregate totals.
Inbound Air Shipments by Industry Group and Destination Market Area	Census Foreign Trade Statistics Study Team	NC traffic estimated from ratio of inbound to outbound for NC airport traffic. RMA traffic estimated as percentage of total non-NC traffic based on outbound distribution. Total US traffic estimated from Census statistics.
Air Shipments by Industry and Market Area (Forecasts to 2010)	BEA Employment Forecasts by Industry and Region Colography Group Boeing World Air Cargo Forecasts	Regional cargo shipment growth based on combination of employment and cargo productivity growth by industry. Employment growth rates derived from BEA projections modified to match geographical and industry grouping. Cargo productivity growth estimated for top industries using trend analysis for Raleigh-Durham and Charlotte market areas (from Colography); growth rates constrained based on national aggregate projections. National totals projected using industry forecasts modified to match time frame.

Exhibit I.2. Airport traffic characteristics.

Data Item	Source	Techniques/Comments
U.S. Airport Traffic (Baseline)	Colography Group Census Foreign Trade Statistics	Based on total U.S. Demand.
State Airport Traffic (Baseline)	FAA Airport Activity Statistics AOCI Worldwide Traffic Report Census Foreign Trade Statistics (for Wilmington, NC, Customs District) Airline/Airport Interviews	International data only available by Customs District (in this case includes all state airports). Total inbound traffic is estimated. Total international outbound traffic includes re-allocation of traffic enplaned on domestic flights at state airports for transshipment at other U.S. international gateways. International inbound traffic assumes same expansion factors as outbound traffic. Domestic inbound traffic is estimated as the residual.
Total NC Airport Traffic (Forecast)	Market Demand Forecasts by Market Region Study Team	Airport projections match market demand forecasts with projected shifts in share (see below).
NC Primary Airports' Traffic (Forecast)	North Carolina Air Cargo Forecasting and Allocation Model	Model allocates total NC airport demand among primary airports based on proximity to regional markets and relative service levels. Model incorporates assumptions about traffic diversion to secondary airports.

U.S. Bureau of Census.<sup>7</sup> Some of the limitations encountered and techniques used include:

- Comprehensive international data was only available in the Census statistics for all airports in the Wilmington, North Carolina, Customs District which fortunately corresponded directly with the state's airports. International estimates for individual airports required a matching of carrier and airport data with the aggregate totals.
- The FAA statistics exclude international carriers and certain all-cargo operators, and only measure enplaned cargo.
- The AOCI statistics incorporate filings by member airports which are not verified. Statistics provided by individual airports were used to verify this source for the study.
- The definition of international cargo used in the market demand forecasts was based on the ultimate origin or destination of the cargo. Airport traffic data may be based on the originating flight (Census data) or type of air bill (FAA). International traffic which included a transshipment at a U.S. airport was estimated and re-allocated.
- Where inbound data was limited, it was assumed that patterns resembled outbound distributions.

Exhibit I.3 summarizes the estimated baseline traffic.

In addition to traffic patterns, a representation of relative service levels was required for the forecasting model. Service levels can be measured in terms of total cargo capacity modified to reflect the timing and type of capacity. The study team derived relative service levels for both the domestic and international markets based on the interview process and a comparison of freight-flow patterns with air-service patterns. These service indices were used in the allocation model and modified during the calibration process. Future service levels were projected based on general scenarios related to available capacity and carrier operating patterns.

Airport traffic flows were compared with market demand to establish baseline cargo routing patterns which were then projected and applied to future market demand (see below). Forecasts of traffic for individual primary airports (including the GACIC) utilized a calibrated route allocation model described in the next section. Secondary airport traffic was assumed to maintain the same share of the projected state total throughout the forecast period.

Forecasts of aircraft activity at primary airports were required for the capacity analysis, as well as to size the proposed GACIC facility. Exhibit I.4 summarizes the characteristics measured. The baseline distribution between passenger and all-cargo flights for each airport was derived from the modified FAA carrier statistics for enplaned cargo. Inbound patterns were assumed to be the same. Average cargo loads per flight operation were derived for both types of flights with passenger patterns assumed to remain constant during the forecast period. For all-cargo operations, average pay-

loads were derived for general classes of aircraft type and weighted based on current and projected flight schedules. This structure was used to measure the impact of trends in equipment technology and fleet mix. Exhibit I.5 shows how aircraft operations were projected.

### *Cargo Routing Patterns*

The interaction between market demand and facility activity can be represented by cargo routing patterns which describe the facility's share of available markets. In this case, the proximity/level-of-service procedure described in Chapter 4 was used to produce initial estimates of baseline cargo routing patterns. The system was then calibrated to produce better estimates of current market and facility activity, and these results were projected for forecast years to derive traffic forecasts for each facility. The two-stage forecasting methodology first assigned total flows to North Carolina airports and then allocated that traffic among the primary cargo airports. Exhibit I.6 describes the characteristics used to represent cargo flow patterns.

The state's share of available domestic and international cargo markets was derived for each of the market demand areas (North Carolina, regional market areas, and all other U.S.). U.S. Census statistics matching state of export shipments with the airport of exit provided information on the share of state airport traffic which originated in North Carolina. These results were modified to include international shipments loaded on domestic flights for transshipment at another U.S. airport (traffic which is not included in the Census totals).

The State of Export series was also utilized in estimating the share of state airport traffic originating from the regional market areas. BEA data measuring personal income for these regions was used to allocate state totals to the sub-state regions. Domestic market distributions were based on the interview program, as no routing data was available. Inbound traffic distributions were based on the outbound patterns, assuming each market region accounted for comparable shares of traffic in both directions.

The market share forecasts were based on the study team's analysis of historical trends and interviews with industry participants concerning future service development plans. Baseline shares were estimated for 2000 and 2010 and matched to projected demand totals in order to forecast total traffic. Exhibit I.7 shows the structure used for these forecasts.

Forecasts for the primary cargo airports utilized a cargo routing model which allocated the assigned state totals based on a combination of proximity and service levels. The structure for the North Carolina Air Cargo Forecasting Model (NCACFM) is shown as Exhibit I.8. The model's structure includes the following components:

- The forecasting of state airport traffic from the Colography baseline data base is incorporated within the model (shown as the top half of the exhibit).

<sup>7</sup> U.S. Bureau of the Census, *U.S. Exports/Imports of Merchandise*, tape, annual.

Exhibit I.3. 1990 baseline North Carolina airport traffic (tons).

	CLT	GSO	RDU	Subtotal	All Other Airports	Total
<u>Outbound</u>						
Domestic	55,995	10,857	28,818	95,670	2,005	97,675
International	<u>10,121</u>	<u>14,248</u>	<u>6,287</u>	<u>30,656</u>	<u>0</u>	<u>30,656</u>
Total	66,116	25,105	35,105	126,326	2,005	128,331
<u>Inbound</u>						
Domestic	44,887	5,397	31,267	81,551	1,971	83,522
International	<u>14,088</u>	<u>19,833</u>	<u>8,752</u>	<u>42,673</u>	<u>0</u>	<u>42,673</u>
Total	58,975	25,230	40,019	124,224	1,971	126,195
<u>Total</u>						
Domestic	100,882	16,254	60,085	177,221	3,976	181,197
International	<u>24,209</u>	<u>34,081</u>	<u>15,039</u>	<u>73,329</u>	<u>0</u>	<u>73,329</u>
Total	125,091	50,335	75,124	250,550	3,976	254,526
<u>Percent of Total</u>						
Domestic	55.7%	9.0%	33.2%	97.8%	2.2%	100.0%
International	33.0%	46.5%	20.5%	100.0%	0.0%	100.0%
Total	49.1%	19.8%	29.5%	98.4%	1.8%	100.0%
Inbound as a Percent of Outbound	89.2%	100.5%	114.0%	98.3%	98.3%	98.3%

1. International inbound traffic estimated as 139.2% of outbound traffic based on the ratio of 1990 Wilmington import weight to reported international waybill exports.
2. Total inbound traffic estimated as percentage of outbound traffic.

- The primary airports are defined by their distance to the regional origin/destination (O/D) "zones" (North Carolina county or regional market area) and their relative service levels for the domestic and international markets. The airport with the highest service level was assigned a value of 100 percent with other airports' values set relative to that level. Forecast values were set rel-

ative to the baseline values based on anticipated service development patterns.

- Cargo originating or terminating at an O/D zone (and designated for a North Carolina airport) is assigned among state airports using an equal weighting of the relative service ratings and a distance comparison weighted towards the closest airport. The service and

Exhibit I.4. Airport aircraft activity characteristics.

Data Item	Source	Techniques/Comments
Primary North Carolina Airports' Aircraft Activity by Type of Carrier and Aircraft	FAA Airport Activity Statistics Airline Interviews	Assume inbound patterns reflect outbound patterns.
Primary North Carolina Airports' Average Load per Flight Operations	FAA Airport Activity Statistics Airline/Airport Interviews Study Team	Cargo flight payloads estimated for nominal aircraft type.
Primary North Carolina Airports' Service Levels	OAG Air Cargo Guide Study Team	Relative service indices estimated for primary airports.

Exhibit I.5. Summary forecast of aircraft operations at the North Carolina commercial airports.

