Freight Demand Modeling: Tools for Public-Sector Decision Making (2008)

DETAILS

105 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-11307-6 | DOI 10.17226/23090

CONTRIBUTORS

SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2008. *Freight Demand Modeling: Tools for Public-Sector Decision Making*. Washington, DC: The National Academies Press. https://doi.org/10.17226/23090.

CONFERENCE PROCEEDINGS 40

Freight Demand Modeling

Tools for Public-Sector Decision Making

Summary of a Conference

KATHLEEN L. HANCOCK, Virginia Polytechnic Institute and State University
Rapporteur

September 25–27, 2006
Keck Center of the National Academies
Washington, D.C.

Sponsored by
Transportation Research Board
Federal Highway Administration
U. S. Army Corps of Engineers
Research and Innovative Technology Administration
Federal Railroad Administration

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Washington, D.C.
2008
www.TRB.org

Transportation Research Board Conference Proceedings 40
ISSN 1073-1652
ISBN 978-0-309-11307-6

Subscriber Categories
IA planning and administration
VIII freight transportation (multimodal)

Transportation Research Board publications are available by ordering individual publications directly from the TRB Business Office, through the Internet at www.TRB.org or national-academies.org/trb, or by annual subscription through organizational or individual affiliation with TRB. Affiliates and library subscribers are eligible for substantial discounts. For further information, contact the Transportation Research Board Business Office, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; or e-mail TRBsales@nas.edu).

Printed in the United States of America.

This project was sponsored by the Transportation Research Board, the Federal Highway Administration, the U.S. Army Corps of Engineers, the Research and Innovative Technology Administration, and the Federal Railroad Administration.

Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making

J. Susie Lahsene, Port of Portland, *Chair*
William R. Black, Indiana University
David Cipra, Wisconsin Department of Transportation
James R. Gosnell, Southern California Association of Governments
John T. Gray, Union Pacific Railroad
J. Douglas Hunt, University of Calgary
Arnim H. Meyburg, Cornell University
Mark L. Schlappi, Maricopa Association of Governments
Huiwei Shen, Florida Department of Transportation
Lorant A. Tavasszy, TNO
John E. Tyworth, Pennsylvania State University

Liaison Representatives

Christina S. Casgar, Office of the Secretary, U.S. Department of Transportation
Ronald J. Duych, Research and Innovative Technology Administration
Scott Greene, Federal Railroad Administration
Bruce Lambert, U.S. Army Corps of Engineers
Rolf Schmitt, Federal Highway Administration
Tianjia Tang, Federal Highway Administration

Rapporteur

Kathleen L. Hancock, Virginia Polytechnic Institute and State University

Transportation Research Board Staff

Mark Norman, Director, Technical Activities
Elaine King, Rail Transport Specialist
David Floyd, Senior Program Associate

TRB Publications Office

Norman Solomon, Senior Editor
Jennifer J. Weeks, Editorial Services Specialist
Mary McLaughlin, Proofreader
Juanita Green, Production Manager

Cover design by Beth Schlenoff, Beth Schlenoff Design.
Typesetting by Carol Levie, Grammarians.

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

Contents

* *Peer-reviewed paper.*

Preface

On September 25–27, 2006, the Transportation Research Board (TRB) convened the conference on Freight Demand Modeling: Tools for Public-Sector Decision Making in Washington, D.C. The conference—sponsored jointly by TRB, the Federal Highway Administration, the U.S. Army Corps of Engineers, the Research and Innovative Technology Administration, and the Federal Railroad Administration—brought together approximately 120 individuals from across the freight transportation communities, at national, state, regional, and local levels and from the public and private sectors and academia. The conference benefited from the contributions of international speakers and participants from Canada, the Netherlands, Sweden, Finland, Australia, and Chile.

The conference was designed to complement the Federal Highway Administration's work on the Freight Model Improvement Program and focused on modeling methodologies, applications of existing models at the national and local levels (including international examples), and related data needed to support modeling efforts. The objectives were to engage members of the freight transportation community in examining current modeling practice and identifying areas where improvement may be needed. To plan the conference and organize and develop the conference program, TRB assembled a committee, appointed by the National Research Council. The conference committee was chaired by J. Susie Lahsene, Manager, Transportation and Land Use Policy, Port of Portland, Oregon. The program was designed to maximize the exchange of information and perspectives among participants.

In planning the program and conducting the conference, the committee developed a matrix laying out important questions related to the types of public-sector decisions that would (or already) benefit from an understanding of freight demand and thus from the use of some type of freight modeling. The purpose of the matrix was to organize discussion about evaluation of currently used models and identification of needed improvements for these models. The committee used the matrix to focus the program content and provided it to the breakout groups to help guide their discussions. The conference program covered the importance of understanding freight, a summary of the state of the practice, an evaluation of the practice today, a definition of future needs, emerging techniques in development and in the state of the art, and perspectives on future trends in freight demand and on where the discipline is going. The matrix, as it evolved throughout the conference, is provided in the Appendix.

This conference summary report is based on the conference agenda and was prepared by Kathleen Hancock of Virginia Polytechnic Institute and State University. The presentations made in each session are summarized in the respective sections and summaries of the breakout sessions are provided. The following five papers prepared in connection with the conference that were peer reviewed by the committee are included:

- Characteristics of Effective Freight Models, by Mark A. Turnquist;
- Freight Modeling: An Overview of International Experiences, by Lorant Tavasszy;

- Oregon Generation 1 Land Use–Transport Economic Model Treatment of Commercial Movements: Case Example, by J. Douglas Hunt and B. J. Gregor;
- Tour-Based Microsimulation of Urban Commercial Vehicle Movements in Calgary, Alberta, Canada: Case Example, by J. Douglas Hunt; and
- Ontario Commercial Vehicle Survey: Use of Geographic Information Systems for Data Collection, Processing, Analysis, and Dissemination, by Selva Sureshan.

A list of conference attendees is also provided.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purposes of this independent review are to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the project charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. TRB thanks the following individuals for their review of this report: Michael S. Bronzini, George Mason University; John T. Gray, Union Pacific Railroad Company; Lorant A. Tavasszy, TNO, the Netherlands; and Richard E. Walker, Portland Metro, Oregon.

Although the reviewers listed above provided many constructive comments and suggestions, they did not see the final draft of the report before its release. The review of this report was overseen by C. Michael Walton, University of Texas at Austin. Appointed by the National Research Council, he was responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered.

Note: Many of the photographs and figures in this publication have been converted from color to grayscale for printing. The electronic file, posted on the web at **onlinepubs.trb.org/onlinepubs/conf/CP40.pdf**, retains the color versions of photographs and figures.

Acronyms

ATRI	American Transportation Research Institute
CBA	cost–benefit analysis
CFS	Commodity Flow Survey
CVS	Ontario Commercial Vehicle Survey
DfT	Department for Transport, United Kingdom
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
FMIP	Freight Model Improvement Program
GDP	gross domestic product
GVW	gross vehicle weight
HarborSym	deep draft harbor simulation
HERS	Highway Economic Requirements System
HPMS	Highway Performance Monitoring System
HS	Harmonized System
ITS	intelligent transportation system
LGV	light goods vehicle
LRM	Lock Risk Module (ORNIM)
LUTI	land use–transport interaction models
MTO	Ministry of Transportation, Ontario
NAFTA	North American Free Trade Agreement
NAPCS	North American Product Classification System
NaSS	Navigation System Simulation
NETS	Navigation Economic Technologies
NHPN	National Highway Planning Network
NIMBY	not in my backyard
NRS	National Roadside Study (Transport Canada)
OMIP	Oregon Modeling Improvement Program
Optimization	Optimal Investment Module (ORNIM)
ORNIM	Ohio River Navigation Investment Model
PCE	passenger car equivalent
PIERS	Port Import–Export Reporting Service
PMA	Pacific Maritime Association
PUMS	Public-Use Microdata Samples
PWC	production–wholesalers–consumption (matrices)
QRFM	Quick Response Freight Manual
RP	revealed preference survey
RTM	Regional Travel Model (Calgary)
SAMGODS	Swedish national freight model system
SIC	Standard Industrial Classification
SCENES	European Union–level transport model
SCGE	spatial computable general equilibrium models
SCTG	Standard Classification of Transported Goods (Netherlands)
SLAM	Spatial Logistics Appended Module (Netherlands)
SMILE	Strategic Model for Integrated Logistics and Evaluations
SP	stated preference survey

STCC	Standard Transportation Commodity Codes
STAN	interactive graphic planning tool used for strategic planning of national and regional freight transportation
STEMM	Strategic European Multimodal Modeling
TENs	Trans-European Networks
TEU	twenty-foot equivalent unit (shipping container measurement)
TLUMIP	Transportation and Land Use Model Integration Program (Oregon)
TMIP	Travel Model Improvement Program
TRANUS	integrated land use and transport modeling system
USDA	U.S. Department of Agriculture
VIUS	Vehicle Inventory and Use Survey
WTA	World Trade Atlas
WSDM	Waterway Supply and Demand Module (ORNIM)

PLENARY SESSION

Introduction, Policy Direction, and Megatrends

J. Susie Lahsene, *Port of Portland*
Tony Furst, *Federal Highway Administration*
Paul Bingham, *Global Insight, Inc.*

The objective of this session was to provide participants with an appreciation of the importance of freight transportation and the role of analytical tools in describing and predicting the impact of modal trade patterns on surface public transportation systems and the operation of private transportation networks.

Introduction

J. Susie Lahsene

This conference is designed to provide participants with an appreciation of the importance of freight transportation and of the role of analytical tools in describing and predicting the impacts of modal trade patterns on the public and private transportation systems and to engage members of the transportation planning and freight transportation communities in examining current modeling practice and identifying areas where improvement may be needed.

The globalization of trade has resulted in dramatic growth in international freight movements in the United States. This increase, coupled with domestic freight growth, is putting tremendous pressure on the nation's freight systems. Measured by tonnage, U.S. domestic freight transportation grew by about 20 percent over the past decade and is expected to increase another 65 to 70 percent by 2020. International shipments are expected to grow even faster—by about 85 percent—in this period, and the value of cargo moving through the U.S. transportation system is expected to triple by 2020, according to the Freight Analysis Framework (FAF). Freight moving through U.S. ports is experiencing record growth, with some estimates that containerized cargo will increase by 350 percent in the next 20 years, according to the *Engineering News-Record* (enr.construction.com/features/transportation/archives/040809-1.asp).

Freight has emerged as a major issue in public transportation agencies that are essentially the "suppliers" of many freight facilities, primarily highways, seaports, intermodal connectors, and to a lesser extent airports and rail lines. These suppliers are feeling the pressure of rapidly increasing freight demand. Likewise, private-sector freight carriers, including truckers, railroads, and shipping companies, are feeling the effects of increased demand. Private and public elements of the freight transportation system are seeing their capacity strained to accommodate current flows and are running out of capacity to accommodate projected increases in the volume of goods to be moved. In an economy organized on the basis of fast and reliable delivery of goods, congestion becomes an important variable in the cost of doing business and in economic development.

Forecasts of commodity flows and freight transportation activity are essential to the suppliers of freight infrastructure, who must make critical—and costly—decisions about investments in increased capacity. The decision-making process, particularly in the public sector, requires a long lead time for planning and funding. Many of these investments are made for facilities with potentially long useful life spans, so it is critical to match the future supply of infrastructure and operational systems with the future demand for freight traffic. Agencies do not want to waste precious public dollars on facilities that are not needed in the long run or underestimate future freight demand that may overwhelm existing facilities. The divergent time lines of decision-making processes in the private and public sectors only add to the dilemma of gauging future supply versus demand. Therefore, the availability of forecasting models that give both public- and private-sector decision makers confidence to make these long-term investment decisions is vital to the nation's economy, which is dependent on the transportation system.

Current methods for forecasting freight are less than adequate to assess these increasingly complex and important issues. Freight demand models are typically based on methods developed for passenger travel demand forecasting. While these methods have evolved over more than four decades, the sources of demand for freight transportation differ significantly from those for passenger travel and may require different approaches to modeling. Many practitioners are calling for improvements in both the state of the practice and the state of the art in modeling freight demand.

This conference brings together representatives of the transportation community to review the state of the practice and the state of the art in freight demand modeling and to identify short-term strategies and long-term research needs to develop effective freight demand models for use at all levels of government.

National Freight Transportation Policy Direction and Why Freight Demand Modeling Is Important

Tony Furst

I see lots of familiar faces, and I am looking forward to reconnecting with you, and for those I do not know, the opportunity to meet you. Thanks for agreeing to be part of this important effort. I am looking forward to the improvement in freight modeling this conference has the potential to provide.

We have come a long way. Within the Office of Freight Management and Operations at the Federal Highway Administration, I know how much effort has gone into building the awareness that we now have for the importance of freight movement to the national economy. But the work goes well beyond my office. I know many of you in this room have been laboring in this field for a lot longer than I have, and I thank you for it. It has paid off. From where I sit, that work is paying big dividends—and for those of you who have been champions of this for a long time, I salute you. Well done.

I feel comfortable stating that I think we are over the hump in getting elected officials and transportation planners to acknowledge and genuinely appreciate the importance of freight movement and that we need to find the right solutions to keeping it moving. We are at the point where larger forces are coming into play.

Look at the freight components in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users:

- Projects of national and regional significance,
- National Corridor Infrastructure Improvement Program,
- Intermodal freight distribution pilot grants,
- Truck parking facilities,
- National Cooperative Freight Research Program,
- Changes in the Transportation Infrastructure Finance and Innovation Act that were more advantageous to freight, and
- Private activity bonds.