	Charlotte				Greensboro				Raleigh-Durham			
	1990	1995	2000	2010	1990	1995	2000	2010	1990	1995	2000	2010
Total Cargo Traffic (000 Tons)	125.1	247.9	424.3	1,179.9	50.3	96.9	155.2	431.8	75.1	135.7	228.8	628.7
<u>Cargo Activity – Passenger Operations</u>												
Allocation of Total Traffic	38.5%	38.5%	38.5%	38.5%	8.1%	8.1%	8.1%	8.1%	35.5%	35.5%	35.5%	35.5%
Traffic (000 Tons)	48.2	95.4	163.4	454.3	4.1	7.6	12.6	35.0	26.7	48.2	81.2	222.5
Number of Flight Operations (000)	238.1	282.0	321.0	449.1	238.1	282.0	321.0	449.1	238.1	282.0	321.0	449.1
Average Pounds per Flight Operation	405	677	1,018	2,023	34	56	78	156	224	342	506	991
<u>Equipment Mix – All Cargo Operations</u>												
Percent of Total Operations												
Feeder	16.7%	19.0%	23.8%	14.3%	54.5%	46.2%	43.8%	47.4%	26.7%	26.3%	25.9%	25.9%
Jet – Small	50.0%	28.6%	14.3%	4.8%	36.4%	23.1%	12.5%	5.3%	60.0%	47.4%	33.3%	29.6%
Jet – Medium	33.3%	42.9%	42.9%	42.9%	9.1%	15.4%	31.3%	26.3%	13.3%	26.3%	37.0%	37.0%
Jet – Large	0.0%	9.5%	19.0%	38.1%	0.0%	15.4%	12.5%	21.1%	0.0%	0.0%	3.7%	7.4%
Average Payload (Pounds/Operation)												
Feeder	1,300	1,300	3,250	3,250	1,300	1,300	3,250	3,250	1,300	1,300	3,250	3,250
Jet – Small	24,000	24,000	26,000	26,000	24,000	24,000	26,000	26,000	24,000	24,000	26,000	26,000
Jet – Medium	45,000	45,000	48,750	48,750	45,000	45,000	48,750	48,750	45,000	45,000	48,750	48,750
Jet – Large	76,000	78,000	84,500	84,500	78,000	78,000	84,500	84,500	78,000	78,000	84,500	84,500
Weighted Average – Jet Operations	32,400	41,471	53,422	63,375	28,200	45,429	51,839	60,775	27,818	31,500	40,300	43,225
Weighted Average – All Operations	27,217	33,819	41,476	54,786	13,527	25,062	30,469	33,526	20,747	23,553	30,894	32,861
<u>Cargo Activity – All Cargo Operations</u>												
Allocation of Total Traffic	61.5%	61.5%	61.5%	61.5%	91.9%	91.9%	91.9%	91.9%	64.5%	64.5%	64.5%	64.5%
Traffic (000 Tons)												
Feeder	0.6	1.1	4.9	6.1	2.4	2.1	6.7	18.2	0.8	1.3	4.1	10.4
Jet	76.3	151.3	256.1	719.5	43.8	86.9	136.0	378.6	47.6	86.3	143.5	393.9
	76.9	152.5	260.9	725.6	46.2	89.1	142.6	396.8	48.4	87.5	147.6	404.2
Number of Flight Operations												
Feeder	942	1,717	2,996	3,784	3,728	3,280	4,096	11,213	1,245	1,956	2,493	6,378
Jet	<u>4,711</u>	<u>7,299</u>	<u>9,587</u>	<u>22,706</u>	<u>3,107</u>	<u>3,827</u>	<u>5,266</u>	<u>12,459</u>	<u>3,424</u>	<u>5,477</u>	<u>7,123</u>	<u>18,224</u>
	5,654	9,016	12,583	26,490	6,384	7,107	9,362	23,672	4,670	7,432	9,616	24,602

Exhibit I.6. Cargo routing pattern characteristics.

Data Item	Source	Techniques/Comments
Total NC Airports' Share of Outbound Traffic by Market Origin (Baseline)	Census State of Export and Foreign Trade Statistics BEA, Local Area Personal Income Study Team	Share of export traffic originating in NC estimated using Census patterns for international flight enplanements averaged with study team estimates for other types of traffic.  Share of exports from RMAs estimated using five-state Census totals with RMA portion based on county-based manufacturing earnings.  Share of domestic outbound traffic based on study team interviews and industry patterns.
Total NC Airports' Share of Inbound Traffic by Market Origin (Baseline)	Study Team	Distributions based on outbound patterns for both domestic and international traffic.
Total NC Airports' Share of Total Traffic by Market Origin (Forecast)	Study Team	Shifts in market shares of regional traffic based on historical trends and assumed service development relative to competing airports.
Primary Airports' Share of State Airport Traffic by Market Origin (Baseline/Forecast)	North Carolina Air Cargo Forecasting and Allocation Model Study Team	Model calibrated to baseline traffic.  Forecast market shares based on relative proximity to markets and service levels.  Model accommodates "new" airport as represented by service levels and location relative to market areas.

distance weighting factors were varied to calibrate model results to actual baseline market shares.

- Projected cargo volumes are utilized by the airport activity module which estimates flight operations.

The model's summary inputs and outputs are shown in Exhibit I.9.

#### *New Industrial Activity*

The proposed GACIC facility would operate as a general cargo airport attracting regional cargo based on proximity and service levels, as well as a magnet to new industrial facilities attracted by the integration of industrial and transportation capabilities. The forecasting model was designed to accommodate a new "primary" airport which would compete for regional cargo which includes new traffic assigned to the county where the facility is located. The study included testing of three different locations for the facility with additional testing conducted in later phases of the development process.

The projection of new activity attracted to or near the GACIC facility was based on an extensive interview and analysis process which identified the types of industries which would best utilize the advantages of the facility and then profiled the industrial and transportation characteristics for those industries. The characteristics used to describe and estimate the new activity is shown as Exhibit I.10.

The GACIC concept was developed based on trends toward integration of production and distribution systems and an increasing reliance on air cargo among the newest

high technology industries. It was assumed that the priority industries would include top air cargo producing industries currently attracted to the Silicon Valley or currently prominent in North Carolina. The profile of industrial and transportation characteristics for each industry was based on baseline year activity for those areas.

The number of new plants assigned to the GACIC area in the forecast period was estimated from the current level of activity for the prototype areas. For example, it was estimated that the GACIC could attract 32 electronic computer facilities by the year 2000, equivalent to 15 percent of the current concentration in Santa Clara County.<sup>8</sup> Projected traffic and employment were calculated using average size and activity factors, as well as general assumptions concerning the balance and composition of activity. Exhibit I.11 summarizes the projected new industrial activity.

#### **Conclusions**

The methodologies applied in this study were designed to project activity for both the existing state airport system and a new facility concept with no available prototype. The techniques used incorporated a wide variety of data sources and attempted to profile the relationships involved in air cargo markets accurately. Typical problems encountered included the synthesis of data with varying levels of detail and defin-

<sup>8</sup> The projected number of plants was based on anticipated growth in the industries over the forecast period and a reasonable share of "new" plant locations. Additional research for the master plan included a more detailed analysis of the probable development scenarios.

Exhibit I.7. Air cargo matrix forecast 2010.

Origin/Destination	North Carolina Airports				Other U.S. Airports				Total U.S. Airports		
	Inbound	Outbound	Total	% of US	Inbound	Outbound	Total	% of U.S.	Inbound	Outbound	Total
<u>North Carolina</u>	A	B	C		D	E	F		G	H	I
Domestic	616.4	720.9	1,337.3	72.159%	237.8	278.1	516.0	27.841%	854.3	999.0	1,853.3
International	325.4	233.7	559.1	61.283%	205.6	147.7	353.2	38.717%	530.9	381.4	912.3
TOTAL	941.8	954.6	1,896.4	68.572%	443.4	425.8	869.2	31.428%	1,385.2	1,380.4	2,765.6
Domestic % of Total	65.5%	75.5%	70.5%		53.6%	65.3%	59.4%		61.7%	72.4%	67.0%
% of All O/Ds	83.5%	83.8%	83.6%		2.1%	2.1%	2.1%		6.3%	6.5%	6.4%
<u>Regional Market Area</u>											
Domestic	102.5	119.9	222.4	9.627%	1,054.8	1,032.3	2,087.2	90.373%	1,157.3	1,152.2	2,309.5
International	44.6	32.0	76.6	10.601%	331.4	314.8	646.2	89.399%	376.0	346.8	722.8
TOTAL	147.1	151.9	299.0	9.860%	1,386.3	1,347.1	2,733.4	90.140%	1,533.4	1,499.0	3,032.4
Domestic % of Total	69.7%	78.9%	74.4%		76.1%	76.6%	76.4%		75.5%	76.9%	76.2%
% of All O/Ds	13.0%	13.3%	13.2%		6.6%	6.7%	6.7%		7.0%	7.1%	7.0%
<u>All Other U.S.</u>											
Domestic	9.0	10.5	19.5	0.093%	10,539.7	10,491.4	21,031.1	99.907%	10,548.7	10,501.9	21,050.6
International	30.5	21.9	52.4	0.319%	8,508.7	7,854.1	16,362.8	99.681%	8,539.2	7,876.0	16,415.2
TOTAL	39.5	32.4	71.8	0.192%	19,048.4	18,345.5	37,394.0	99.808%	19,087.9	18,377.9	37,465.8
Domestic % of Total	22.8%	32.4%	27.1%		55.3%	57.2%	56.2%		55.3%	57.1%	56.2%
% of All O/Ds	3.5%	2.8%	3.2%		91.1%	91.3%	91.2%		86.6%	86.5%	86.6%
<u>Total U.S.</u>											
Domestic	727.9	851.2	1,579.1	6.263%	11,878.8	11,755.5	23,634.3	93.737%	12,606.7	12,606.7	25,213.4
International	400.4	287.7	688.1	3.812%	9,021.6	8,340.6	17,362.2	96.188%	9,422.0	8,628.3	10,050.3
TOTAL	1,128.3	1,138.9	2,267.2	5.241%	20,900.4	20,096.0	40,996.5	94.759%	22,028.8	21,235.0	43,263.7
Domestic % of Total	64.5%	74.7%	69.7%		56.8%	58.5%	57.6%		57.2%	59.4%	58.3%

Exhibit I.8. North Carolina air cargo forecasting and allocation model.

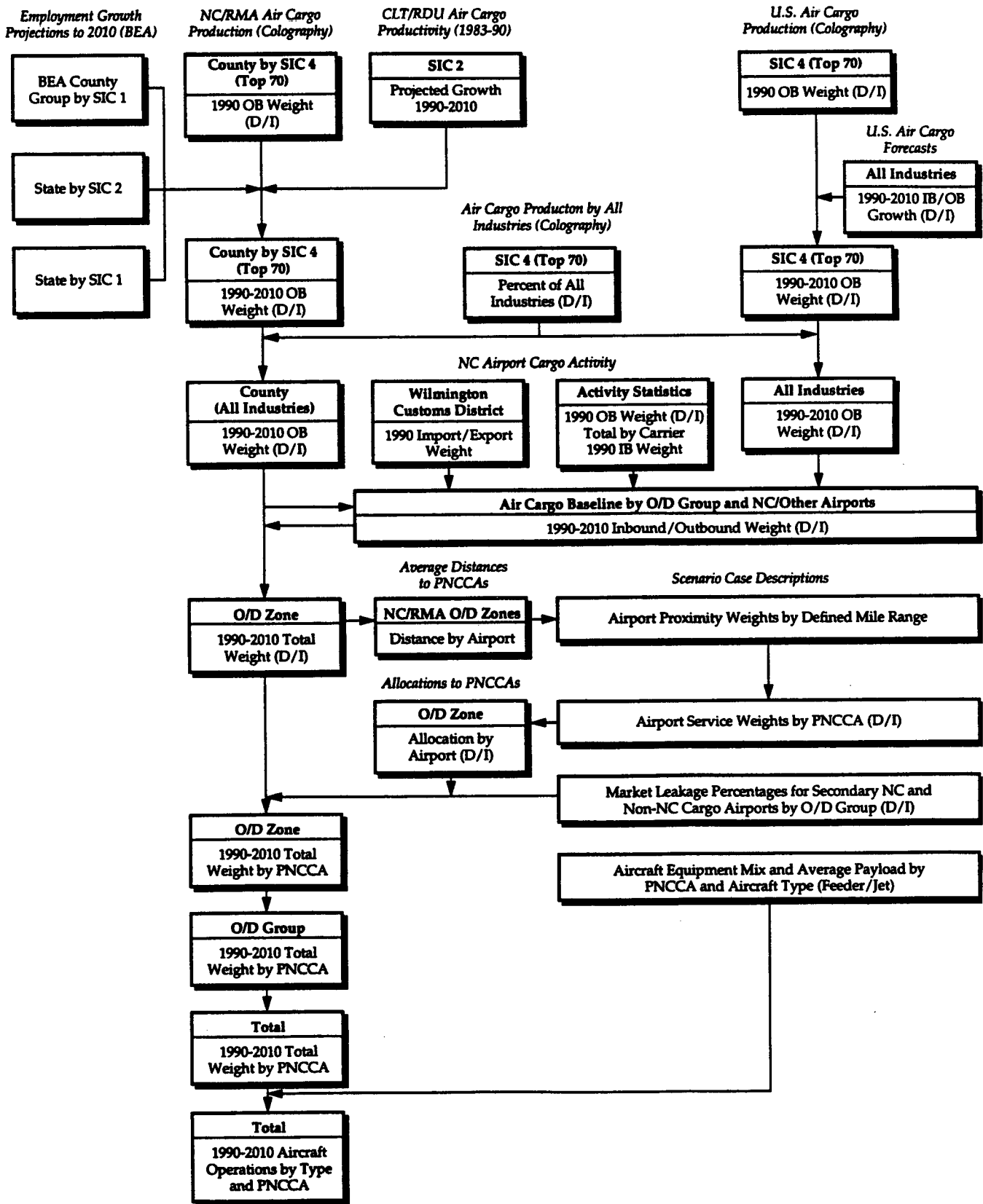






Exhibit I.9. (continued).

Origin/Destination County/Area		Total Traffic Generated			Charlotte			Greensboro			Raleigh-Durham		
Total by O/D Group		Dom.	Int'l	Total	Dom.	Int'l	Total	Dom	Int'l	Total	Dom.	Int'l	Total
North Carolina Counties	1990	254.2	140.4	394.6	85.9	18.9	104.8	14.3	27.0	41.3	53.9	12.0	65.9
	1995	467.2	243.8	710.9	168.0	40.2	208.2	35.0	44.8	79.8	91.8	27.8	119.6
	2000	740.6	378.0	1,118.6	280.0	72.3	352.3	68.7	59.0	127.0	137.1	62.6	199.7
	2010	1,853.3	912.3	2,765.6	755.7	209.8	965.5	184.0	169.4	353.6	368.6	179.7	548.3
Regional Market Areas	1990	328.8	130.4	459.3	9.8	0.3	10.1	1.5	0.4	1.9	3.8	0.1	3.9
	1995	612.8	220.3	833.1	23.3	2.7	26.2	4.6	3.0	7.6	7.9	1.1	9.0
	2000	978.6	335.7	1,314.3	45.6	8.0	53.6	10.6	6.5	17.1	13.6	4.3	17.9
	2010	2,309.5	722.8	3,032.4	148.1	33.8	181.9	33.0	25.8	58.9	41.2	17.0	58.2
All Other U.S. Counties	1990	8,608.4	4,575.7	13,184.2	4.8	5.0	9.8	0.7	7.1	7.8	2.5	2.5	5.1
	1995	10,706.8	6,315.7	17,022.5	6.0	7.5	13.6	1.2	8.3	9.5	2.8	4.2	7.1
	2000	13,467.9	8,682.5	22,150.4	7.7	10.8	18.5	1.7	8.8	10.5	3.1	8.1	11.2
	2010	21,050.6	16,415.2	37,465.8	12.0	20.4	32.5	2.7	16.6	19.3	4.8	15.3	20.2
Total U.S.	1990	9,191.4	4,846.6	14,038.0	100.5	242.2	124.7	16.5	34.4	51.0	60.3	14.7	74.9
	1995	11,786.8	6,779.8	18,566.6	197.5	50.5	2247.9	40.8	56.1	96.9	102.5	33.3	135.7
	2000	15,187.1	9,396.2	24,583.2	333.3	91.1	424.3	81.0	74.3	155.2	153.8	75.0	228.8
	2010	25,213.4	18,050.3	43,263.7	915.9	264.0	1,179.9	219.7	212.1	431.8	414.7	212.0	626.7

Percent of NC Airport Total												
NC Primary Airport Total				Charlotte			Greensboro			Raleigh-Durham		
Dom.	Int'l	Total		Dom.	Int'l	Total	Dom.	Int'l	Total	Dom.	Int'l	Total
1990	177.3	73.3	250.6	57%	33%	50%	9%	47%	20%	34%	20%	30%
1995	340.7	139.8	480.5	58%	36%	52%	12%	40%	20%	30%	24%	28%
2000	568.1	240.3	808.4	59%	38%	52%	14%	31%	19%	27%	31%	28%
2010	1,550.2	688.1	2,238.3	59%	38%	53%	14%	31%	19%	27%	31%	28%

Exhibit I.10. New industrial activity characteristics.

Data Item	Source	Techniques/Comments
Target Industries for GACIC	Colography Group Industry Interview Program	Assumes GACIC would attract high technology companies dependent on air cargo similar to Silicon Valley plus expansion of industries already active in North Carolina.  New plants would be attracted in and around GACIC.  Selected top air-cargo producing industries (Colography industries) from Silicon Valley (Santa Clara Co. CA) and North Carolina based on plant size and air cargo productivity per employee in 1990.  14 from Silicon Valley and 8 from North Carolina (at four-digit SIC level).
Number of Plants and Employment for GACIC Industries (2000/2010 Forecast)	Colography Group Statistical Abstract of the United States FAA Airport Impact Study Industry Interview Program Study Team	Projected number of plants assumes share of existing Silicon Valley (15 percent) and North Carolina (10 percent) locations in 2000, expanding by 5 percent annually to 2010.  Projected employees per plant in 2000 is assumed at 1990 levels with 1 percent annual growth to 2010.  Employment for industries supporting manufacturing activity estimated based on U.S. ratio of transportation/public utility sectors to manufacturing sector.  Total employment impact on state estimated using multipliers from FAA study (Measuring the Regional Economic Significance of Airports, October 1986).
Air Cargo Production (Tons and Value) for GACIC Industries	Colography Group Study Team	Growth in outbound cargo tons per employee for San Francisco market area (at two-digit SIC level) from 1983 to 1990 extrapolated to 2000 and 2010 and applied to 1990 averages for Silicon Valley/North Carolina industries.  Average value per pound assumed at 1990 levels using constant dollars.  Outbound cargo generated by industries supporting manufacturing activity assumed at 50 percent of manufacturing total.  Inbound traffic assumed equal to outbound volumes.

**Exhibit I.11. Summary of air cargo produced by the GACIC and the economic impacts of GACIC activities.**

	Forecast Year	
	2000	2010
<b>Cargo Impact (Tons)</b>		
New Traffic by Industry Type - Outbound	40,984	139,439
Manufacturing	<u>20,492</u>	<u>69,720</u>
Supporting Industries	61,476	209,159
Domestic Percent of Outbound Traffic	45%	40%
Ratio of Inbound-to-Outbound Traffic	1.0000	1.0000
<b>New Traffic by Cargo Type - Summary</b>		
(a) Domestic	27,664	83,663
Outbound	<u>27,664</u>	<u>83,663</u>
Inbound	55,328	167,327
(b) International	33,812	125,495
Outbound	<u>33,812</u>	<u>125,495</u>
Inbound	67,624	250,990
(c) Total	61,476	209,159
Outbound	<u>61,476</u>	<u>209,159</u>
Inbound	122,952	418,317
<b>Employment Impact (Number of Full-time Jobs)</b>		
Direct Employment		
Manufacturing	23,594	40,368
Transportation Support Industries	<u>4,318</u>	<u>7,387</u>
	27,912	47,756
Employment Multiplier	2.12	2.12
Total Employment	59,173	101,242
<b>Revenue Impact (Million \$)</b>		
Direct Revenues		
Manufacturing	\$3,411.2	\$11,837.8
Transportation Support Industries	<u>172.7</u>	<u>295.5</u>
	\$3,583.9	\$12,133.3
Net State Impact (50% of Direct Impact)	\$1,791.9	\$6,066.6
Revenue Multiplier	2.12	2.12
Total Revenues	\$3,798.9	\$12,861.3

itions, identifying and defining appropriate market ranges, and the incompatibility of historical data sets. The selected approach was designed to allow flexible scenario testing and assure that projected activity was based on a reasonable market allocation process as opposed to an independent trend projection of existing traffic.