Look at the hearings that are taking place in the House Transportation and Infrastructure Committee on freight mobility:

- Highway capacity and freight mobility,
- Current status and future challenges,
- U.S. rail capacity crunch,
- Intermodalism,
- Freight logistics, and
- The road ahead as seen by users of the system.

Look at the number of Government Accountability Office studies under way that address freight movement:

- Public–private partnerships,
- Better utilization of existing infrastructure,
- Intermodalism, and
- Freight bottlenecks.

And look at the number of states and metropolitan planning organizations (MPOs) that have resources focused on freight movement.

The message is getting through. The trick is that those larger forces bring expectations with them. We are at the point where we can no longer celebrate the problem. Documenting increasing volumes is not going to get it anymore. Lots of people now understand that the volumes of freight we anticipate will, unless we do something, overwhelm the system.

So what are we going to do about it? We need to drive to solutions. And that is what this conference is about. It is about helping us get to those solutions. This is not just an academic exercise (I suppose I need to be careful about how loudly I say that at TRB). There is a hunger for better information on freight movement—after we released the second generation of the FAF, we were scratching our heads over the numbers and types of groups that were actively seeking the data—other government agencies, the private sector, and state departments of transportation and MPOs.

We need applications that can be put into operation across the spectrum from the national level to the users and practitioners at the state and MPO levels. At the national level we need improved freight modeling for the future of programs like projects of national and regional significance, the National Corridor Infrastructure Improvement Program, and the Corridors of the Future project that is part of the Secretary's congestion initiative.

At the state and local levels we need improved freight modeling for project-level decision making. We have been advancing courses that seek to integrate freight into the transportation planning process and utilize freight data. Through the freight professional development program, its peer-to-peer exchange, and the Freight Planning Listserv, we have a ready-made distribution mechanism for the information. TRB also has an extensive network.

I have no doubt that the research agenda this conference develops will get support. I am anticipating elements of it in my office's unit plan. There is the potential of utilizing the newly crafted National Cooperative Freight Research Program to help. There is, of course, the National Cooperative Highway Research Program.

The activity that this research can support is part of the National Freight Policy—developing data and analytical capacity for making future investment decisions. The research agenda that this conference provides works hand in glove with the concept behind the National Freight Policy. It is national and not just federal. Just as the many assets of the transportation system are dispersed across a spectrum of public and private players, so too are the potential solutions. The National Freight Policy was designed to be a collaborative effort to develop solutions by all the players that are part of freight movement, including academia, the private sector, and state and local governments.

Much of this conference taps the collective power of all these groups to help solve some of the data and analytical capacity issues. The National Freight Policy can also "get smarter"—it is a living document incorporating the idea that strategies and tactics to achieve an objective can morph as we learn more. Yet even with that support, you have a formidable challenge. Modeling freight is, as I am sure all of you know, vastly different from modeling travel demand for passengers. Commuting patterns, once established, change around the edges but are pretty static. Freight, on the other hand, is extremely dynamic. It is multimodal and interdependent. Manufacturing patterns change. Distribution patterns change. Supply lines change. The locations of distribution centers change. Vessel size and port calls change. And it goes on.

But the time is right. The broader audience is receptive and, I daresay, expecting it. Keep in mind the users, the practitioners. The outcome cannot be a huge data hog that is too expensive to run. It needs to be nimble to be utilized at different levels. It needs to be cognizant of the data requirements and how they can be acquired—though there could be more receptivity here.

And I will go out on a limb and say that it will likely get industry support. At an industry meeting I was talking about the FAF with a shipper who remarked how beneficial it had been in raising awareness. I thanked him for his support since the Commodity Flow Survey (CFS) was integral to the FAF. He was puzzled—the CFS? "I usually throw that survey in the bottom drawer until I get pestered enough to fill it out. The next time I will pay more attention, and I will talk it up with my peers."

The industry is starting to see the advantage and the payback from data collaboration. Another example is the Freight Performance Measure project, where we utilize Global Positioning System transponder data from 25,000 trucks a day to calculate speed and travel time reliability on our Interstate system. This provides the industry with information it can use.

Many of the puzzle pieces are in place: the interest is there, the support for implementation is there, and potential data providers are receptive to being approached.

So be bold, be creative. I am looking forward to a dynamic and creative research agenda. Thank you.

Freight Transportation Megatrends

Paul Bingham

This presentation is intended to provide a big picture overview of freight transport and then link this to freight forecasting.

Megatrends

What are megatrends? In 1982, a popular book was published with this title, updated in 1991 in *Megatrends 2000*. The book included a list of trends that looked into the 1990s and onwards. This set of general trends can be translated into what they mean for freight. Some may be a bit of a stretch, but many are remarkably prescient in terms of what was expected and what has actually happened in the world and in the global economy, and specifically for freight.

The Global Boom of the 1990s

Indeed we had a boom. It included the Internet boom and then led into the global recession of 2001. What has that meant in terms of freight? There has been an enormous advance in terms of technology across all levels of business, which has changed freight movement in dramatic ways.

Renaissance and the Arts

This translates to more high-value goods. An incredible amount of global trade is occurring through the World Wide Web and eBay. Items of very high value are moved around the world, and the shipments would have been inconceivable 15 or 20 years ago.

Emergence of Free-Market Socialism

In terms of goods movement, this relates to the opening of China and the resulting opportunities for and realization of higher volumes of trade because of global lifestyle changes and cultural nationalism. In the case of freight, cultural nationalism is defined as not necessarily meaning that all goods are homogenized around the world but are tailored to local markets, even if produced elsewhere.

Privatization of the Welfare State

This is readily seen in less public money for freight. Infrastructure investment that benefited freight—for example, the development and expansion of the Interstate system many years ago—is decreasing. Public entities have less ability to use purely public funds to pay for infrastructure, and the evolution is toward public–private partnerships and even pure privatization in terms of ownership and responsibility for operation and maintenance of facilities.

Rise of the Pacific Rim

This has clearly occurred in terms of the mix of the international goods trade into the United States. In the past 5 years, changes in the mix of goods have been led by the dominance of China in world trade growth.

1990s: Decade of Women in Leadership

This translates into a more diverse workforce. In some ways, in some markets, we take that for granted. Women participate fully at the highest levels in the current workforce, including government transportation agencies and such organizations as port authorities.

Age of Biology

This is reflected in more high-tech goods and growth in services that represent the advancement, more broadly, of science. Specifically in terms of biology, this trend is also a measure of where we are going as a society with respect to health care. A large portion of technology spending is in health care as the population ages, which means more related consumption and, therefore, increased movement of related goods.

Religious Revival of the Third Millennium

From the perspective of the safety and security environment and the war on terror, this translates into obstacles to trade. There are forces working against the advancement of market economies and full open trade in some areas of the world.

Triumph of the Individual

This relates to the shift from mass markets to customization of products and their movement. Consumer goods companies are using information and other technologies to split up markets into smaller and smaller pieces. The ability to tailor goods toward the individual has implications for how goods are manufactured and are being transported.

Globalization

Among the issues that affect freight transport, the biggest is the impact of globalization. Over the past 30 to 40 years, the importance of international trade in the U.S. economy has increased dramatically. The reasons are apparent to anyone with any understanding of the economics of international trade. Comparative advantages are to be had from engaging in international trade; they are observed in terms of reduced prices, increased quality, and available choices of traded goods.

Even though U.S. residents may be hesitant to obtain passports and go overseas, they are not hesitant to purchase goods made overseas. In fact, they have proved more willing to do that every year through their purchasing decisions. The result has been that the United States is now enjoying lower prices for most imported goods, which have affected our consumer prices and the economy. Exporters in this country who have been able to sell more broadly into open markets have also seen benefits, but such benefits result only if exporters are able to be competitive at a world-class level.

A consequence of these trends is higher job growth in trade and transport and distribution sectors. There is, however, a measured and absolute decline in noncompetitive producer industries—the manufacturing sectors that have been outsourced overseas and are not going to return.

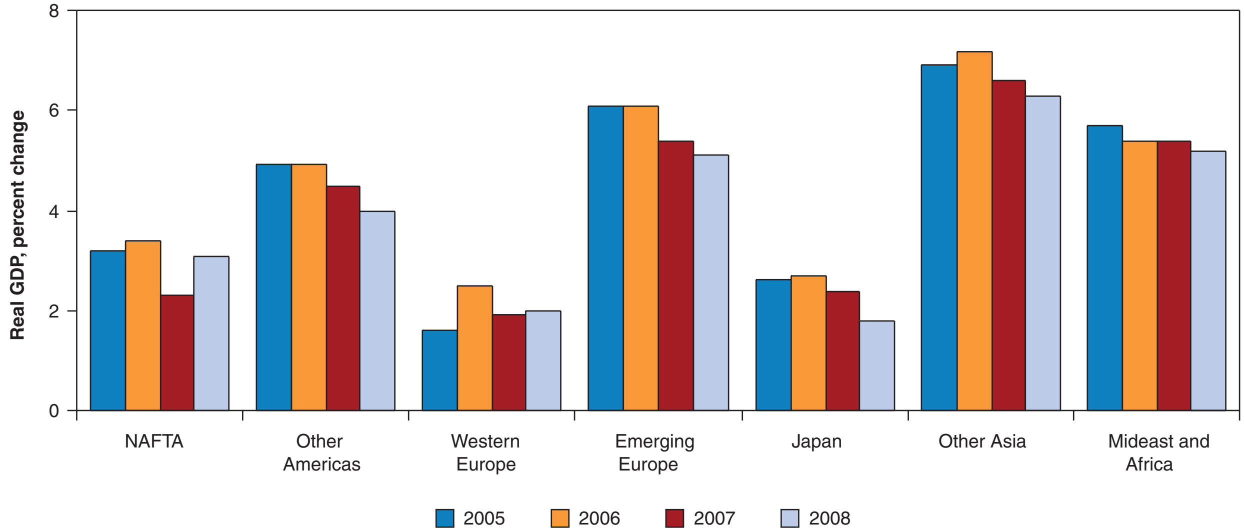

FIGURE 1 Forecasts of GDP growth by region. (Source: Global Insight, Inc.)

We have seen faster development of gateway regions and exporting industries that are still successful in selling globally, but a decline in regions with noncompetitive producers. Markets are tied to production that is less observant of international borders than before. This affects the distribution of manufacturing and consumption and thus the geography of freight movement inside the United States.

Globalization is not just about economics in terms of goods movements. Other significant dimensions are environmental impacts and safety and security, which are changing as a result of and in reaction to the globalization of manufacturing and trade.

Trade is not measured merely in terms of overall growth. There is tremendous growth in trade with "Other Asia" (including China) as seen in Figure 1, which shows Global Insight forecasts of gross domestic product (GDP) growth by region to 2008 (the United States is included in the North American Free Trade Agreement region). Much slower growth is projected in our trading partners in Western Europe and Japan, which are the developed, mature economies. We see much faster growth in some of the developing countries included in Emerging Europe, Mideast and Africa, and Other Asia.

For the United States, the most significant aspect of this disparity in regional growth rates in the past few years has been the growth in China. It is really hard to overstate the importance of how fast trade with China has grown and what this means. The growth of the transpacific share of total U.S. ocean container volumes [measured in 20-foot equivalent units (TEUs)] for waterborne container freight, which then comes onto the highways or the intermodal rail network, is mapped from 1995 through 2005 in Figure 2. China's share has doubled to 38 percent of the entire U.S. container trade for inbound movements.

Figure 3 shows annual growth rates in world ocean container trade (in green) across almost all trading

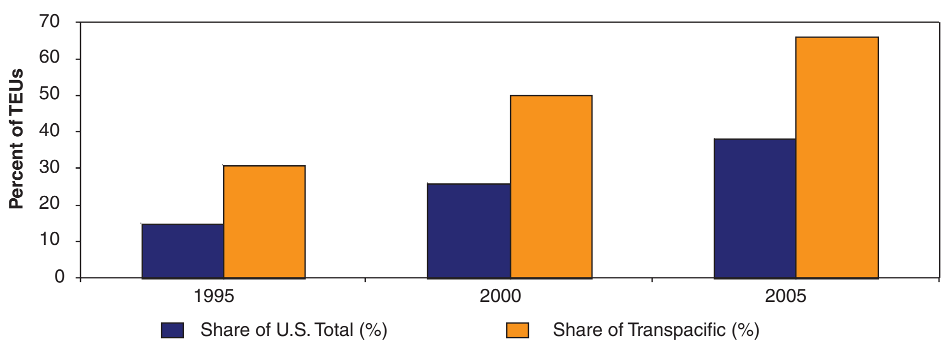

FIGURE 2 China's share of U.S. and transpacific-route containerized import TEUs, 1995–2005. (Source: Global Insight, Inc.)