## **I.2 CASE STUDY: TRUCK SIZE AND WEIGHT POLICY**

Truck size and weight regulation is an important policy issue that demonstrates the use of many of the techniques discussed in this chapter.

Any change in Federal or State size and weight regulations can be expected to have at least some effect on the vehicles used and the cost of using these vehicles, and usually on shipment sizes and vehicle-miles of travel (VMT) by various categories of trucks. These changes, in turn, can affect highway

safety, congestion, bridge and pavement costs, fuel consumption, emissions, diversion of traffic between rail and truck, overall costs for truck and rail transportation and for associated logistical functions, and the financial viability of affected truck and rail carriers. For most potential policy changes the direction of the various effects is fairly obvious, but their magnitudes are not.

Since all or nearly all potential policy changes produce a combination of desirable and undesirable effects, careful estimates of a relatively large set of likely effects of such changes are required in order to evaluate the overall desirability of the changes. The development of these estimates requires assessments of the likely effects on demand for and use of affected truck configurations and competing rail service. The development of these estimates for a specified policy change of some interest is presented below. A thorough analysis of the effects of this policy change would use these assessments as the basis for developing additional estimates

of the effects on (at least) safety, congestion, highway costs, transport costs, and the viability of carriers.

### 1. Define Policy

The first step in the analytic process is the development of a clear operational definition of the policy to be analyzed.

For the purpose of this case study, we consider the possible lifting of the 80,000 pound cap on gross vehicle weight (GVW) from the Interstate System (IS), from all other rural principal arterials, and from all other urban principal arterials that are on the National Network for trucks. Under this policy, GVWs on this system of roads would be controlled by the number and spacing of axles as specified by Bridge Formula B. This formula would produce effective GVW limits of about 86,500 pounds for six-axle semi-trailer combinations (six-axle "semis") and about 108,000 pounds for nine-axle twin 28-foot trailer configurations (twin 28s).

It is assumed that access provisions for trucks with GVWs above 80,000 pounds to origins and destinations located off the Principal Arterial System are fairly liberal, with the most restrictive provisions in effect in several Mississippi valley states. It is assumed that all existing length limits remain unchanged.

This policy was one of several analyzed by Sydec in the last several years in a series of studies of possible changes in truck size and weight limits.<sup>9</sup>

### 2. Base-Case Forecasts

The second step in the analysis is to develop forecasts of truck usage in the absence of any change in policy.<sup>10</sup> These forecasts were developed using:

- Highway Performance Monitoring System (HPMS) estimates of 1987 VMT by truck configuration, state, and highway system;
- Truck Weight Study data on average overall GVW and average GVW of empty trucks by truck configuration and state; and
- Forecasts of VMT growth between 1987 and 1995 for two categories of combination truck from the FHWA/Faucett VMT Forecasting Model.<sup>11</sup>

<sup>9</sup> This policy was one of seven studied in Sydec, Inc., Jack Faucett Associates, and the Transportation Consulting Group, Inc., *Truck Size and Weight and User Fee Policy Analysis Study*, Part One, prepared for the Federal Highway Administration, March 1991. Additional policies were studied in: Sydec, Inc., Transmode Consultants, Inc., and Jack Faucett Associates, *Analysis of Longer Combination Vehicles*, prepared for the Federal Railroad Administration, Federal Highway Administration, and the Office of the Secretary of Transportation, November 1993; Sydec, Inc., and Jack Faucett Associates, *Productivity Analysis for Truck Weight Study*, prepared for the Transportation Research Board, October 1989; and Sydec, Inc., and Jack Faucett Associates, *Productivity and Consumer Benefits of Longer Combination Vehicles*, prepared for the Trucking Research Institute, Alexandria, VA, June 1990.

<sup>10</sup> Sydec, Inc., Jack Faucett Associates, and Transportation Consulting Group, Inc., *op. cit.*, pp. II-10-II-13.

<sup>11</sup> Herbert Weinblatt, *The FHWA/Faucett VMT Forecasting Model*, prepared by Jack Faucett Associates for the Federal Highway Administration, Washington, D.C., August 1988.

These sources were used to produce forecasts of VMT and truck payload ton-miles for 1995 by trailer and axle configuration, region, GVW range, and highway system (distinguishing IS vs. non-IS and rural vs. urban).

### 3. Cost Impacts

The third step in the analysis is to estimate the effect of the policy on transport costs and, if necessary, on other logistics costs.

For this purpose, a detailed analysis was conducted of how the costs of linehaul operation of combination trucks vary with trailer and axle configuration, trailer type, and GVW. The analysis considered variations in costs for drivers, fuel, equipment, tires, maintenance and repair, and overhead, as well as the effect of empty movements on costs per loaded mile. The resulting estimates of linehaul truck costs per vehicle-mile and per ton-mile used in the original Sydec study were presented in a working paper<sup>12</sup> and later revised and updated<sup>13</sup> for use in a subsequent study. Excerpts from the updated working paper are presented in Appendix F.

The analysis also considered extra per-trip costs for assembling and disassembling double-trailer configurations (estimated in 1988 dollars to be \$30 per trip for vans and \$15 per trip for dump trailers), and for cleaning extra tank trailers (estimated to average \$100 per trip for chemicals and \$20 per trip for food products).

### 4. Changes in Vehicles Used

The fourth step consists of estimating how changes in the cost of operating various truck configurations are likely to affect usage of these configurations. These estimates were developed by Sydec judgmentally by considering the advantages and disadvantages of switching to configurations that can operate at the higher weight limits being considered. Separate estimates of the extent to which carriers are likely to change configurations were developed for carriers operating different trailer types. These estimates were based on the Step 3 cost estimates, information obtained in a series of carrier interviews, and other information about the trucking industry. Estimates of overall conversion to new configurations were then developed by combining the estimates for the separate trailer types with data on the relative usage of the different trailer types obtained from the Bureau of Census' *Truck Inventory and Use Survey*.

The first two subsections below present a general discussion of: the opportunities for reducing truck transport costs that would be created by the policy option analyzed; and the varying effects that these opportunities would be

<sup>12</sup> Herbert Weinblatt, *The Effect of Size and Weight Limits on Truck Costs*, Working Paper, prepared by Jack Faucett Associates, for the Federal Highway Administration, June 1990.

<sup>13</sup> *Ibid.*, updated, October 1991.

**Exhibit I.12. Relative efficiency of alternative configurations for weight-limited truckload linehaul operation.**

	Loaded Weight (lbs)	Percent Change in Cost per Ton-Mile Relative to Five Axle Semi <sup>1</sup>					
		Dry Van	Reefer	Flatbed	Tank	Hopper	Dump
6 Axle 48 Foot Semi	80,000	+2.1%	+1.7%	+2.2%	+4.7%	+4.2%	NE
	86,500	-8.5	-9.3	-8.4	-6.1	-6.4	NE
5 Axle Twin 28	80,000	+6.1	+16.6	NE	NE	NE	NE
	91,500	-8.9	-3.0	NE	NE	NE	NE
9 Axle Twin 28	80,000	+35.5	+52.8	+37.4	+38.0	+41.5	+30.0%
	108,000	-15.3	-9.5	-9.5	-13.0	-11.0	-21.5

<sup>1</sup> Forty-two foot trailer for tanks and hoppers; 36 feet for dump trailers; 48 feet for other trailer types.

Source: Herbert Weinblatt, *The Effect of Size and Weight Limits on Truck Costs*, Working Paper, prepared by Jack Faucett Associates for the Federal Highway Administration, Washington, D.C., Revised, October 1991.

expected to have on different types of trucking operation. For each policy option, the information presented in these two subsections was used to develop estimates of the overall effects on VMT and payload ton-miles transported by vehicle configuration and region (and also the effects on transport costs by region). The final subsection below describes the way in which the information presented in the first two subsections was used to develop estimates of the impacts on configurations used.

#### *Potential Savings*

Exhibit I.12 lists several vehicle configurations that could be operated at weights above 80,000 pounds under the policy being considered. For each configuration, this exhibit shows the estimated percentage difference between linehaul costs per ton-mile for typical truckload operation of that configuration when it is loaded to the indicated GVW and the corresponding costs for a five-axle semi loaded to 78,000 pounds, a practical weight attainable under current weight limits.<sup>14</sup> Percentage cost differences are shown for six trailer types: dry vans, refrigerated vans ("reefers"), flatbeds, tankers, hoppers, and dump trucks. The percentage cost differences were derived using empty mileage ratios that vary by trailer type. However, for each trailer type, the same empty mileage ratios and annual mileages were assumed for all configurations, and all loaded miles were assumed to be operating at the indicated GVW.

The estimates shown in Exhibit I.12 indicate that, except for reefers and dump trucks, linehaul operation of nine-axle twin 28s at Bridge Formula B limits is 11 to 15 percent less expensive per ton-mile than operation of five-axle semis at 78,000 pounds. The smaller (9.5 percent) saving for reefers

is due to the extra cost of refrigerating two small trailers. The large (21.5 percent) saving for dump trailers occurs because the comparison is made to semis with 36-foot trailers that are limited to a GVW of 70,000 pounds by Bridge Formula B. (The length of dump trailers is limited by stability considerations.)

Exhibit I.12 also indicates that linehaul operation of six-axle 48-foot semis at the Formula B limits is six to nine percent less expensive per ton-mile than operation of five-axle semis, and that linehaul operation of five-axle twin 28s at these limits is about nine percent less expensive for dry vans and three percent less expensive for reefers. Five-axle twin 28s are included in Exhibit I.12 and discussed in this Case Study because the possibility of allowing these vehicles to operate at Bridge Formula B limits was considered in the study being summarized here. However, it since has been concluded that such a possibility would be undesirable because of the pavement damage caused by heavily loaded single axles, and this possibility has not been considered in any of the more recent Sydec analyses.

The estimated savings presume that there is no difference in vehicle utilization between the five-axle semis and the alternative configurations; i.e., there is no difference in annual mileage, empty mileage, or the extent to which loads carried fall short of those that would be allowed under Bridge Formula B. Under the policy studied, however, many origins and destinations cannot be served by vehicles operating at GVWs over 80,000 pounds. To the extent that a vehicle designed for operation at a higher weight would be used to serve such an origin or destination, that vehicle would not be utilized fully. As can be seen from Exhibit I.12, it costs *more* to use such a vehicle for weight-limited hauls to or from such shippers than to use a five-axle semi. The increased cost is two to five percent for six-axle semis of various body types, and is substantially higher for the heavier configurations.

The above discussion indicates that carriers of weight-limited cargo would be able to benefit from removal of the

<sup>14</sup> The percentage cost differences in Exhibit I.12 are from the October 1991 version of the referenced Working Paper rather than from the June 1990 version used in the original Sydec study.

80,000 pound cap by switching from five-axle semis to various heavier configurations *provided* they can do so with little or no reduction in effective utilization; i.e., there is little or no reduction in annual loaded mileage and nearly all the loads carried are ones that can be carried more efficiently in the new vehicles than in five-axle semis. Any reduction in effective utilization reduces the savings obtained from the switch in equipment, and it takes only a moderate reduction in utilization to negate the savings obtained. Hence, the transport-cost savings that result from removal of the 80,000 pound GVW cap would be affected significantly by the number of origins and destinations that can be accessed by vehicles weighing more than 80,000 pounds.

### *Responses by Type of Operation*

As the above discussion indicates, the ability of a carrier to reduce transport costs per ton-mile by converting part or all of its fleet from five-axle semis to an alternative configuration depends on its ability to use the alternative configuration primarily or exclusively to carry cargo at or close to the Bridge Formula GVW limits. This ability depends on the cargo normally carried by the vehicle and the origins and destinations served.

Consider operations that involve weight-limited carriage between a relatively small number of locations. Such an operation might be conducted by a private carrier between its plants and warehouses, or by a contract carrier transporting natural resources to any of several types of collection points (processing plant, railhead, grain elevator, etc.). If all locations can be served by vehicles weighing more than 80,000 pounds with little or no increase in circuitry, or if a portion of the fleet can be dedicated to serving locations with this characteristic, a switch to vehicles designed for operation above 80,000 pounds would prove desirable. However, a change in equipment generally would not be advantageous for operations of this type when any significant amount of service is required to or from locations that cannot be accessed by vehicles operating at Bridge Formula B limits.

The situation is somewhat more complex for operations serving a relatively large number of locations. The most typical example of such an operation is a for-hire truckload carrier that uses a single fleet of vehicles to serve a large (and frequently changing) number of shippers. For such operations, replacement of five-axle semis by vehicles capable of operating at GVWs above 80,000 pounds would prove cost effective only to the extent that the new vehicles could be used primarily to carry shipments that they can carry more efficiently than can five-axle semis, and also to the extent that such shipments can be obtained without any reduction in annual loaded miles. This type of operator is likely to change vehicle configurations only to the extent that it appears that the new vehicles can be used primarily to carry such shipments. Because of mismatches between the characteristics of potential fronthaul and backhaul traffic, it is likely that conversion to the heavier and larger configurations would not be sufficient to carry all traffic that could potentially be carried by such vehicles.

To the extent that five-axle semis would be replaced by vehicles designed for operation at GVWs above 80,000 pounds, use of the new configurations would vary by commodity and operational considerations. The remainder of this subsection discusses the preferred configurations for several different types of operation when the 80,000 pound GVW limit is not a factor in vehicle selection.

For commodities carried in hoppers or dry-bulk tankers, the preferred configuration would nearly always be a nine-axle double, with six-axle 48-foot semis usually used where access restrictions limit the use of twins but not the use of 86,500 pound semis.

For some liquid bulk commodities, the preferred configuration frequently would also be a nine-axle twin 28. The use of doubles for carrying chemicals and many food products, however, would be limited both because the use of twin 28s would increase tank-cleaning costs, and, in the case of chemicals, because many receivers want only a limited volume in any one delivery. Accordingly, the preferred configuration for chemicals and many food products would usually be a six-axle 48-foot semi or a five-axle semi.

Because of concerns about stability, some reticence to use twin 28-foot trailers exists among petroleum carriers. Thus, the preferred configurations for carrying petroleum products are likely to be six-axle 48-foot semis and three-axle trucks pulling four-axle full trailers. Due to the high cost of tank trailers, the phase-in period for new equipment would be appreciably longer than for other trailer types.

Because of stability considerations, rear-dump trailers normally are no longer than 36 feet, and Bridge Formula B currently limits semis using these trailers to 70,000 pounds GVW. On a per ton-mile basis, Exhibit I.12 shows a 21.5 percent line-haul cost savings obtainable by switching to nine-axle twin 28s.

Twin dump trailers would have to be disassembled for unloading (at an estimated cost of about \$15 per trip), and, in some cases, for loading as well. For this reason, semis and single-unit trucks would generally still be preferred for hauls of less than 25 miles and for some longer hauls as well.

Flatbed operators would be likely to prefer heavy doubles for much of their operations where access restrictions do not inhibit the use of twins, and to prefer six-axle semis for loads that require longer trailers and also for access to locations where use of twins is not feasible. Indeed, in the case of flatbeds, a switch to six-axle semis is attractive even for vehicles that provide a significant portion of their service to or from locations that can only be served by 80,000 pound rigs. This is the case because the extra axle (or, alternatively, the use of a spread tandem) usually is necessary in order to make it practical to approach a GVW of 80,000 pounds while carrying loads that cannot easily be spread evenly across two pairs of normally spaced tandem axles that cannot legally be loaded above 34,000 pounds.

The benefits of higher weight limits to truckload operators of dry vans are somewhat less significant. Most such vehicles run cube-limited at least part of the time, and some private carriers frequently carry only partial loads. Some carriers focus on the cube-limited market with vans that are 53 feet long or longer or with five-axle twin 28s.

Because of their higher cost of operation, heavy twin 28s would appear to be of interest to very few operators of dry vans. However, both six-axle semis and five-axle twins would offer some advantages for weight-limited carriage, and five-axle twins would also offer advantages (relative to 48-foot vans) for most cube-limited hauls of over 200 miles. Lifting the 80,000 pound cap on five-axle twins would enable existing operators of twin vans to improve equipment utilization by competing effectively in both weight-limited and cube-limited markets, particularly in several Eastern states that sharply restrict the use of 53-foot trailers. Accordingly, lifting the cap would be expected to result in a modest shift from five-axle 48-foot vans to five-axle twins and a small shift to six-axle semis.

The extra cost of refrigerating a second trailer limits the attractiveness of twin 28s for operators of refrigerated vans. Accordingly, (except where longer combinations are allowed) the preferred new configuration would be six-axle semis. The attractiveness of conversion, however, would be limited by the likely difficulty of being able to utilize fully the increased weight capacity offered by six-axle semis—both because of origins and destinations served only by 80,000 pound GVW roads and because of the common use of reefers for cube-limited cargo or partial loads on backhauls.

Finally, raising GVW limits would have no effect on configurations used by LTL operators. However, replacing existing weight limits on seven-axle triples by those allowed under Bridge Formula B would permit increased loading of triples in several Western states where constraints imposed by 105,500 pound GVW limits would be eliminated. Similarly, eliminating the 80,000 pound cap on five-axle twins would permit increased loading of twin 28s in a few LTL traffic lanes in which a high proportion of dense cargo results in some runs that are weight limited under the current GVW cap.

### *Quantifying the Effects*

The effects of increased weight limits on VMT and payload ton-miles by configuration and region were estimated by interpreting the information presented above in the light of specific characteristics of the policy options being analyzed.

Key information used in the analysis included:

- Region-specific characteristics of each policy option:
  - The extent to which GVW limits would be raised; and
  - The likely percentages of shipments originating or terminating at locations that could be efficiently served by semis and doubles operating at the new GVW limits.
- Likely responses of different types of truck operators (as discussed above).
- Region-specific distributions of VMT across trailer types obtained from a special tabulation of data from the Truck Inventory and Use Survey (TIUS).

All impacts were estimated as changes from the 1995 base case, but they represent the percentage changes that are expected to occur at some future time when the nation's truck fleet would have evolved sufficiently to allow full advantage to be taken of the higher weight limits. The analysis assumed there would be continued liberalization of access provisions for twin 28s in Eastern states and no change in current access provisions for 48-foot semis. Access restrictions were assumed to reduce usage of twin 28s by 50 percent in New England and 25 percent in the Middle and South Atlantic regions relative to the usage that would occur in the absence of these restrictions. The analysis assumed that the changes in weight limits would not be accompanied by any changes in size limits.

Specific substeps in estimating changes in vehicle usage were:

1. Review information presented in the preceding subsections in the light of region-specific characteristics of the policy option to determine the relative importance of the potential responses of different types of truck operation.
2. Apply these results to the TIUS data to obtain estimates of the percentages of payload ton-miles currently carried by vehicle configurations (e.g., five-axle semis) that would likely be diverted to various alternative ("new") configurations.
3. Estimate the distribution of diverted ton-miles across operating weights when carried by the current vehicle configuration and the corresponding distributions when carried by the new configurations.
4. For nondiverted traffic carried by configurations for which GVW limits would be increased (e.g., in most states, five-axle twins), estimate the shift in the distribution of ton-miles across operating weights.
5. Obtain estimates of the total and percentage change in payload ton-miles and VMT by vehicle configuration.<sup>15</sup>

### **5. Modal Diversion**

The final step in estimating the effects of changes in truck size and weight regulations on transport demand is the estimation of diversion to or from other modes.<sup>16</sup> For this purpose, the Sydec study used the results of a special run of the Intermodal Competition Model (ICM), a proprietary

<sup>15</sup> As an example of Steps 2, 3, and 5, the analysis suggested that, in the Middle Atlantic region, 23 percent of traffic currently carried in five-axle semis would be diverted to six-axle semis. (The percentage diverted varies by region due to differences in the distribution of body types used and in current GVW limits.) Total ton-miles diverted is 24.9 billion (23 percent of an estimated 108.2 billion base-case ton-miles). The average payload of diverted traffic was estimated to be 16.4 tons when carried in five-axle semis (allowing for empty backhauls, partial loads, etc.) and 17.8 tons when carried in six-axle semis. Accordingly, VMT of five-axle semis was estimated to decline by 1.52 billion (16 percent of estimated base-case VMT), and, after adjusting for a small increase in circuitry, VMT of six-axle semis was estimated to increase by 1.41 billion.