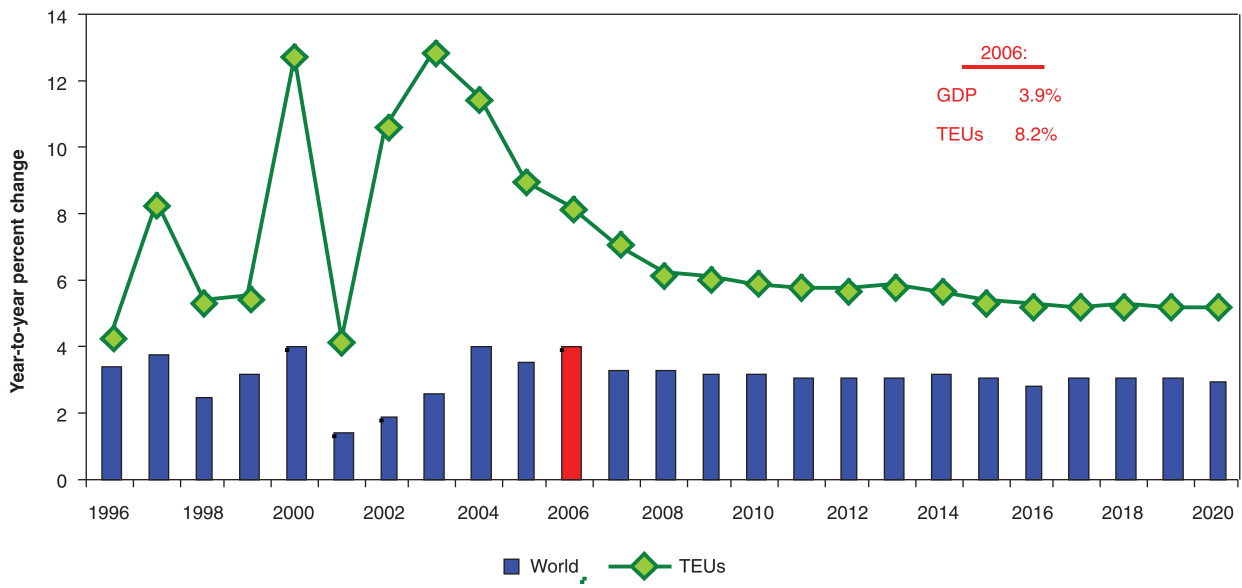

FIGURE 3 Growth in ocean container trade versus world economic growth. (Source: Global Insight, Inc.)

regions of the world compared with growth in the world economy, measured as real GDP in the bars. Trade has grown on a sustained basis, and trade growth is predicted to continue to be much faster than the growth in the underlying economies. The fact that the growth in trade is outpacing the growth in the economy as a whole implies that more and more of what is moving is a result of the growth in international trade.

Trade Imbalance

The United States is suffering from an enormous trade imbalance that is not forecast to resolve quickly. However, dynamics are at work affecting the deficit from which we can draw some conclusions. One is that this problem is not sustainable. The deficit is occurring because the United States is a very large debtor country, currently the largest, and the appetite and ability of our trade partners to finance our imports cannot be assured. This likely means that some fundamental changes are necessary. Many trends show those changes already under way, including a decline in the U.S. dollar exchange rate. In addition, some of the markets in the United States that had grown over the 5 years since the 2001 recession are cooling.

Significantly, this change must occur in the goods-supplying countries as well as in the United States. The reason is that many of these countries have based their growth on export-led development and U.S. consumers' willingness to buy what is produced. And it is being driven not so much from a financial perspective as from a jobs perspective in these exporting countries. Many of the developing countries have looked to export trade as the solution to providing employment for their populations, which are growing much faster than is that of the United States.

Recently, we have also seen faster domestic growth in Western Europe and Asia than in the past few years. The U.S. dollar exchange rate against foreign currencies is depreciating, and the flip side of this for the majority of U.S. trading partners is that their currencies are appreciating. The Chinese have moved away from the peg of the yuan to the dollar, which is significant in terms of the competitiveness of U.S. exports and the cost of imports.

The conclusion is that the trade deficit is not going to go away, nor will it reverse at some point in the future. This means that for as far as we can see in the long term from a goods trade balance perspective, much of our export trade capacity will continue to move empty, which will provide a multitude of challenges in dealing with imbalanced trade.

Up to this point the discussion has focused on the demand for transportation to handle trade. The market is not ignorant of the trade deficit issue and the pressures from growth in trade and has been responding with investment in capacity. This is the supply side of transportation capacity. As one modal example of growth in transportation supply, Figure 4 shows the total world container vessel fleet capacity currently on order. These are vessels not yet in service; they are either being built in the shipyards or still on order. They are grouped by capacity size range in number of containers measured in thousands of TEUs. The greatest growth is in the post-Panamax vessel size category, with an enormous investment by vessel operators and steamship owners in large vessels that do not fit through the Panama Canal because of their desire to reduce unit costs and benefit from economies of scale.

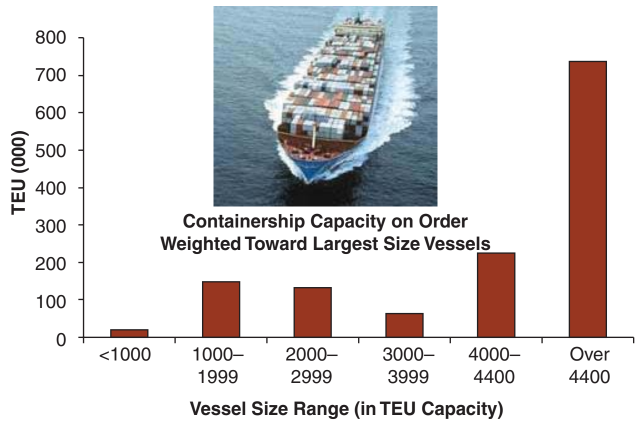

FIGURE 4 Total world container vessel capacity on order, by ship capacity size range in TEUs (2006 data). Note: The split between 4,000–4,400 and over 4,400 is approximate; the actual split is up to Panamax and post-Panamax. (Source: Global Insight, Inc., from Clarkson Research Studies.)

Methods to increase capacity have been used in other modes of transport where possible; for example, Class I railroads have moved to increase train lengths. The trucking industry has revived discussions about relaxing some truck size and weight restraints. Market pressures will continue, and advantage will be taken of economies of scale when doing so is economically viable. What does this really mean? Growth in economies of scale lowers the unit shipping cost, which in turn dampens the growth in transportation rates. If rates are reduced and competition is working, more transport is encouraged.

Other Factors

Many other factors are changing within the supply chain. Some observations of the industry indicate the following:

- Increasingly demand-driven, time-definite freight requires greater reliability, visibility, and security of transit. This has implications for mode choice, the technology used, and the cost of providing service.
- From industrywide logistics practices, increasingly distributed, point-to-point, direct-to-customer shipments (“direct-to-store”) can add volume at smaller gateways and on secondary traffic lanes. This allows industry to move away from the hub-and-spoke pattern of shipping. This is analogous, in the passenger world, to Southwest Airlines filling in a network with already established nodes. The links are added as the volume grows to justify their addition.
- There is demand for more efficient flows—more products per shipment to reduce rehandling; preblocking containers on ships abroad for U.S. intermodal trains; reduction in empties.
- Overall, trade in lighter-weight, higher-value products outpaces growth in bulk commodity categories. This means more air and ocean container trade, more expedited truck freight, and more intermodal rail freight.

Technology makes all this possible. Everything listed above is dependent on advances in technology and related investments and the expectation that technology will continue to evolve.

Globalization affects the domestic system as well. Global trade growth is going to continue at rates faster than U.S. economic growth and much faster than the growth of U.S. domestic capacity of airports, seaports, terminals, railroads, trucking, warehousing, and labor. Reactions to global trade growth have resulted in the following changes in goods movement:

- International transportation will be increasingly integrated with domestic transportation—less West Coast transloading; more hub-and-spoke inland distribution; more bulk import distribution centers.
- Smaller, more frequent shipments favor truck over rail and intermodal container over intermodal rail trailer-on-flatcar.
- Improved double-stack intermodal rail service captures more line-haul long-distance trucking (and not just truckload).
- Sustained regional trucking growth swamps other domestic mode growth. Trucking remains the default solution that provides the ultimate challenge for everyone. The highway network is ultimately going to be what matters to get freight delivered regardless of our efforts to move freight to more efficient modes. We still need trucking.

Another challenge to the freight industry is labor. Demographics are working against the industry in the United States. The country has an aging workforce with adequate opportunities from other professions for a better perceived quality of life for new entrants. New entrants and those workers making up the qualified pool of applicants are shrinking, in part because of restrictions based on safety and security regulations. Consequently, we see shortages by mode for workers at current wage rates. The market response will be that labor costs will go up, which will promote substitution of capital (e.g., equipment, technology) for labor and change where labor is employed (e.g., off-shore consolidation).

What are the consequences of growth for available capacity?

- Worsening congestion as urban slack capacity is used up;

- Deteriorating travel times and delivery time reliability;
- Increasing costs to shippers (freight rates, ancillary fees, etc.);
- More community not-in-my-backyard opposition to freight activity;
- Inadequate public finance and investment in building freight infrastructure, operations, and maintenance; and
- Increasing mismatch between scale of shipper and carrier networks and government jurisdiction and interests.

The public sector will respond to these challenges with the following:

- Better match of benefits with costs;
- New mileage-based or ton-based fees for highway use;
- More toll roads, potentially including truck-only lanes;
- For all modes, tighter emissions limits, alternative fuel equipment mandates, new operation restrictions, new (carbon) taxes, and more user fees;
- Further logistics workforce regulations (security and safety);
- Higher-productivity equipment, including increases in truck size and weight, perhaps with user fees; and
- Subsidies and tax benefits solely for environmental reasons.

Modeling Expectations

Ultimately, what does this mean for freight modelers? Freight modelers will need to address further complexity in the relationships that contribute to decision making about freight system use. Greater demand will arise for forecasts sensitive to alternative policy scenarios and linked to other related models including environment, land use, security and risk, and public finance. Increasingly, we will be required to model a moving target to capture the increased pace of change for transportation and logistics networks, practices, and underlying production and consumption geography that we are trying to quantify. Finally, modelers will face continued difficulties in obtaining freight activity data to meet the needs of the models to support decision making in this changing environment.

J. Susie Lahsene moderated this session.

Characteristics of Effective Freight Models

Mark A. Turnquist, *Cornell University*

The conference organizers suggested that the topic of this paper should be, "What makes a freight model 'good'?" However, a slightly less presumptuous title has been chosen. The paper describes characteristics that are believed important in making freight models effective—that is, useful for specific intended purposes—but it stops short of asserting that all "good" models must possess all of these characteristics.

These thoughts concerning characteristics of effective models are based on personal experience from more than 30 years of building models for use in a wide variety of freight contexts and for a variety of users—shippers, carriers, and public agencies. This experience is supported by both theory and common sense, but what this paper has to say is from personal experience, and this may differ in some respects from the experiences of other modelers and model users.

Most of the experience on which this paper is based is not in freight demand forecasting, even though that is the primary focus of this conference. Some of the work that forms the personal experience base (for example, synthesizing truck origin–destination tables from link counts and other available count data) might fall into the demand forecasting category, but mostly the experience is in other aspects of freight systems—carrier operations, distribution system design, specialized operations for highly hazardous cargoes (e.g., nuclear materials), and so forth. Thus, the perspective in this paper is not what makes an effective freight *demand* model, but rather what are the important characteristics of models of *freight systems*. This perspective also has value for freight demand modeling, but many of the examples cited here are from models that are not focused on demand forecasting.

The peer review of this paper was conducted by the Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making.

Modeling as an Art

Most transportation system modelers come from a scientific or engineering background. We are taught from the beginning of our technical education that models (especially mathematical models) are the appropriate way to express our understanding of "the way the world works." This is important and useful, but as we build models, especially of social and economic systems, we must also recognize modeling as an art.

Georgia O'Keeffe, the well-known 20th-century American painter, once commented, "Nothing is less real than realism. Details are confusing. It is only by selection, by elimination, by emphasis, that we get at the real meaning of things" (quotation courtesy of the Georgia O'Keeffe Museum, Santa Fe, New Mexico). She was talking about an approach to painting, but she could just as well have been talking about building mathematical models of transportation systems. We do not get to effective models by including every detail of every action that occurs in the freight transportation system every day. Effective modeling forces us to be selective in what we include, to eliminate unimportant details, to emphasize important relationships. In this way, we can "get at the real meaning of things."

With this philosophical base as a starting point, this paper postulates four main characteristics that are important for effective modeling. The characteristics apply more broadly than to modeling freight systems, but the present interest is there, so the subsequent discussion is grounded in that context. The four characteristics are as follows:

1. An effective model is focused on producing an output that someone wants and knows how to use.
2. An effective model includes the important variables that describe how the system works and represents their interactions clearly and correctly.
3. An effective model operates in a way that is verifiable and understandable.
4. An effective model is based on data that can be provided, so that it can be calibrated and tested.

These ideas probably do not appear earth-shattering, and perhaps they seem self-evident. If this is true, the task of this paper is already half accomplished. It does not have to convince you as a reader that some bizarre concept is true; it only has to persuade you that failure to pay attention to these straightforward ideas is common and often leads to model (and modeling project) failures. In the following four sections, these ideas are discussed in greater detail in the context of freight transportation system models.

Produce an Output That Someone Wants and Knows How to Use

In the late 1970s, the author was part of a project team that estimated short-run total cost functions for railroads. The team experimented with using new techniques for combining engineering and econometric analysis and produced a set of models with statistically estimated parameters for predicting railroad costs. The results of the analyses were published in well-regarded economics journals (*1*, *2*), and over the next 10 years or so those papers were cited relatively frequently in other academic papers. However, as far as this author is aware, no railroad manager ever used those models directly.

Thus, there is a legitimate question: Was that an effective modeling effort? The answer, of course, depends on who the "someone" is whose desires for model output are being met. From an academic perspective, other researchers could (and did) use the model output, so the question might well be answered in the affirmative. From the perspective that is central to this conference (understanding how to transfer the state of the art effectively into practice), however, it is not clear that any practitioner wanted what the project produced or knew how to use it.

Freight models may be built with several different ideas in mind about who will use the results, and aiming different types of modeling efforts at different users is a perfectly valid exercise. If a particular modeling effort is aimed at practitioners, it is important to understand who those practitioners are and to know that they will understand how to use what is produced. Often, the "user" is an organization, and the ability to use a model is subject to the culture and knowledge within that organization. This can be a major challenge.

Last year a team from General Motors (GM), of which the author was a part, was awarded the Franz Edelman Prize for Achievement in the Management Sciences. The focus of this effort was an integrated suite of models for identifying bottlenecks in production lines at GM so that changes could be made to increase throughput (*3*). Over an 18-year period, the tools from this modeling effort have become ingrained in GM's culture and have produced documented cost savings in excess of $2 billion. A small group of original model builders (including the author) started this effort in the late 1980s, but the real heroes of this story are the people who first convinced managers in a few plants to implement changes on the basis of the model analyses. They created an internal corporate consulting group to help other plants adopt the models and change processes and have literally changed the way GM managers think about production bottlenecks. This group inside GM has trained more than 4,500 GM employees from around the world in the practical use of the tools.

The team that started this work foresaw very little of the eventual success. At the beginning, plant production managers and line designers in GM had some simulation tools, but these models were difficult to calibrate and use, and as a result they were mostly ignored—especially by the people "on the firing line" in the plants. We decided to approach the problem from a different perspective: to focus particularly on potential users in the plants and to build models that could be supported by data the plant production people could understand how to collect for themselves. It took some time for this process to be successful; GM is a huge organization and any change takes time and persistence, but eventually the focus on making sure that users could really use the models we were producing paid off in a dramatic way.

Include the Important Variables and Interactions

The freight system is complex. There are many actors and modal options, a huge range of commodities being transported, and shipper–receiver locations that span the globe. It is difficult to describe concisely what elements of this complex system are most important, but one of the best short summaries available is Chapter 2 of *NCHRP Report 388* (*4*). While this report was published nearly 10 years ago and was written somewhat before that, its description of the key elements of the freight system and the role of public-sector planning is still highly relevant and well worth reading.

In an aggregate sense, an important item in focusing modeling efforts in freight is the change over the past 20 years in transportation and inventory costs as a percentage of national GDP. This is illustrated in Figure 1, with observations at 5-year intervals, except for the last. The last observation is for 2004 because the 2005 values were not yet published. Considering transportation and inventory costs together is important because their combination makes up the total logistics cost in the economy.

At least three vital pieces of aggregate information about the U.S. logistics system are discernible from Figure 1:

1. The logistics system has become much more efficient over the past 20 years, so that logistics costs (in actual dollars) have increased much more slowly than the economy as a whole has grown, and measured as a percentage of GDP, logistics costs have decreased by about 30 percent since 1985.
2. Inventory costs (as a percentage of GDP) have decreased much faster than transportation costs over the same period.
3. Transportation costs (as a percentage of GDP) have decreased more since 2000 than they did over the previous 15 years, despite the run-up in fuel costs that was noticeable in 2004 (and has continued with a vengeance since).

These three observations lead to a core set of ideas about how shippers and carriers operate, and those ideas need to be incorporated into effective freight models. The first of these ideas is that shippers increasingly focus on total logistics costs (transportation plus inventory), not just transportation costs, when they make decisions about how to ship materials across the supply chain. Paying more for faster, more reliable transportation is a key way to reduce inventory requirements, and this has happened in a dramatic way over the past 20 years. This is a primary reason why inventory costs have fallen faster than transportation costs. This has obvious important implications for freight demand modeling, especially with respect to mode shares.

A second core idea is that the inventory–transportation cost evaluation is not done in isolation, but has significant related implications for location decisions and service quality as firms design their supply networks and product distribution networks. For example, Bowman (*7*) describes the efforts of Best Buy (a large consumer electronics retailer) to reconfigure its distribution center (DC) system, emphasizing customer responsiveness. The desire to provide faster delivery of products to customers, by using smaller and more frequent shipments, means that outbound transportation costs from the DCs are relatively high. This creates an incentive to locate DCs near major customers.

An integrated analysis of distribution system design, like that by Nozick and Turnquist (*8*), includes location decisions, inventory costs, transportation costs, and service quality measures in an overall assessment of how a firm might best distribute its products. For example, Figure 2 illustrates a set of trade-off possibilities between total logistics costs (including inventory, transportation, and facility costs) and "200-mile coverage" (i.e., the percentage of total final demand within 200 miles of a DC) for a U.S. automotive manufacturer. Increasing service quality (as measured by increasing coverage) is achievable at increasing total cost, and the marginal rate of cost increase is also increasing.

Figure 3 shows the solution for 29 DCs in this case. As indicated in Figure 2, this solution has an annual cost

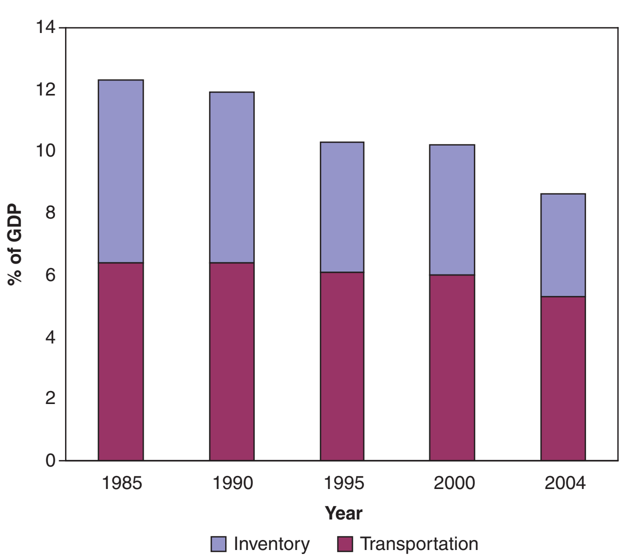

FIGURE 1 Freight transportation and inventory costs as a percentage of U.S. GDP (*5, 6*).

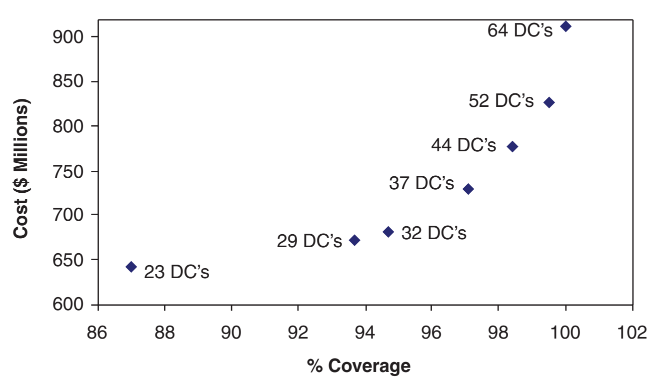

FIGURE 2 Trade-offs of total cost versus service quality (percent coverage at 200 miles) for DC locations (*8*).

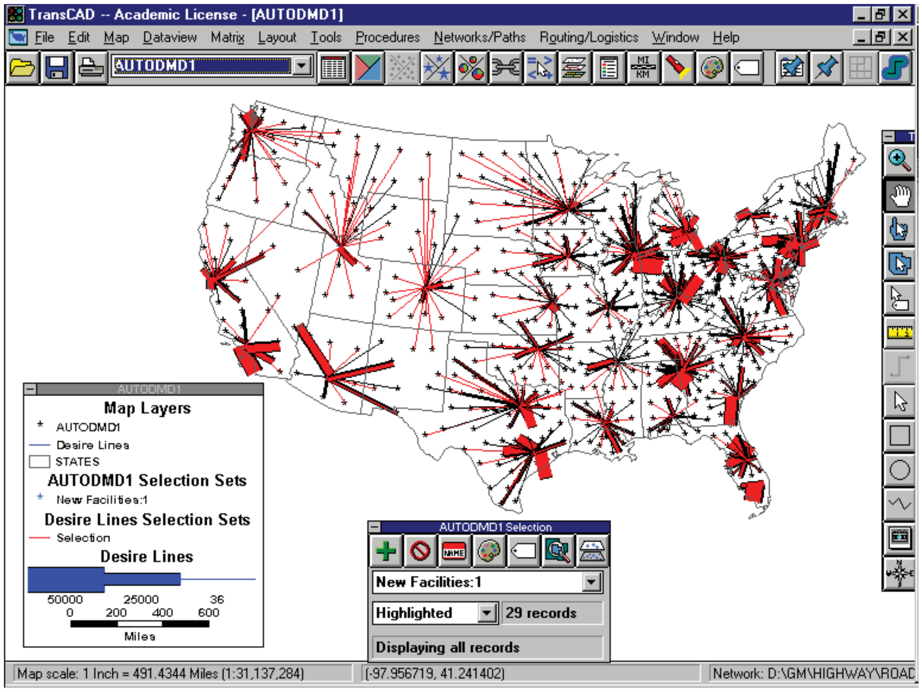

FIGURE 3 Locations for 29 DCs (*8*).

of $672 million (about 5 percent above the minimum cost solution) and covers 94 percent of demand within 200 miles (allowing overnight delivery to be realistic).

The implications of this integrated analysis of locations, inventory, and transportation costs and service quality for freight demand forecasting are clear. If firms make these decisions in an integrated way, forecasts of origin–destination patterns for freight should also reflect this type of integrated analysis.

A third core idea is that carriers are getting better and better at optimizing their operations to reduce costs. Even in the face of shippers' use of higher-cost services to reduce inventory costs, transportation costs have grown more slowly than GDP, and since 2000, the reduction in transportation costs has been dramatic. Continuing pressure from high fuel costs will likely produce more focus on optimizing operations in the future, as carriers continue to find ways to improve productivity of labor and physical assets and reduce fuel consumption.

As shippers have decreased shipment sizes and increased frequency to provide improved service and reduce inventory, carriers have responded by getting better at combining shipments in vehicles by using cross-dock operations, at using vehicle-routing software to optimize routes with multiple stops, and at reducing empty equipment repositioning costs. This also has direct implications for freight flow forecasting because the underlying decisions that carriers make (which create the vehicle flows in the transportation network) are becoming more complex, and forecasting models need to reflect that.

Models That Are Verifiable and Understandable

Most model users are not model builders, and they are not comfortable "slogging through" much heavy-duty mathematics or statistics. However, they do have a clear need to be able to verify models that they are considering for use. Verification means that the model operates correctly—it is logically consistent and complete. This is different from validation, which is the process of determining whether the model is a sufficiently accurate representation of the real system it is designed to reflect. Verification is frequently done by a series of basic checks, such as the following: If 10 trucks enter the system here, do they come out over there? If this is an optimal location for a DC and it is moved a little, does cost go up? If this parameter is set to zero, does the expected thing happen? Model builders need to do a careful job of model verification themselves, and they should expect to go through similar exercises with potential users to build their confidence. It is also vital to be able to explain the output of the models in clear, logical terms.

This author has had recent experience with these issues in the context of using national-level models of freight flows to test the performance of the system under stressful conditions (inability to use certain parts of the system, etc.). The model built to answer the questions posed by the users (in this case, federal officials) is based on fairly standard network flow computations (conservation of flow equations at network nodes, time delays as a function of volume on links, etc.). The users may not appreciate the details of the nonlinear optimization methods being used to compute the network flow solution, but they can easily trace aggregate flow volumes and identify traffic diversions around portions of the network that are taken out of service in various experiments. The fact that model solutions can be explained in a straightforward way has served to increase confidence in the model's use.

This can be contrasted with the outcomes of some types of simulation studies. Telling a client that some specific outcome of the model "just happened" through unpredictable interaction of a collection of agents does not tend to instill confidence that the modeler understands what is being modeled. Agent-based simulation (as well as other types of simulation) is a vital modeling tool, and as computing power continues to increase at an exponential rate, it is ever more useful. However, simulations need to be verifiable and understandable, just as other analytic models are. This means that careful attention must be paid to estimating probability distributions and other parameters of the simulations from observable data, explaining the structure of the model to the user, and reporting the outputs of the simulation in statistically valid ways.

Models Supportable by Data

The issue of estimating model parameters and probability distributions from real data is the fourth main point of this paper. For some modelers in the demand forecasting arena, especially those who focus on econometrically estimated models, this is almost the only point. The structure of their data set (what variables have been included, how they have been measured, and from what population sample they have been drawn) defines the range of models they can consider. At the other extreme, there are modelers who believe and argue that the "structure" of the model is the only important part—parameter values can be guessed and data are (at best) of secondary importance.

The author does not subscribe to the view that model calibration is unimportant. One of the lessons of the success at GM described earlier is that organizing the data collection to support the modeling and making sure that people understand how specific model parameters are derived from the data are both vital activities.

In the mid-1980s, a project at a major U.S. railroad tested a new approach to empty railcar distribution. The model was based on research done with one of the author's PhD students (*9*). At the time, that railroad was creating a monthly plan for redistributing empty railcars on the basis of average supply and demand values at various terminals over the previous month. The new model was a stochastic optimization at a daily level, using forecast data on means and variances of daily supply, demand, and travel time across the network. The project participants were confident that we were about to make a "quantum leap" in capability at the railroad. As the project began, it became clear that the company had (at that time) no way of collecting and processing data on car supplies or orders to produce the daily estimates of variability that were needed for the model. A major reformulation of the model should have been done at that stage so that it would have been consistent with the level of detail the railroad's information systems were capable of providing, but that did not happen. The project team decided to "solve the data problem later" and focused on getting the computer implementation of the algorithm functioning on the railroad's mainframe system. This was a serious strategic error and was one of the major factors contributing to the demise of the project. This unfortunate outcome did, however, have a significant personal benefit. In subsequent projects (both relating to railroad car distribution and other modeling efforts), the author has paid much more attention to where the data will come from, how we will use the data, who owns the data, and so forth. This has proven to be a valuable lesson.