<sup>16</sup> An additional step estimating induced or suppressed demand can be performed. However, because this effect is quite small and difficult to quantify, it usually is not considered to be worth estimating.

model developed by the Association of American Railroads (AAR). This model is described briefly in Section H.1, and some results produced by this model are discussed in Section G.1.

For this run of the ICM, the Sydec study team provided AAR with cost specifications that were designed to produce percentage changes in average truck payloads and in truck costs per ton-mile relative to an existing base-case ICM run that are identical to those developed in the Step 3 analysis of truck costs. Separate estimates were provided for two alternatives to a conventional five-axle semi for each of five trailer types (van, reefer, flatbed, tanker, and hopper). For each trailer type, the alternatives consisted of a six-axle semi and an appropriate double-bottom configuration.

The cost changes used were those for the most likely alternative configurations for each trailer type. The results of this run provided an estimate of the modal diversion that would result if six-axle semis and twin 28s could be operated at Bridge Formula B limits between every O/D pair currently served by rail. The results of this model run were then scaled to reflect the study team's estimate of the actual ability of the alternative configurations to operate between relevant O/D pairs at the proposed bridge formula limits.

The results of each of the ICM runs included estimates, by commodity group, of:

- Rail ton-miles diverted to truck;
- The corresponding increase in truck ton-miles (lower than the rail ton-mile figures because of less circuitry);
- Current railroad revenue from diverted traffic;
- Avoidable railroad costs associated with this traffic;
- Costs of truck transport for diverted traffic; and
- Reductions in railroad revenue resulting from competitive rate reductions on other traffic retained by the railroads.

Each ICM run also produced a single estimate (not by commodity group) of the relative usage of semis and twins by diverted traffic. For each policy option, this last estimate was used to split the scaled ICM estimates of increased truck ton-miles between semis and twins. The increase in semi-trailer ton-miles was then distributed across weight brackets for six-axle semis using the same distribution as was used for freight carried by five-axle semis converting to this configuration; and the increase in twin-trailer ton-miles was similarly distributed across heavy twin configurations and weight brackets. The distributions of increased ton-miles across weight brackets were then used to derive estimates of increased VMT.

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## APPENDIX J

### INFORMATION NEEDS PERCEIVED BY PUBLIC AGENCIES

Identification of the information needs perceived by public agencies was an important objective of Phase I of this study. Interviews with and surveys of public officials were conducted to: (1) identify the freight demand questions they would most like to see addressed in our research; (2) learn about the methods they have used to address these issues in the past; and (3) obtain any information about models and data sources they may be able to provide to us. Specific activities that were carried out included the following:

- Interviews with federal planners and policy analysts in DOT and other federal agencies;
- A survey of state DOTs and other state agencies potentially interested in freight forecasts, with followup phone calls to selected survey respondents;
- A survey of metropolitan planning organizations (MPOs);
- A survey of coastal ports;
- A survey of inland river ports; and
- A survey of airports.

This appendix summarizes our findings from these surveys and interviews. Detailed survey results are presented in three appendices to our Phase I report,<sup>1</sup> and a list of federal interviewees is contained in a fourth appendix to that report.

#### J.1 FEDERAL POLICY ANALYSTS

Our interviews with federal officials indicated substantial differences between the needs of policy analysts and planners, so we prepared separate summaries for these two groups.

With some exceptions, the policy analysts we interviewed had relatively little interest in forecasting as such. Some interest was expressed in identifying likely improvements to the intermodal system and the resulting effects on demand for intermodal transport. One person was interested in "strategic" forecasts that could identify transportation flows that will grow significantly in the long run. Another expressed an interest in multimodal forecasts that are consistent across modes, and a third in forecasts of the decline in less-than-truckload (LTL) traffic. However, the primary use of forecasts by these persons is to provide a platform for ana-

lyzing the future effects of potential policy changes. They use exogenous economic forecasts produced by Data Resources, Inc., and other private and public-sector economic forecasters for this purpose, but no more than passing mention was made of these forecasts in any of the interviews.

Of substantially greater interest to federal policy analysts is information that would provide a better understanding of the freight demand system and the influences on this system. Most of these persons expressed a strong interest in the effects on transportation flows of changing patterns in international trade, and, in particular, in changes likely to result from the North American Free Trade Agreement (NAFTA). The interest in NAFTA is due not only to the immediacy of the liberalization of trade rules and cross-border transportation operations, but also to the current high rates of growth in the affected trade (12 percent per year with Canada, 7 percent with Mexico).

One person generalized the interest in international trade to include all influences on transportation demand that originate outside of the transportation system, broadly defined. In addition to international trade, such influences would include changes in production processes, distribution systems, inventory ratios, commodity characteristics, industry location, and demographics that might affect commodity flows, service requirements, or modal choice.

A related set of interests centered around obtaining better information about current freight demand. One broad component of this information would consist of commodity specific characteristics that influence the choice of modes and vehicles to be used. These characteristics include density, value, packaging, shipment sizes, lengths of haul (by region), and relevant shipper/consignee characteristics. It was observed that commonly used data on commodity density were developed many years ago and do not reflect the effects of increased use of low-density packing materials.

Other desired freight-demand information includes better data on truck flows, numbers of trucks and truck drivers, truck VMT by time of day, distinctions between domestic and international air freight and between the land and air portions of intermodal movements, the true origins and destinations of rail intermodal movements, and the true origins and destinations of international movements (not exporter and importer addresses). A federal truck-stop survey [along the lines of the one conducted for the Association of American Railroads' North American Trucking Survey (NATS)] was suggested as one way of obtaining better data on intercity

<sup>1</sup> Cambridge Systematics, Inc., et al., *Characteristics and Changes in Freight Transportation Demand*, Interim Report, prepared for the National Cooperative Highway Research Program, Project 8-30, Washington, D.C., August 1993.

movements of truckload freight. It was observed that the Commodity Flow Survey (CFS) would likely be a good source of data on nationwide traffic flows and modal shares (of increasing interest because of ISTEA), but that disclosure limitations would create major gaps for state-level analyses and the data would be of little value for site-specific analyses. Nonetheless, one federal official thought a package to translate CFS data for use by MPOs could be useful. An interest was also expressed in obtaining data on rail and motor-carrier rates.

Several federal policy analysts suggested our study should assist states and MPOs in preparing the freight portion of Intermodal System Plans. One individual suggested that we produce a "tool box" containing different tools for large MPOs and for small MPOs. It was observed that, while the former may have significant modal interface problems to be addressed, the latter are more likely to think of intermodal planning in economic development terms (though not necessarily with any understanding of the impact on development).

There was also clear interest in developing a set of performance measures for the transportation system, though this would seem to be more a supply issue than a demand issue.

Policy issues of interest to federal officials include the effects of NAFTA; truck size and weight policy (and the relationship between NAFTA and size and weight policy); deregulation and reregulation; just-in-time requirements; strikes; ISTEA regulations; landside access to ports and airports; rail mergers; rail abandonments; and weight-enforcement problems related to truck transport of shipping containers.

## J.2 FEDERAL TRANSPORTATION PLANNERS

Unlike policy analysts, transportation planners are specifically interested in transportation forecasts, quite frequently for far into the future. Usually the forecasts of interest represent the demand for a specific facility or set of related facilities.

The most active federal transportation planning agency is the U.S. Army Corps of Engineers (COE). The COE and its consultants have produced numerous forecasts of traffic on different waterways using aggregate and disaggregate economic forecasts from various sources and rail/water modal split models. The COE is required to analyze the effects of high and low economic forecasts, but ultimately all decisions have been based on their "most likely" forecasts. These have usually turned out to overestimate waterway traffic volumes, apparently in part because the costs of underdesigning waterway capacity are much higher than the costs of overdesigning, and in part because some of the COE's local information sources perceive overestimates to be in their self interest. The COE has conflicting goals of improving the uniformity of their forecasts and of the methodologies used while allowing methodologies used for specific analyses to be tailored to the special characteristics of the situation.

Although many of the COE's past forecasts have been produced as part of the planning process for major waterway projects, few such projects are anticipated in the future. The current focus is on fine-tuning, fixing and maintaining the waterway system, with a need for short-term forecasts using the most current data obtainable. Short-term analyses are also used for forecasting trust fund revenue. The new emphasis on short term forecasting has resulted in an effort to base forecasts on monthly lockage data rather than on the more comprehensive and less timely waterborne commerce data. Environmental issues of increasing interest relate to analysis of sediment flows, disposal sites for dredged material, where fleeting should be allowed, and the type, volume and routes of hazardous materials movements.

Other federal respondents mentioned state and MPO needs for forecasts of access requirements at ports and rail facilities, and needs for port expansion. The U.S. Maritime Administration has used forecasting in the past to estimate port needs, but their only current use is to forecast the share of ocean commerce carried by U.S. flag carriers to justify federal subsidy and cargo-performance programs.

## J.3 STATE AGENCIES

Surveys were mailed to the chief administrative officer of all state departments of transportation, asking for their assistance in identifying freight demand information needs and current methods and data sources. Responses were received from 38 states, a response rate of 76 percent. A copy of the survey form, tabulations of responses to closed-ended questions, and summaries of responses to open-ended questions are presented in Appendix C of our first Interim Report.<sup>2</sup> That appendix also contains summaries of follow-up telephone interviews with DOT personnel in selected states.