The issue of supporting models with appropriate data has a particular poignancy when freight flow forecasting in the public sector is the focus. Earlier in this paper, emphasis was placed on how shippers make decisions as the basis for understanding and modeling how freight flows (at the commodity level) occur. There is a further argument that the translation of the demand for types of shipments (by commodity, shipment size, frequency, and mode) into vehicle movements on networks is the result of increasingly sophisticated optimization by carriers. A possible response from the public sector is, "Fine, but how does a state department of transportation or MPO make any use of these ideas without data that shippers and carriers will consider proprietary and are therefore unavailable to a public agency?"

This is, indeed, a reasonable question. Much of the experience related here has been acquired by working directly with the private companies that have the data and need to make the decisions. The standard publicly available freight data sets (the Commodity Flow Survey, the public use Rail Waybill Sample, etc.) are woefully inadequate for the type of modeling and understanding of freight flows advocated in this paper. They are sufficient to provide aggregate checks on the types of models described here, and they can offer a "broad brush" picture of what happened a few years ago, but they provide little basis for modeling *why* it happened.

This paper does not offer a "magic bullet" solution to this problem, but there is hope that a solution is possible. This hope is based on the fact that much of the work this author has done under private-sector sponsorship has been allowed to be published (*1–3*, *8*, and other papers). Ways have been found to protect the companies' proprietary interests and still make the work available in the public domain. This gives at least some confidence that ways can be worked out to accomplish similar things on a larger scale.

Some Conclusions and a Suggested Path Forward

It is to be hoped that through the series of anecdotes and opinions (and even a little discussion of recent data) in this paper, some valuable points have been made on how to build useful freight models. As the profession moves forward and considers what kinds of models to build in the near future and how to implement them in practice, a few major trends are important and affect the context within which freight systems operate.

The first of these is that international freight movements are growing much faster than domestic freight movements. Over the recent past, global trade has expanded at a rate that is about 2.5 times the growth rate of world GDP (*10*). For the future, this means continuing growth in containerized movements, more use of complex intermodal services, and patterns of domestic origins and destinations that are increasingly focused on ports and border crossings.

A second important trend is that increasingly global sources of production and consumption are focusing larger volumes of movement through seaports and airports. If these port facilities are the domestic origin or domestic destination of many shipments within the United States, it creates an incentive for U.S. companies to rethink the locations of their U.S. production and distribution facilities. This, in turn, increases the importance of the integrated view of location, transportation and inventory costs, and service quality that was described earlier in this paper.

A third major trend is coordinated decision making across the supply chain. Over the past decade, firms have made considerable strides in coordinating supply chain decisions that are *within* the firm. The next frontier is collaboration *across* firms, with suppliers and customers sharing more information with regard to inventory positions, production schedules, and so forth. As suppliers and customers find mutually beneficial opportunities to make collaborative decisions on shipment size, timing, mode, and so forth, there will be a direct impact on the character of freight movements.

If the ideas expressed in this paper are carried to a conclusion (although perhaps a conclusion beyond what is justified), there is a basis for considering a method of freight flow forecasting at a regional or national level different from what has typically been used in the past. This approach would start with the integrated decisions made by representative firms as they design their supply and distribution networks, including decisions on facility location, transportation and inventory levels, and service characteristics to their customer base. For specific movements in this network, a more detailed analysis of inventory and transportation costs would be done to create representative shipment sizes, frequencies, and mode choices. Then on the carrier side, these shipments would be translated (at least in a statistical sense) into likely vehicle movements on an origin–destination basis.

Obviously, there are data challenges in supporting such an approach, as described in the preceding section. The one-paragraph description of the approach provided here is also far short of a full model specification. It does, however, indicate a direction in which this author believes the profession should move as we seek greater understanding of freight movements and the ability to make effective transportation policy in the public sector.

References

1. Breautigam, R. R., A. F. Daughety, and M. A. Turnquist. The Estimation of a Hybrid Cost Function for a Railroad Firm. *Review of Economics and Statistics*, Vol. 64, No. 3, 1982, pp. 394–404.
2. Daughety, A. F., M. A. Turnquist, and S. L. Griesbach. Estimating Origin–Destination Specific Railroad Marginal Operating Cost Functions. *Transportation Research A*, Vol. 17, No. 6, 1983, pp. 451–462.
3. Alden, J. M., L. D. Burns, T. Costy, R. D. Hutton, C. A. Jackson, D. S. Kim, K. A. Kohls, J. H. Owen, M. A. Turnquist, and D. J. VanderVeen. General Motors Increases Its Production Throughput. *Interfaces*, Vol. 36, No. 1, 2006, pp. 6–25.
4. Cambridge Systematics, Inc. *NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand*. TRB, National Research Council, Washington, D.C., 1997.
5. Thomas, J. Where the Money Is. *Distribution*, July 1997, pp. 14–20.
6. Trunick, P. A. Can We Hold the Line on Logistics Costs? *Logistics Today*, Aug. 2005, pp. 27–30.
7. Bowman, R. Getting Bigger and Bigger. *Distribution*, Jan. 1996, pp. 46–49.
8. Nozick, L. K., and M. A. Turnquist. Inventory, Transportation, Service Quality and the Location of Distribution Centers. *European Journal of Operational Research*, Vol. 129, 2001, pp. 362–371.
9. Jordan, W. C., and M. A. Turnquist. A Stochastic, Dynamic Network Model for Railroad Car Distribution. *Transportation Science*, Vol. 17, No. 2, 1983, pp. 123–145.
10. Wade, F. E., and S. J. Callaway. Location, Location, Location. *Supply Chain Management Review*, Vol. 9, No. 7, 2005, pp. 9–10.

The Importance of Understanding Freight

J. Richard Capka, *Federal Highway Administration*

This is the right conference at the right time. Freight has emerged not only as a major issue within the transportation community but also as a concern for all Americans. It is an issue that will be with us for many years to come.

Right now, our models point toward greater congestion. We need new ways to understand how freight affects congestion and how congestion affects freight—and how they both affect the nation's economy.

Trucks are a significant share of traffic on highways, many of which have reached capacity. Ports and railroads have difficulty handling current freight volume. As volume grows, so does the demand for fast and reliable delivery to support our just-in-time economy. Interregional freight contributes to local congestion, and local congestion disrupts the flow of freight that fuels our economy. From a larger perspective, congestion can reduce our competitiveness in the global economy.

Freight is a major topic at the highest levels of the U.S. Department of Transportation. We worked with shippers and carriers through the TRB Freight Roundtable to develop the Framework for a National Freight Policy, rolled out last January by Under Secretary Jeff Shane.

The Bush administration's National Congestion Initiative should stimulate investment that will benefit freight.

Especially through the Corridors for the Future effort, innovative congestion mitigation strategies are being developed for major bottlenecks, such as the Ports of Los Angeles and Long Beach, with continued emphasis on efficient border crossings. The Federal Highway Administration created the Office of Freight Management and Operations to focus our resources on freight issues.

Congress continues to demonstrate a growing concern with freight. It is holding a series of hearings on freight mobility. The Government Accountability Office, an arm of Congress, has several studies of freight transportation under way.

Freight was a major part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, including $4 billion for new investment in Projects of National and Regional Significance, the National Corridor Infrastructure Improvement Program, the Coordinated Border Infrastructure Program, Freight Intermodal Distribution Pilot Grants, and truck parking facilities. The act also includes changes that could attract billions more in private-sector investment. A cabinet-level committee has been established by the White House to coordinate the marine transportation system.

Many state departments of transportation have created freight offices or designated freight coordinators to better understand freight issues and devise solutions. States and metropolitan planning organizations are working together in corridor coalitions to improve freight flows through their regions.

TRB created a new Freight Systems Group and is launching the National Cooperative Freight Research Program. I have been talking about freight in most of my public remarks—the message has to get to a broader audience.

Hunger for Information

The rising awareness of freight has created a real hunger for information. *Freight Facts and Figures* is one of the Federal Highway Administration's most popular publications. The maps from our Freight Analysis Framework are used by agencies at all levels of government, major shippers, carriers, and even land developers. Several states are working with us to apply the Freight Analysis Framework and our new Freight Performance Measures program to state and local freight issues.

We must do a much better job of feeding the hunger for information on trends and forecasts of future volume and corridors. Our forecasts during the 1980s were far short of the growth we experienced by 2000. Our current understanding is too often tied to analytical tools that were developed for passenger travel, and freight containers do not behave like people.

Vital Work

So I am asking you to be creative and bold during the rest of this conference to help us understand how to keep goods moving and the economy strong. I look forward to your recommendations to help us devise the road map to better models of freight demand.

The work you are doing is vital. As we all know, good transportation protects the quality of life we enjoy and the economic growth our nation needs.

Never question the significance of the role you play, as well as the incredible opportunity we have to make a difference.

Current Practice

Freight Modeling
State of the Practice

Bruce Spear, *Federal Highway Administration*
Greg Giaimo, *Ohio Department of Transportation*
T. Randall Curlee, *Oak Ridge National Laboratory*
Kevin Neels, *Brattle Group*

The objective of this session was to improve understanding of current modeling tools and methods used in the public sector and the potential uses and benefits of private demand modeling.

Freight Modeling in Urban Areas: State of the Practice

Bruce Spear

Freight modeling is not a high-priority activity in most metropolitan planning organizations (MPOs). In a survey of MPOs conducted by the Association of Metropolitan Planning Organizations for its *2005 Profiles* publication, only 20 percent of the MPOs included freight planning among their program activities. In comparison, nearly 70 percent included travel demand forecasting among their program activities.

There are several reasons why freight modeling is not a priority at more MPOs. First, in many metropolitan areas, freight traffic represents a comparatively small share of total vehicular traffic. Second, unlike household-based travel demand forecasting, there is no standard methodology for modeling urban freight flows. Moreover, the data needed to build and validate freight models (vehicle classification counts, truck loading and dispatching practices, etc.) are much more difficult to collect, especially from private shippers and trucking firms. Finally, MPOs have limited staff resources and budgets and must direct these resources to other mandatory or higher-priority planning activities (e.g., long-range plan and Transportation Improvement Program, conformity determination, special project studies). Freight modeling is often seen as requiring too much expenditure of limited resources for little payoff toward improving overall transportation in the area.

On the other hand, many more MPOs could benefit from better freight planning. Relative to their vehicle miles traveled, heavy single-unit and combination trucks contribute disproportionately to certain air pollutant emissions (oxides of nitrogen, particulate matter of size 2.5 microns and smaller) and to traffic congestion. For example, heavy trucks are slower to accelerate in stop-and-go traffic, crashes involving trucks are typically more serious and take longer to clear, and trucks often block lanes or entire streets while making deliveries. Freight traffic may also respond to mitigation strategies different from those appropriate for general vehicular traffic, such as truck-only lanes on highways or pricing incentives to shift urban goods deliveries to off-peak times. These strategies may be less costly or more politically acceptable to implement than strategies aimed at the general public, such as areawide pricing or new high-occupancy vehicle lanes.

Urban freight traffic is made up of three distinct components: through trips, internal–external trips, and internal distribution trips. Each component is different with respect to what causes it, how it can be modeled, and what factors influence it. The relative magnitudes of these three components also vary significantly from one metropolitan area to another.

Through trips are those whose origin and destination both lie outside the metropolitan area. They represent traffic that passes through the area because certain network links make up part of the shortest (or fastest, least congested, or most reliable as perceived by a driver or shipper) path between the origin and destination. Most through trips are routed on principal arterials and designated truck routes and are unlikely to be influenced by most policies implemented at the metropolitan level. Current estimates and forecasts of through trips can be developed from interregional truck flow models such as the Freight Analysis Framework (FAF) or statewide freight flow models.

Internal–external trips either originate or terminate within the metropolitan area but have their other end outside the area. While interregional truck or commodity flow models provide a useful starting point, the key to modeling internal–external trips is to identify and locate the principal origins and destinations within the metropolitan area and the commodities that they handle. Principal origins or destinations include intermodal freight terminals (airports, seaports, rail yards), manufacturing sites, and truck distribution centers or warehouses. Depending on the commodity, models of internal–external trips may require local forecasts of economic growth (e.g., whether a particular industry will increase or decrease production in the area, whether there are plans to increase throughput capacity at a port) as well as the mode share of truck versus rail. As are through trips, most internal–external trips are routed on principal arterials or designated truck routes, with additional access links from the principal arterial to the specific terminal locations.

Internal distribution trips represent the classic urban goods movement and consist of intraurban truck flows from distribution centers and warehouses to retail stores or directly to the consumer. Interregional truck or commodity flow models are of little or no use in determining the destinations or network paths of these trips. The origins of most internal trips are the same truck distribution centers located for internal–external trips. Destinations are located throughout the metropolitan area and are typically modeled by using some form of gravity model, where attractiveness is based on a measure of distributive capacity such as retail floor space or sales volumes. In contrast to other freight trip components, significant volumes of internal distribution trips use lower-level network links (e.g., minor arterials and collectors). Most operational urban goods models assign trips by using shortest-path routes and partitioning destinations according to the closest distribution centers. Use of more realistic tour-based models requires data and understanding of freight distribution practices that are typically not available to public-sector agencies.

Many MPOs can significantly improve the ability of their travel models to address freight traffic by better understanding the relative contributions made by each of the three freight components. The overall volume and composition of freight traffic can vary significantly across urban areas. By addressing each component of freight traffic separately, MPOs can allocate resources on the basis of the relative impacts of each component on regional traffic conditions.

However, to understand freight traffic within a metropolitan area requires that certain data be collected. At a minimum, metropolitan areas would need to collect vehicle classification counts (identifying the relative volumes of medium and combination trucks versus light trucks and automobiles) on all principal arterials and truck routes. Also, metropolitan areas would need to collect and maintain an inventory of major freight generators, including intermodal terminals, manufacturing sites with heavy volumes of truck traffic, and intercity truck distribution centers and warehouses. Some of these data may be available from national sources like the Highway Performance Monitoring System and the National Highway Planning Network intermodal terminal database but would need to be enhanced and expanded for each metropolitan area.

In addition to basic freight data, there are several research areas that could directly address current deficiencies in urban freight models. There is need for a common approach for modeling internal distribution trips. Current approaches generally apply elements of the four-step model used for household trips to urban goods movements, but this does not effectively handle multistop tours or commercial scheduling constraints. Some work has been done in this area, but further validation is needed. Additional research is also needed to better understand the behavior of freight carriers (e.g., what factors influence the routes and schedules of specific commodity shipments). Finally, additional research is needed to develop effective approaches and parameters for translating commodity flows into truck flows (e.g., accounting for empty backhauls by commodity and for commodity-based truck loading policies).

State of the Practice in Freight Modeling at State Departments of Transportation

Greg Giaimo

Freight modeling at the state department of transportation level is almost always a component of a larger travel demand forecasting model. The freight components invariably focus on truck flows since the studies are chiefly interested in the demand for highway facilities. The models are primarily designed to study intercity corridors; however, secondary purposes such as statewide systems planning and bypass studies are also common.

In a recent survey conducted as part of *NCHRP Synthesis 358*, freight planning was only the eighth most common use of statewide travel demand forecasting models. These models were extremely uncommon until the 1990s. This was largely due to the lack of adequate computing resources. However, lack of understanding about the nature of intercity transport played its role as well since most research to that time had been on urban travel demand (as is the case today). Since that time, the availability of better computing technology has resulted in the rapid proliferation of statewide travel demand models. Today, roughly half of the states have or are developing such models. Early efforts at statewide models were simply larger versions of the urban four-step travel demand forecasting model. These models either ignored freight altogether or contained a rudimentary truck model. Today, however, commodity-based approaches have become more popular. The advent of these approaches and the explicit representation of long-distance passenger travel are the two most significant advances that have been made in the current statewide travel demand models. In other respects, statewide models are analogous to their urban cousins. There are currently four general methods for modeling freight in these models:

1. None,
2. Traditional,
3. Commodity based, and
4. Integrated land use–economic commodity based.

The models with no freight component are typically those in small, densely populated eastern states. They are simply urban passenger travel demand forecasting models. They follow that paradigm exactly since the geographic scale and nature of the problems to be studied are similar. There are exceptions, however, where larger states have chosen to ignore freight travel, largely for budgetary reasons.

The traditional method is to use four-step techniques resulting in a truck model. These models use either regression equations or trip rates to generate trucks and either a gravity model or Fratar model to distribute them. The *Quick Response Freight Manual* (QRFM) (Report DOT-T-97-10) demonstrates this methodology, and many states use some form of this procedure. This is the same method usually employed in urban models and was the earliest method used in statewide models. It suffers from the lack of a behavioral reason for the trucks to be on the highway that could be exploited in making forecasts. Today, this method is mostly used by smaller eastern states for the same reason that some choose not to model freight at all.

To address the problems inherent in the traditional method, most states developing statewide models have moved to a commodity-based freight model. This methodology uses flows of commodities between various industries. This type of model can allow more basic changes in the economy to be reflected through a series of freight decision-making models resulting in flows of trucks, trains, and so forth. However, at this time, most of these models use static mode, payload, and value factors to translate commodities into transportation system flows. Most of the applications in this category do not actually contain a forecasting model. Instead, the base-year commodity flow matrix is simply factored by using a Fratar or similar technique based on socioeconomic growth. In a few cases, commodity generation and distribution models analogous to the four-step model are developed from the base-year commodity flow data and applied in the forecast year. The main problem facing more advanced methods is lack of data. There are two primary problems. First is the lack of geographic specificity in the commodity flow data. This problem means that such models must devise methods to disaggregate the flows to traffic analysis zone level so that they can be assigned to the network. This is usually accomplished by using employment factors by industry. The second problem is the limited commodity or industry coverage of the available data. Most models using a commodity flow representation have chosen to solve this in one of three ways: ignore the missing commercial vehicles, use matrix estimation techniques in conjunction with truck counts to synthesize them, or use traditional techniques such as QRFM to account for the missing movements.

The last method now being employed is to take the commodity-based approach one step further by adding an integrated land use–economic model to create the forecast commodity flows. Two implementations currently exist, one in Oregon and one in Ohio. Both approaches begin with macroeconomic land development and activity allocation models to derive the commodity flows between industries in a series of time steps into the future. In Ohio, the macroeconomic model uses an interregional social accounting matrix that is influenced by both national economic conditions from above and the composite production utilities in Ohio from below. The land development and activity allocation models use logit models to describe developer decisions and allocate activity on the basis of amounts of land and socioeconomic activity in a zone along with inertia terms representing its state in the previous time interval. Once commodity flows are obtained, the two implementations vary somewhat. In the Oregon model a more detailed representation of the multimodal intermodal system is sought as well as a more explicit treatment of the routing–mode choice–shipment size behavior. The Ohio model looks similar to other commodity flow representations from that point. However, the Ohio model goes a step further in its effort to represent other commercial vehicle flows not well represented in the national commodity flow databases. A disaggregate commercial vehicle model is added on the basis of establishment surveys conducted in Ohio and Canada. The model is analogous to activity/tour-based microsimulation models used in the urban passenger travel demand model field to model household travel. However, this model is work based and models the following trip purposes: goods delivery, service, meetings, and other. This model's goods delivery purpose is designed to pick up the short-distance freight movements not represented in the national commodity flow databases from the employee rather than the logistics perspective. This was accomplished by structuring the establishment survey appropriately.

While state departments of transportation have made much progress in leveraging existing data and techniques to develop new and better freight models, much more remains to be done. However, these efforts are largely hampered by the lack of data necessary to make the desired improvements.

Freight Demand Modeling: State of the Practice Within Federal Agencies

T. Randall Curlee

The state of practice in freight demand modeling within federal agencies is represented by two sets of models—the FAF built and maintained by the Federal Highway Administration and the Ohio River Navigation Investment Model (ORNIM) and the Navigation Economic Technologies (NETS) program supported by the U.S. Army Corps of Engineers.

These two modeling systems take different approaches to freight demand modeling to serve different needs at the federal level. Freight models provided by federal agencies serve numerous purposes. Base freight estimates and forecasts are used by state and metropolitan governments and private-sector firms and by decision makers at the federal level who make freight policy. Freight forecasts are key inputs to policy decisions about macroeconomic growth, land use, transport congestion, environmental externalities, national security, and so forth. They are equally important to federal decisions about investments in transport infrastructure.

The FAF consists of a set of models that are based primarily on survey data and statistical approaches to estimate freight flows at a significant level of detail. The 2002 FAF consists of the following:

1. Three four-dimensional matrices (for tons, ton-miles, and value) in which the four dimensions are origin, destination, commodity, and mode, referred to as the Freight Flow Database. Origins and destinations consist of 114 regions as defined and used in the 2002 Commodity Flow Survey (CFS) and 17 additional international gateways. Commodities are defined at the two-digit Standard Classification of Transported Goods level. Modes are defined as in the 2002 CFS—that is, 11 separate modes, multimodal combinations, and unknown modes. The 2002 CFS serves as the foundation of the Freight Flow Database. Unfortunately, the CFS has several major commodity gaps, referred to as out-of-scope commodities. In addition, the CFS is known to undercount some categories of trade and movements of freight—for example, imports, in-transit movements between Mexico and Canada, petroleum products, and movements from ports to auxiliary warehouses. These CFS out-of-scope commodities and undercounts are estimated on the basis of a variety of economic and statistical methods.
2. A Network Flow Database that assigns the freight flows developed in the Freight Flow Database at the level of detail as given in that database. This database requires assignment for all modes and for both interzonal and intrazonal movements. Total ton-miles are estimated in this step.
3. Forecasts of both freight flows and network flows in 5-year increments for the 2005 to 2035 time frame. Forecasts are at the geography, commodity, and mode levels as in the Freight Flow Database.
4. Annual provisional estimates for the Freight Flow Database for 2005. Annual provisional estimates will be provided for 2005 by tons and value. The Network Flow Database, which requires freight assignment, will not be updated annually.

The 2002 CFS serves as the starting point for four-dimensional freight flow matrices in FAF. The CFS has two problems: (*a*) some commodity flows covered by the survey are suppressed because of statistical reliability problems and (*b*) other flows such as imports are out of scope. Several studies were undertaken to estimate the amount of out-of-scope commodities, and the suppressed and out-of-scope flows were estimated by a combination of commodity-specific spatial interaction models, log-linear modeling, and iterative proportional fitting.

Models associated with ORNIM and NETS take a different approach to freight demand modeling. Whereas FAF is based on survey data and matrix filling, ORNIM and NETS are based on economic and engineering models. The purpose of ORNIM is to estimate the benefits of improvements to the navigation infrastructure of the Ohio River System—extended or new locks, channel improvements, replacement of key lock and dam components, alternative maintenance policies, and so forth—and to balance those benefits against the estimated costs of those improvements. By doing so, ORNIM can suggest the optimal set of infrastructure investments over time. ORNIM is dependent on base-case freight flows from external economic models.

ORNIM is composed of three modules—the Lock Risk Module (LRM), the Waterway Supply and Demand Module (WSDM), and the Optimal Investment Module (Optimization). LRM takes engineering inputs—for example, reliability estimates, component hazard functions, and repair protocols—to determine the probabilities of unplanned closures for each lock for each year. WSDM utilizes detailed information about the Ohio River network, towboat and barge operations, lock operations, and cargo forecasts to estimate the annual equilibrium traffic. Optimization, which can be budget constrained, identifies the optimal set of investment options (e.g., construction, rehabs, and maintenance) at each lock for a horizon that can be up to 70 years. ORNIM's major economic assumptions are embedded within WSDM.

NETS uses a hierarchical approach consisting of three tiers of modeling, one that moves from a broad regional and global geography in Tier 1 down to a detailed project and facility-specific level of detail in Tier 3. Tier 1 modeling is focused on econometric estimation and forecasting of future year commodity production, consumption, and broad transglobal trading patterns. The Global Grain Model is the first NETS product of this type. Tier 2 modeling disaggregates these forecasts to a point where they can be assigned as freight traffic to specific modes and routes within the U.S. transportation network. The NETS program is developing a regional routing model to disaggregate the Tier 1 forecast to route the traffic through specific freight corridors. Tier 3 uses these mode- and route-specific forecasts to optimize investments in navigable waterways and in operational and maintenance policies associated with structures such as locks and harbors. Tier 3 models include both microscopic models, which route individual vessels through a transportation network (HarborSym and NaSS), and an annual model, which uses annual averages (Survey Model). Both types estimate transportation cost for with- and without-project conditions. While ORNIM is not part of the NETS suite of tools, it is comparable with NETS Tier 3 models in that it takes a disaggregated forecast from an external source (equivalent to NETS Tier 2) and is used to evaluate specific management measures for their economic efficiency. More information on the NETS program is available at www.nets.iwr.usace.army.mil/.

Private Sector: Lessons for the Public Sector

Kevin Neels

Private-sector approaches to freight forecasting differ from those used in the public sector in a number of significant respects. Firms in the private sector are subject to different economic incentives and pressures. They operate within different decision horizons, and key decision makers are subject to different reward structures. These differences in the economic and institutional environment within which they operate determine the resources and mind-set that private-sector actors bring to the task of forecast development and shape the expectation with regard to what they hope to achieve.

The private sector is also highly diverse, making it difficult to generalize. Thus, when I describe how the private sector approaches the task of forecasting, my comments should be interpreted more as general tendencies rather than as hard-and-fast rules that are universally followed.

Private-sector firms that are known for doing good analytical work pay a lot of attention to data collection. Many of these firms make heavy investments in systems to capture transactional and operational data and make them available in a form suitable for easy analysis and manipulation. Firms that are good at this sort of work appear to operate on the basis of a belief that if you do not have a good picture of what is happening today, you do not stand a chance of being able to predict what is likely to happen tomorrow.

As a rule, private-sector firms also tend to rely heavily on qualitative market insights and intelligence provided by their sales and marketing staffs. The supplier–customer relationship thereby becomes a critically important source of information, providing real-time visibility into emerging market trends.

As the observations outlined above suggest, private firms as a rule tend to be more concerned with the freshness and accuracy of the data and information on which forecasts are based than with the techniques and methodologies used in their preparation. While technical training and methodological sophistication will often be recognized and rewarded in private-sector settings, they represent only one valued skill set among many, and not necessarily the most highly valued. In the end, what matters is being able to make the right decision.

Routine preparation of long-range forecasts is relatively rare among the private firms that I have worked with. Most harbor serious doubts as to whether accurate long-range forecasting is even possible and view claims by practitioners of such black arts with a good deal of skepticism. Private-sector forecasting methods tend to be "bottom-up," starting with known facts and identified trends and moving from these details to a more marketwide perspective. "Top-down" forecasts, if they are used at all, are used largely to provide a sanity check. In carrying out such sanity checks, private firms often turn to forecasts prepared by public agencies.