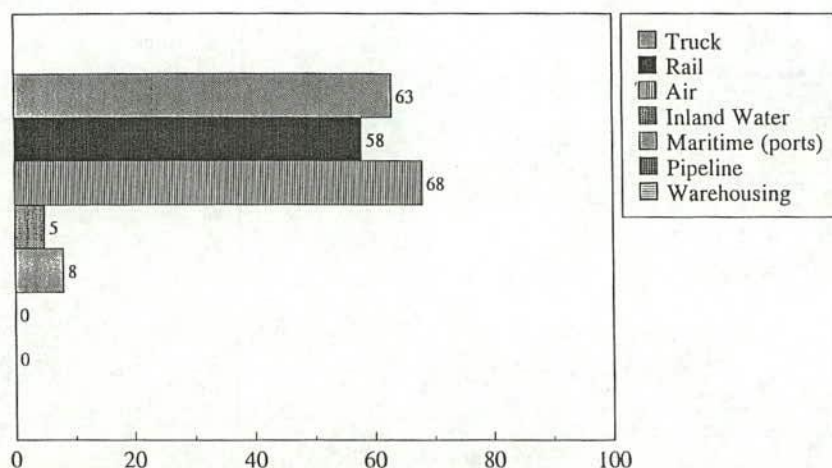
More than half of all states surveyed indicated that they had major planning responsibilities for truck, rail, and air freight (see Exhibit J.1). Few indicated major planning responsibility for ports and none indicated major planning responsibility for pipeline or warehousing. Also, many states indicated that they had regulatory responsibility for trucks, rail, and air freight (see Exhibit J.2) and a few states indicated that they had operating responsibilities (see Exhibit J.3).

States were asked to identify the planning and policy issues for which freight transportation forecasts would be most valuable to their agency. The most commonly selected items by the 38 states responding were as follows:

- Highway needs analysis (36 states)
- Truck routes and restrictions (35 states)
- Highway planning (35 states)
- Truck size and weight regulations (34 states)
- Planning of truck/rail intermodal facilities (35 states)
- Airport planning (31 states)

<sup>2</sup> *Ibid.*

**Exhibit J.1. State DOTs with major planning responsibility for freight (percent).**



- Rail facility and access planning (31 states)
- Promotion of economic development (30 states)

Most of the states surveyed indicated that they had little or no experience in freight forecasting. Exceptions were Iowa (which indicated extensive use of traffic and commodity forecasts to support efforts to identify needed transportation improvements), Oregon (which used freight forecasts in developing its statewide transportation plan), and Washington (which uses forecasts in rail abandonment cases and in preparing its freight rail plan and airport system plan).

In response to a question about what sources of freight transportation data do they use or currently have available, common responses were as follows:

- Rail carload waybill sample
- Corps of Engineers data on waterborne commerce
- Truck counts and truck weight data

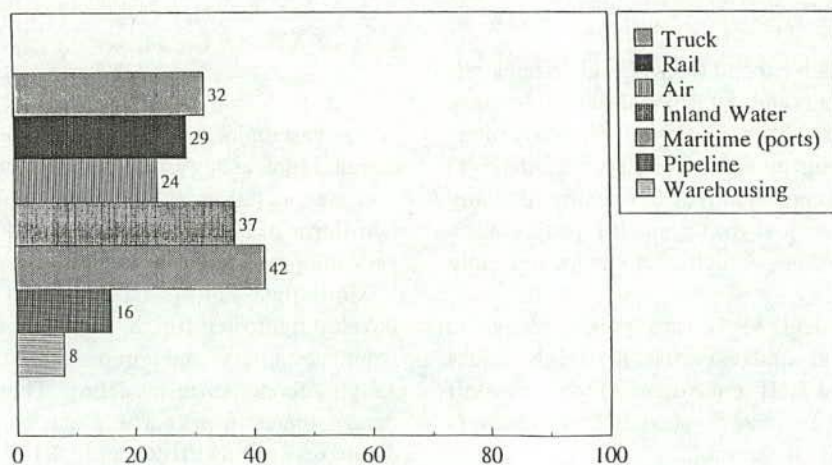
- Air cargo activity by airport
- Reebie and Associates Transearch data
- Census Bureau's Truck Inventory and Use Survey

#### J.4 METROPOLITAN PLANNING ORGANIZATIONS

A total of 64 surveys were mailed to MPOs serving areas with a population of 500,000 or more. A total of 33 completed forms from 24 different states were received, for a response rate of 52 percent.

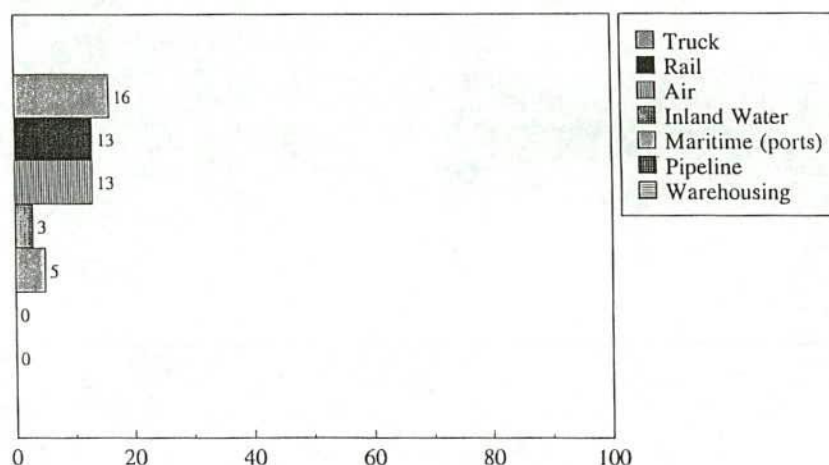
When asked to indicate the level of importance which freight transportation demand has with respect to the MPO's responsibility for regional transportation planning and policy issues, the greatest share view it as "somewhat important" to "very important", particularly with respect to noise/congestion and traffic management issues and landside access and facility planning (see Exhibit J.4).

**Exhibit J.2. State DOTs with regulatory responsibility for freight (percent).**





**Exhibit J.3. State DOTs with operating responsibility for freight (percent).**



The principal sources of freight data compiled or used by individual MPOs include traffic and truck counts, some of which are provided by state DOTs. Those MPOs which routinely use freight data rely primarily on data from secondary sources or on data collected by DOTs, state trucking associations, airport or port authorities, and carriers. A few of the MPOs have conducted freight surveys, albeit on an infrequent basis (every five to ten years). Only two indicated they use commercial data services, specifically Reebie Associates' Transearch database.

Of the 14 MPOs which develop or utilize economic and/or freight forecasts, most indicate they currently focus on economic, demographic, and employment forecasts. Only three currently use freight-related forecasts, two of which focus on truck and one on air cargo. Two MPOs anticipate increased use of forecasts in the future.

Nineteen of the respondents (58 percent) currently include freight-related facilities and issues in their transportation improvement plans (TIPs), with particular emphasis on:

- Roadway improvements for enhanced goods movement
- Port and airport landside access
- Intermodal terminal access and development.

ISTEA provisions which expand the role and responsibilities of MPOs in freight and intermodal planning have resulted in an increased involvement of freight industry interests in the MPO planning process. This has included: (a) adding freight industry representatives to existing planning and technical committees; and (b) organizing freight advisory councils or task forces which include local freight interests.

Many of the respondent MPOs are seeking ways to improve their knowledge and expertise in freight issues either through additional staff, consultant support, or staff training programs. Some expressed a need for better data and tools relating to freight transportation.

The majority of respondents (85 percent) currently coordinate or integrate their freight transportation and facility process with other public agencies; specifically:

Coordinate with	No. of Respondents
State DOTs	23
Port/Airport/Transit Authorities	20
County/Local Agencies	14
Carriers/Carrier Associations	8
Federal Agencies	1

Most MPOs anticipate increased coordination and cooperation as a result of the ISTEA requirements.

## J.5 COASTAL PORTS

A total of 53 surveys were mailed to major coastal ports throughout the U.S. A total of 26 completed forms from ports in 13 states were received, for a response rate of 49 percent. The breakout of responses by coastal region was as follows:

West Coast	8 Ports
South Atlantic	7 Ports
Gulf Coast	6 Ports
Great Lakes	3 Ports
North Atlantic	2 Ports

The vast majority of respondent ports indicated that freight demand forecasting is an important component in their planning and operations activity (see Exhibit J.5). Approximately two-thirds of the respondents also stated it was somewhat to very important in relation to policy issues.

More than half (58 percent) of the respondent ports develop their own freight forecasts, using methods ranging from "best guess" and port user contacts to time series analysis and econometric modeling. They utilize both in-house data gathered from carriers and shippers and commercial databases such as PIERS and DRI-McGraw-Hill.

Exhibit J.4. Importance of freight demand to port operations/planning functions.