Private-sector forecasting efforts are generally oriented toward one of four decision contexts. Tactical forecasts focus on near-term developments and are intended to support operational decision making. Forecasts carried out as part of the annual planning cycle focus on revenues, costs, and investments over the year ahead. Significant investments will be subjected to careful review and economic analysis, and forecasts prepared as part of this process will play a key role in establishing the business case for the investment. Finally, periodic strategic planning efforts may trigger the preparation of special forecasts or market assessments. Such efforts will often be carried out with the help of consultants.

Public agencies can draw some important lessons from the approaches that private-sector firms have used.

First, public agencies will need to work to protect their informational supply lines. Efforts to ensure that forecasting efforts are always informed by extensive and up-to-date information on market trends are likely to yield significant benefits. Data collection has to be viewed as an ongoing responsibility rather than a one-time or episodic event. Agencies need to develop and have at hand forecasting processes to make use of the information that is routinely available.

Second, public agencies must continue to play an important role in providing the high-level market overview forecasts that many parties rely on. The public good nature of such work implies that we will never be able to rely entirely on private-sector efforts in this area.

Finally, and most important, private-sector experience emphasizes the crucial importance of focusing on the decision that the forecast is supposed to inform rather than on the forecast itself.

Keith Hofseth, U.S. Army Corps of Engineers, moderated this session.

Evaluation of Practice Today

Rick Donnelly, *PB Consult, Inc.*
Arnim H. Meyburg, *Cornell University*
Huiwei Shen, *Florida Department of Transportation*
Rob Leachman, *University of California, Berkeley*

The objective of this session was to transition from descriptions of current practice to evaluation of "the state of the practice." The panel was tasked to consider the assessment of methodologies and applications in practice today as referenced against needs and an evaluation of what drives forecasts, sensitivity, trade-offs, data needs, economic forecasting components, and cost-effectiveness.

Evaluation of Practice Today

Rick Donnelly

This is a look at the state of the practice in modeling freight activities. The context is established, and modeling criteria are then defined. Summaries of current modeling activities at the urban level and then at the regional and statewide levels are presented. A brief critique of the most common existing models and approaches concludes the discussion.

Context

On the basis of work done by Wigan and Southworth (*1*), the current state of the practice includes models that address the following aspects: traffic management studies; infrastructure investment; logistics/supply chain analyses; mode/carrier choice analyses; vehicle load factors, ton-miles, and so forth; light goods vehicle analyses; specific facility generation–attraction analyses; market share and competition; freight–automobile competition; and pricing and regulation.

The experience of the presenter focuses on modeling of freight activities, economic impacts, identification of bottlenecks, and analysis of truck–rail diversions.

Criteria

Several criteria for best practice freight modeling can be identified as follows:

- An explicit linkage to economic forecasts is important.
- The study area is best placed within a global trading context.
- Capturing important dynamics is necessary within the model.
- Models are more effective when they include multimodal options.
- Commodity flows are important.
- Commodity flows converted to modal vehicle flows are more important.
- A robust truck–rail diversion analysis capability is also useful.
- Sensitivity and the ability to evaluate policy options are key.
- Minimizing data requirements ensures continued use.
- Finally, if operational and proven to meet the needs of users, the model will support decision makers.

In addition, Mark Turnquist made several key observations in his presentation that relate to effective freight modeling and are worth repeating here. Models should produce output that someone wants and knows how to use. They should include important variables and interactions. They should be verifiable and understandable, and they should be based on data.

Summary of Current Models

Several types of models currently exist in practice. In general, they can be categorized at the urban scale and at the regional and statewide scale as summarized below.

Urban Scale

- Do nothing: Many urban areas simply do not include freight in their modeling work at all, owing to a lack of data, modeling capability, or agency interest in freight or its inclusion in the metropolitan planning process.
- Factor 1968 trip matrix: More than one metropolitan planning organization (MPO) has simply applied growth factors to an old truck trip matrix—whose progeny is often obscure or unknown.
- Simple matrix estimation: There are a variety of matrix estimation (ME) techniques in the literature and practice. The simplest uses a single seed ("best guess") matrix and truck counts to derive a likely truck trip matrix, which can then be assigned to alternative networks and growth-factored into the future. Such models replicate observed flows but have little explanatory power.
- Elegant matrix estimation: More sophisticated ME techniques have been applied in some areas, such as New York City. The work of List and Turnquist includes a more stable solution methodology, admits multiple sources of seed data (each of which can be weighted to reflect their quality and confidence), and permits simultaneous solution of multiple truck classes. While they are applied in the same way as a simple ME model, these more sophisticated models often perform better and allow the analyst to better understand the sensitivity of the model to the various inputs.
- *Quick Response Freight Manual* (QRFM) model: The QRFM provides an abundance of data about urban freight patterns, compiled from a variety of sources. While it does not specify a particular modeling approach, it provides enough data to build a traditional sequential demand model.
- QRFM plus matrix estimation: Several agencies use the trip rates and trip distribution parameters from the QRFM to develop a seed matrix, which is then fed into matrix estimation.
- Three-step model: Some urban areas have developed three-step (trip generation, trip distribution, and traffic assignment) models by using locally collected establishment and truck intercept surveys. They have an obvious advantage over the QRFM or direct demand models in that they better reflect local conditions, but they are much more costly to develop and maintain.
- Three-step plus port model: The presence of a marine port heavily influences urban freight patterns, especially with respect to peaking characteristics. Several urban areas, particularly on the West Coast, have developed separate models of trip generation and distribution for their ports. These models are typically used in conjunction with models that estimate local truck travel.
- Tour-based microsimulation: Even more so than is person travel, urban truck movements are a story about trip chaining and tours that involve distribution centers. Two such models have emerged in Calgary and Portland that try to capture the dynamics of truck tours. In both cases individual tours are built on the basis of survey data and assigned to the network by using customary techniques.

Regional and Statewide

- Do nothing: A fortunately shrinking number of states do not have the data, models, or mandate to include freight in their statewide planning process at all, or they use simple trend extrapolation of existing traffic counts.
- Polenske–Roberts (PR) variant: Researchers in the 1970s came up with ways to use input–output models with county business pattern data to allocate the Commodity Flow Survey (CFS) or TRANSEARCH data to traffic analysis zones below the county level. Variants of this approach are the most widely used method for forecasting freight flows at the statewide level.
- PR variant plus matrix estimation: Some states couple a variant of the PR approach with matrix estimation. This is mainly used for major intercity corridors, since comprehensive truck count data are still largely lacking in most states.
- Tour-based microsimulation: The tour-based microsimulation model used in Portland has been extended to cover the state of Oregon. It provides an explicit representation of transshipment and distribution centers, which are of particular concern there.
- Sample enumeration (SE): Another microsimulation technique, SE repeatedly samples from a large-scale survey to develop truck trip matrices for an entire metropolitan area or state. This obviously places a considerable emphasis on robust and extensive data collection. The Ontario Ministry of Transportation has achieved remarkable success with this technique.

Critique

Given the complexity of decision making today, existing models have many limitations. They are often used beyond their original design. Because we have a hierarchy of needs, we need a hierarchy of models. The traditional four-step sequential models are on shaky ground. Figure 1 shows a simple example of questionable results obtained when this approach is applied to a basic freight problem. The trip matrix on the left should look familiar to most planners and modelers. Let's say this represents hypothetical shippers and receivers in each of four cities. If this trip matrix is assigned to a network, separate trips will be made from A to B, C, and D. If the matrix is transposed as usual to obtain the flows in the reverse direction, we'll similarly obtain individual trips from B, C, and D back to A. The implied cost to the shipper (e.g., travel time or generalized cost) would be twice the sum of AB, AC, and AD. However, most shippers will form a single tour that originates at A and travels to each destination in succession, as shown in the figure. The resulting cost is about half the cost implied by the simple trip matrix solution and is closer to the reality of efficiencies sought by shippers and carriers. If the shippers at B, C, and D also used tours, it is clear that network flow patterns would result that are quite different from those obtained by simply assigning the trip matrix on the left to the network.

Gravity model distribution...

Destinations (columns) / *Origins* (rows)

		490	248	109	51
		A	B	C	D
291	A	0	203.5	61.8	25.7
253	B	230.2	0	17.5	5.3
90	C	68.8	1.2	0	20
264	D	191	43.3	29.7	0

...and its implications

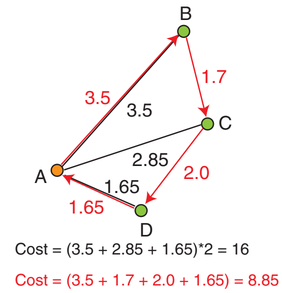

FIGURE 1 Example of questionable results from the use of a current model for freight modeling.

Figure 2 shows a comparison of the complexity of the freight movement compared with the modeling used for personal travel. As shown, the two are not the same, and many of our current methods of modeling them are not comparable. Many of the complexities and important dynamics of freight are missing.

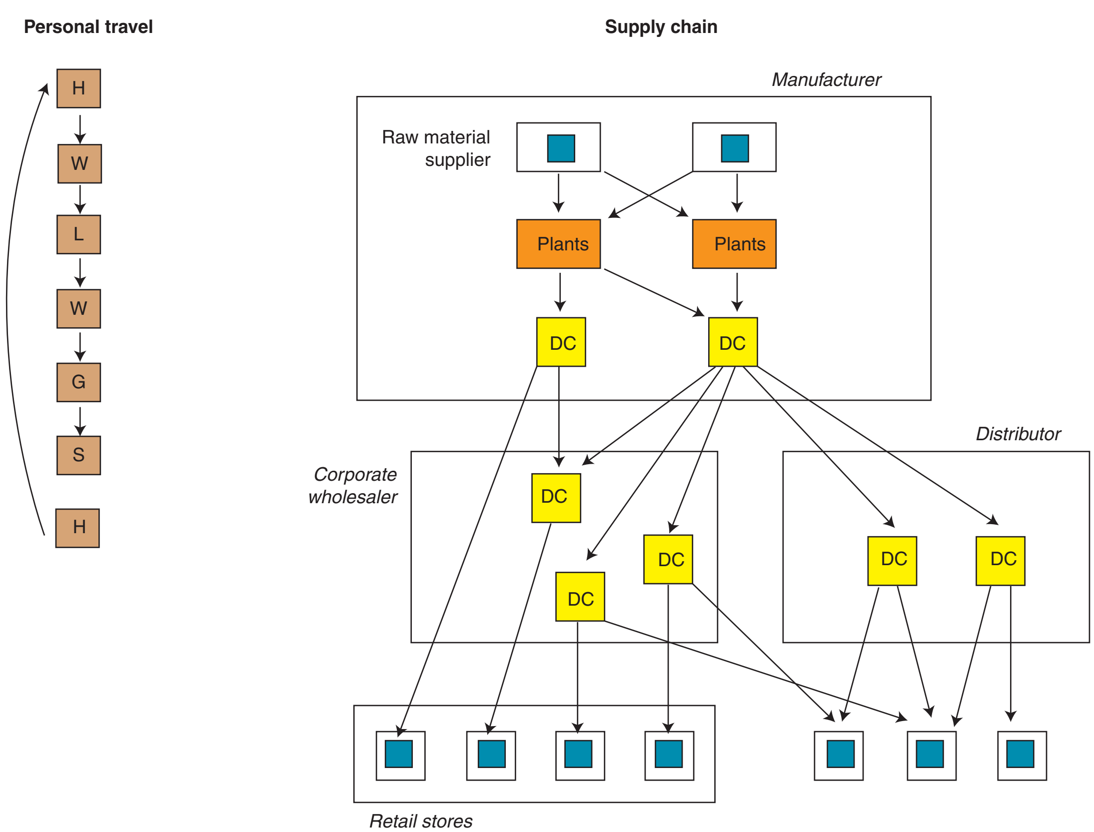

FIGURE 2 Comparison of personal travel with freight movement.

Current modeling provides only limited additional knowledge. The ideal model will provide theory → data → model → knowledge and be based on reality: traffic counts → flows → data. As things stand now, most models cannot respond to policy makers.

In conclusion, we have a long way to go.

Reference

1. Wigan, M. R., and F. Southworth. What's Wrong with Freight Models? Presented at European Transport Conference, Strasbourg, France, Oct. 2005.

Evaluation of Practice Today: Data Needs

Arnim H. Meyburg

Some of you exercised decision making under uncertainty this afternoon because there were four names listed under the program for this session and nothing listed with them, so you had no idea what we were going to talk about. Getting a bunch of modelers together was a questionable undertaking because they would probably focus on their favorite models and their favorite mathematics and not look left and right. So somebody was needed to remind them that models need to be fed.

It is also obvious at this point that this talk is redundant because the earlier presentations looked at the package—the input, the information, the data—that is fodder for the models. So, as has been elaborated, why are we building models? We are building models to inform decision making. This broader perspective has come out at this modeling conference. This has not always been the case at modeling conferences. Often, the mathematical niceties were the focal point. When we were working on the disaggregate behavior models of the 1970s we were just concerned with building models, with having an elegant structure, with having models that worked. We did not care about data. We would grab any data set that was available anywhere and twist it and turn it until it was sort of useful.

The issues in terms of information input to the modeling process derive from the need for information to describe a problem. Why are we collecting information? Why are we building models? We obviously want to answer some questions, we want to make forecasts, we want to solve a problem.