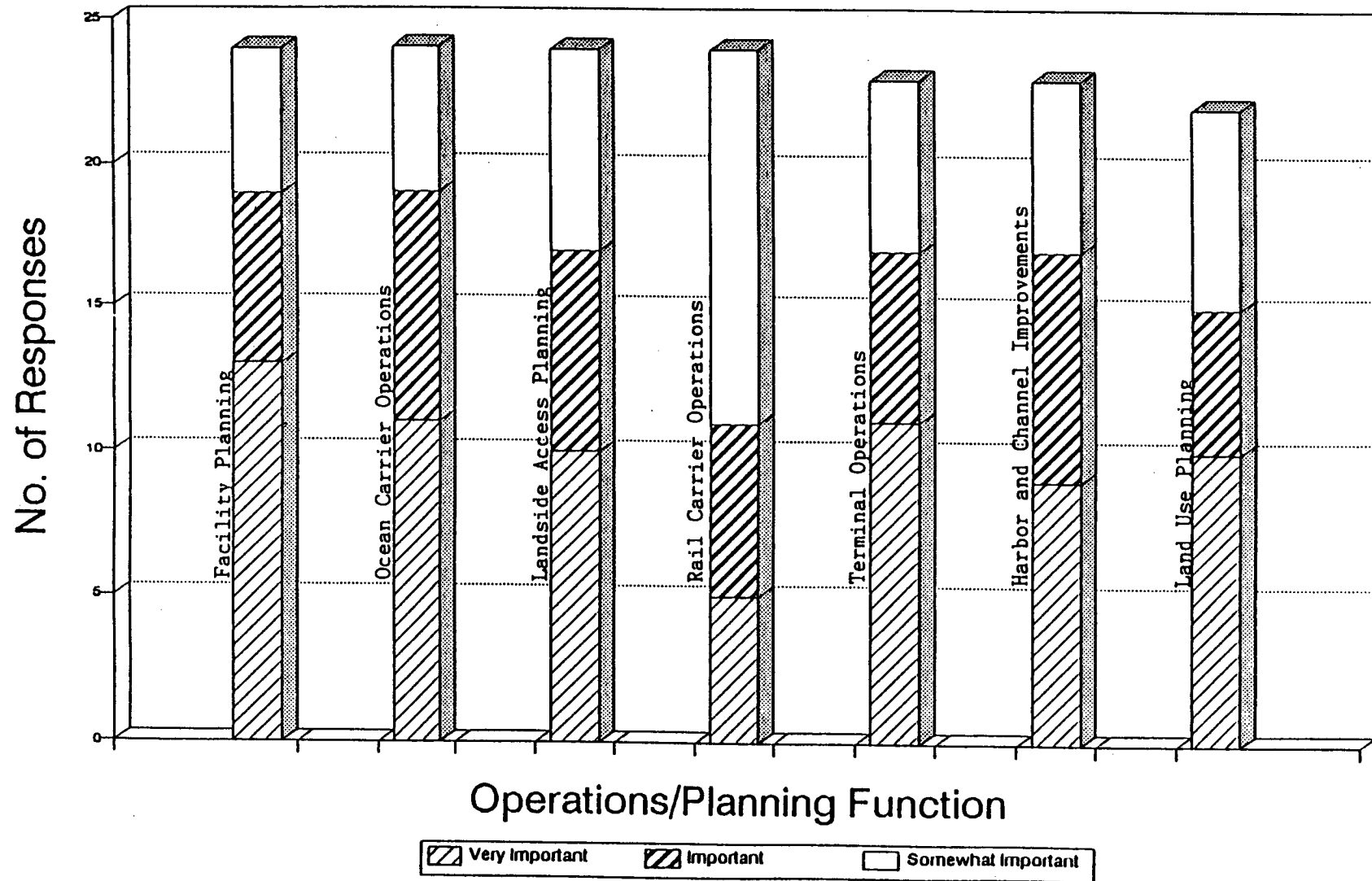
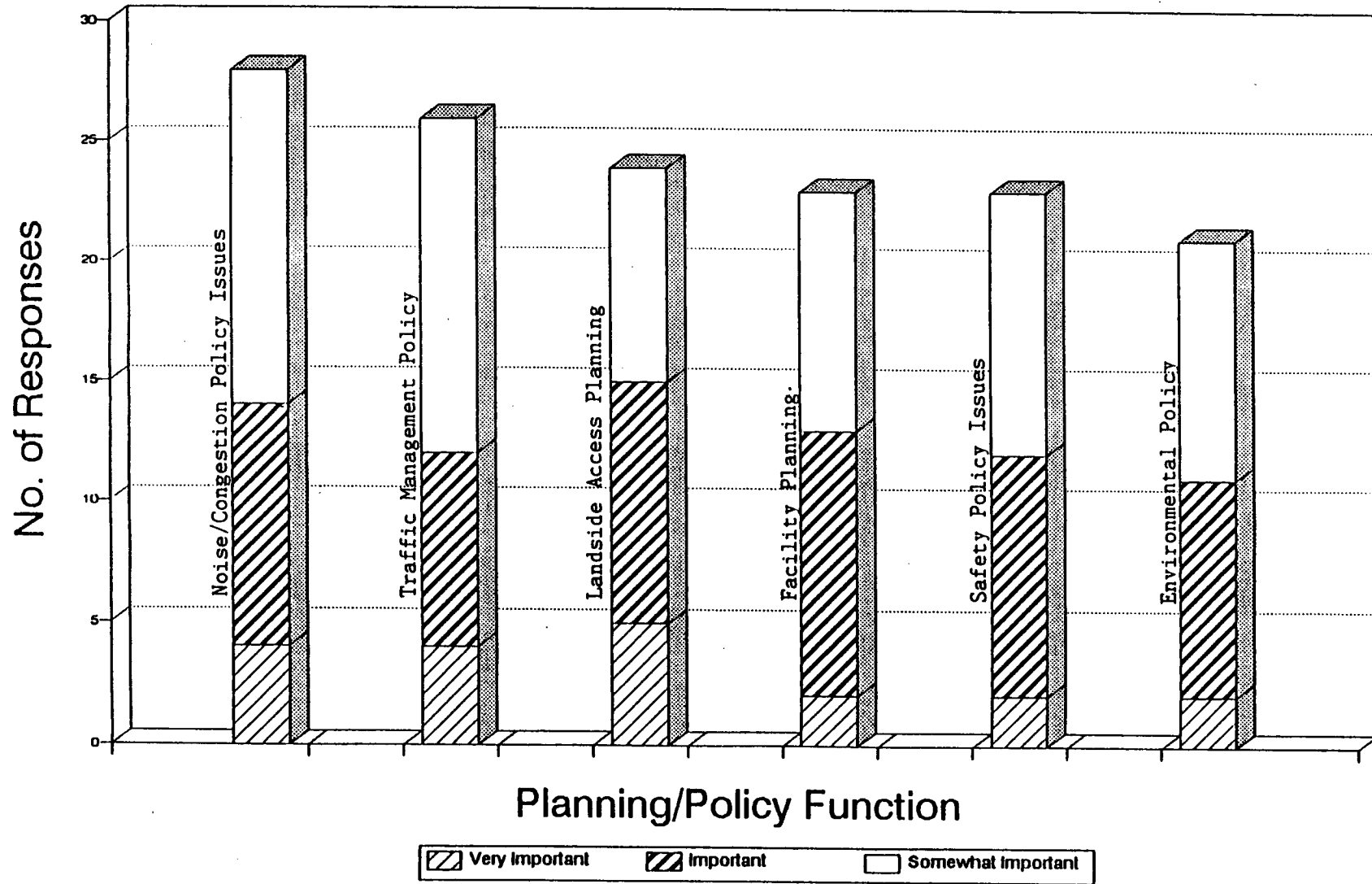


Exhibit J.5. Importance of freight demand to MPO policy/planning functions.



The principal sources of freight and freight-related data compiled and/or used by the ports include:

Journal of Commerce PERS	16
In-House Carrier/Shipper Data	14
Bureau of the Census	8
Corps of Engineers	4
Trade Publications	2
Other Ports	2
U.S. Customs Service	1
Statistics Canada	1
Maritime Administration	1
Other	3

Eleven of the respondent ports (42 percent) utilize commercial forecasting services, with DRI-McGraw-Hill's World Sea Trade Service and Journal of Commerce Trade Horizons being the two most frequently mentioned. Others included the WEFA Group, BST Associates, and TRADE (formerly TIPS).

The frequency with which the ports develop or contract for freight forecasts ranged from quarterly or semi-annually (on a commercial contract basis) to every five years.

The majority of the respondent ports (65 percent) coordinate their freight transportation and facility planning process with other public agencies and the private sector; specifically:

Coordinate with	No. of Respondents
State DOT	13
MPO	10
City/County Agencies	6
Highway Transportation Authorities	2
Advisory Councils	2
Corps of Engineers	1
Railway Commission	1
State Dept. of Commerce	1
Carriers/Shippers	1

## J.6 INLAND RIVER PORTS

A total of 32 survey forms were sent to members of the Inland River Ports and Terminals Association; however, responses were received from only four. Since the sample was primarily public port agencies or commissions and most inland river operations are privately owned and operated, the low response was not unexpected.

Those that did respond indicated that freight transportation demand forecasting was most important with respect to planning activities—land use planning and landside access. None of the respondents develops any type of freight forecast, but rather periodically consults with terminal operators and users.

The principal sources of data used by the agency respondents include the Corps of Engineers waterborne commerce statistics, the USDA grain transportation statistics, and the Journal of Commerce data.

One respondent indicated planning is coordinated with the local MPO, while another coordinates planning with state and county agencies and private terminal operators.

## J.7 AIRPORTS

While a total of 30 surveys were mailed to those airports with the greatest volume of air freight traffic, only seven airports responded, six with completed forms and one by letter. The low response rate was not unexpected since the majority of airports focus far greater attention on passenger operations than freight, and in many cases they have no staff positions or personnel assigned to air freight issues or cargo development.

In recent years, several airports have begun to realize that air freight services are or should be an important component of their operations. However, planning for air freight operations remains far behind that for passenger operations. A case in point is the new international airport at Denver. Air cargo interests were so dissatisfied with the location proposed for them at the new facility that several considered moving their operations to an alternative site at Front Range, which was being promoted as a potential all-cargo airport. Subsequently, plans at the new international airport were revised to ensure that air freight operations were more accessible to the surface transportation network.

The concept of all-cargo airports has also grown in recent years, with Alliance Airport in Texas being the most notable example. Plans for a "global transpark"—intermodal and industrial complex centered around an airport—has also been proposed in the State of North Carolina.

Depending on the location of an airport, the issue of nighttime operations and associated aircraft noise is one with which many airports continue to grapple. Because a significant share of air freight operations—particularly those of the all-cargo and air express carriers—occurs at night using older and noisier aircraft, this has been a matter of concern and debate in many communities.

Of those airports that did respond to the survey, most felt that freight demand forecasting was important to very important with respect to air carrier and all-cargo operations, as well as land use planning and landside access.

Only two of the airports indicated they develop their own freight forecasts. One indicated use of trend-line analysis and the other regression analysis to develop the forecasts.

For five of the six airports, the monthly airline reports of pounds enplaned and deplaned are the principal source of freight data. Individual airports also indicated they use U.S. DOT and Census trade data. Only one airport uses a commercial forecasting service, while another relies on an outside consultant to develop periodic air freight forecasts.

Three of the respondents indicated they coordinate planning with federal, state, and local government agencies. One coordinates with a private developer, while another has just begun coordinating with the local MPO.

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation



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