I can think of two basic categories of data. One category is collected to measure the phenomenon and see how things exist—in other words, the data for statistical analysis purposes. That is not the focus here. The focus here is the data for modeling. The first question to ask is why do the modeling, how does modeling inform the decision process. To do this, you need reliable models. To have reliable models, you need not only a good model but also reliable inputs.

The steps for proper model calibration are identification of the following:

- Problem,
- Scope and scale of the problem,
- Geographic scale,
- Analysis objective,
- Model structure, and
- Calibration data needs.

We know by now that there is no single one-size-fits-all data set. The variety of applications, contexts, scales, and models is mind-boggling. The variety of data needs and information requirements is significant. We have repeatedly talked about private- and public-sector modeling and, consequently, private- and public-sector data availability. The optimistic view is that a cooperative arrangement ultimately will come to fruition, where the abundant data sources that exist in the private sector will become available on a grand scale to public-sector decision making. This makes a lot of sense because, if the public invests in the infrastructure in an inferior way, then the private sector will suffer.

We have also heard the view that the private sector will do what it wants to do and the public sector will simply follow suit. There are two significantly different schools of thought. In one case the public sector creates the infrastructure to support economic development and investment, and in the other case the public sector responds to private freight actions and decision making.

One of the key points of TRB's *Special Report 276: A Concept for a National Freight Data Program* was that there must be a way to get private-sector data into the public arena. There must be intelligent people who can come up with safeguards so that the private sector does not feel that its proprietary data will be compromised or misused.

It is fair to say that the public-sector data at the national level are limited to the CFS and Rail Waybill Sample and their derivatives. These are suitable for gross analysis, but if you look at what they do not have or what you have to infer to fill the empty cells, and so forth, they are not designed for the purposes for which, in many cases, they are used. The excuse, of course, is that nothing better is available. But to use these data sets at even the statewide level, and certainly at the MPO level, is a questionable thing.

It is clear that our friends at the Bureau of Transportation Statistics and the Census Bureau are aware of the limitations of the CFS. They are aware that people use the data sets in contexts and applications and at a scale for which the data are inappropriate. They are intelligent and they know what an ideal CFS data set would be. But we also need some leadership to push for providing the resources to overcome the problems of the CFS so that it can become more useful for a greater variety of applications. It is important to agree on a data structure so that if a municipality or a state collects freight data, the data will be compatible with the CFS and can be integrated up and down according to certain rules and guidelines that have been developed and accepted. We need leadership to implement a CFS that allows this type of integration. *Special Report 276* provides suggestions as to how this could be done.

Evaluation of Practice Today: Florida's Statewide Model

Huiwei Shen

Florida has a statewide model that incorporates both a passenger model and a freight model, as shown in Figure 1.

The freight component uses the following techniques to estimate truck volumes:

- Freight trucks—commodity based
  - Tonnages associated with long-haul transportation
  - Commodity groups
  - Employment and population data
- Nonfreight trucks—vehicle based
  - Truck volumes in urban areas
  - Vehicle classes (light, medium, and heavy)
  - QRFM default parameters with adjustments

Freight tonnage is generated by using the TRANSEARCH database and regression equations by using population or Standard Industrial Classification employment categories, or both. Commodity tonnages are correlated with relevant employment categories. Fourteen commodity groups are used to categorize freight: agriculture; nonmetallic minerals; coal; food; nondurable manufactured goods; lumber; chemicals; paper; petroleum products; other durable manufactured goods; clay, concrete, and glass; waste; miscellaneous freight; and warehouse.

These commodity flows are distributed by using the standard gravity model with the impedance function

$$f = e^{-cV_{ij}}$$

where V_{ij} is impedance between origin (i) and destination (j) (distance or time) and c is a commodity-specific constant.

The next step is freight mode choice, which includes truck, intermodal rail, carload rail, air, and water. For trucks, tonnages are converted to number of trucks on the basis of the Vehicle Inventory and Use Survey. Special cases include

- Nonmetallic minerals and coal, carload rail only;
- Waste and warehouse, truck only; and
- Miscellaneous freight, intermodal rail only.

For nonfreight trucks, Florida follows the QRFM and uses employment and household information for trip generation. The standard gravity model is used for distribution with travel time as the impedance function.

The joint trip assignment is shown in Figure 2.

The focus of the Florida statewide model is on the Strategic Intermodal System (SIS), which consists of the statewide system of high-priority transportation hubs, corridors, and connectors. The statewide model provides for the development of an effective evaluation process for the SIS and each of its modal components (airports, highways, ports, and railroads). The SIS intermodal decision support activities include the use of an evaluation process that considers a combination of the SIS goals: safety and security, preservation of the environment, mobility, economy, and impact on the community.

Specific SIS freight analysis needs include the following:

- New and existing corridor origin–destination analysis,
- Alternative testing,
- Select link/select zone analysis for SIS terminals,

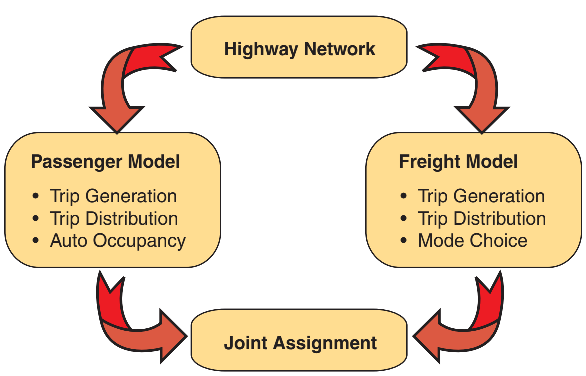

FIGURE 1 Florida's statewide model structure.

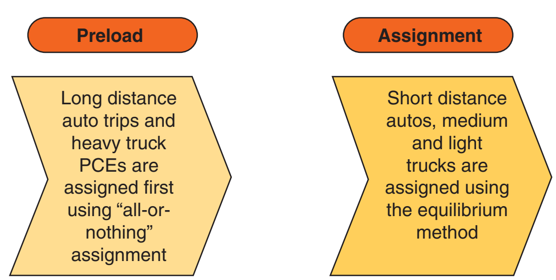

FIGURE 2 Joint trip assignment (PCE = passenger car equivalent).

- SIS highway performance analysis,
- SIS interchange analysis,
- Rail crossing prioritization, and
- Intermodal transfer analysis.

Planned future improvements of the freight model include development of a geographic information system–based multimodal network; development of base-year commodity flows for air, rail, and waterways; and the building of trip chaining for urban nonfreight truck movements.

Florida faces several challenges:

- International trade,
- Lack of disaggregated freight data for planning purposes,
- Intermodal transfer facilities and distribution centers,
- Freight mode choice and distribution, and
- Statewide focus.

Evaluation of Practice Today: Port and Modal Elasticity Study

Rob Leachman

The purpose of this study was to predict changes in flows of containerized Asia–U.S. imports in response to changes in transportation rates and fees and changes in ports or landside infrastructure. The study was also intended to support policy and investment analysis.

Methodology

The methodology consisted of analyzing total transportation and inventory costs borne by importers and retailers. The top 85 actual importers were considered, as were 15 generic proxy importers, which were used to represent low-volume importers. Import values were allocated to ports and inland supply channels so that total costs for each importer were minimized. The analysis was then rerun on the assumption that proposed fees and infrastructure were in place, and the changes in container flows were observed.

The following major assumptions went into the analysis:

- All Asian imports are consumed across 21 regions of the continental United States in proportion to the relative purchasing power in that region.
- All imports consumed in a region originate at a single port in Asia and are destined to a single prespecified distribution point serving the region.
- Each of 85 major importers and 15 generic proxy importers is assigned a uniform supply chain strategy for its portfolio of imported goods that optimizes its total supply chain costs assuming the average declared value is applied to its entire portfolio.
- A Pareto-like distribution of import volume versus declared value is posited on the basis of raw customs data as shown in Figure 1.

Required Data

The following data were used in the study:

- Port Import–Export Reporting Service (PIERS) total 20-foot equivalent units (TEUs), Asia to United States, by commodity code
- PIERS total TEUs, Asia to United States, by top 85 importers
- World Trade Atlas total declared value, Asia to United States, by commodity code

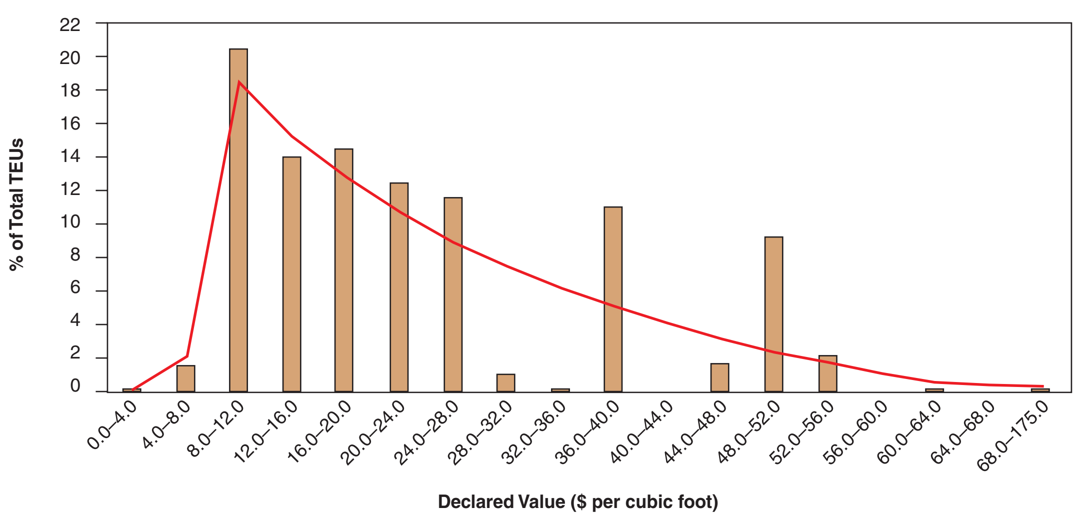

FIGURE 1 Distribution of import volume versus declared value.

- Pacific Maritime Association discharge mix of 20s, 40s, 45s
- Steamship, intermodal, truck, dray, and transloading rates by channel
  - Asia to ports to 21 selected U.S. distribution points
  - Average across baskets of quoted rates
- Statistics on mean and standard deviation of container flow times by port and landside channel, peak and off-peak

The following data were required for the short-run model:

- Ports—berths, container yard acreage;
- Intermodal terminals—working tracks, acreage;
- Rail lines—miles single, double, triple track;
- Available transloading warehouse space in port hinterlands;
- Number of draymen in port hinterlands; and
- Statistics on volume versus container dwell/flow time for ports, intermodal terminals, and channels.

Mathematical Formulas

Safety stock levels at regional distribution centers were considered to be a function of both mean and standard deviation of flow times and of consolidation–deconsolidation. Queuing formulas were developed to predict container flow time versus import volume by port and channel for the short-run model. We consider the general case to be that of multiple North American ports of entry and multiple regional distribution center (RDC) destinations. The various combinations have different shipment lead times. Moreover, the volumes at the various RDCs are not necessarily equal. The parameters are as follows:

n = index for RDC.
m = index for port of entry (POE).
D = nationwide average sales volume per week (in physical units, not dollars).
MAPE = mean absolute percentage error (expressed as a fraction of 1) in 1-week-ahead forecasts of nationwide sales.
D_n = amount of sales distributed from RDC n. It is assumed that $\sum_n D_n = D$ and that the proportion of nationwide sales handled by each RDC is fixed.
$D_{m,n}$ = amount of imports en route to RDC n that are passed through port m. It is assumed that $\sum_m D_{m,n} = D_n$.
R = time between replenishment orders (from Asian suppliers). R is assumed to be 1 week for all importers.
L_{AO} = mean lead time (expressed in weeks) from time order is placed until port of entry for shipment is selected.
$L_{AW}(m)$ = mean lead time (expressed in weeks) for a shipment from point of origin to port of entry m, measured from time the port of entry for shipment is selected until RDC is selected for land transport from POE m.
$L_W(m)$ = mean lead time (expressed in weeks) from departure from point of origin until RDC is selected for land transport from POE m.
$L_{NA}(m, n)$ = mean lead time (expressed in weeks) from time RDC n is selected for land transport from POE m until processed through the RDC n.
$\sigma_{L_{AW}}(m)$ = standard deviation of $L_{AW}(m)$.
$\sigma_{L_{NA}}(m,n)$ = standard deviation of $L_{NA}(m, n)$.
k = safety factor determining the level of safety stocks at RDCs. (Choosing $k = 2$ implies approximately a 98 percent probability of no stock-out.)

In the case of deconsolidation and transloading in the hinterlands of the ports of entry, the total nationwide safety stock is expressed as follows:

$$(k)\left\{L_{AO}(1.25)^2(\text{MAPE})^2 D^2 + \left(\sum_m \sqrt{\sum_n \left(\frac{D_{m,n}L_{AW}(m)}{D_n}\right)\left(\frac{D_n}{D}\right)(1.25)^2(\text{MAPE})^2 D^2}\right)^2 + \left(\sum_n \left(\frac{\sum_m D_{m,n}\sqrt{L_{NA}(m,n)+R}}{D_n}\right)\sqrt{\frac{D_n}{D}}(1.25)(\text{MAPE})D\right)^2 + \left(\sum_{m,n} D_{m,n}\sqrt{\frac{\sum_m D_{m,n}}{\sum_n D_{m,n}}\sigma^2_{L_{AW}}(m)+\sigma^2_{L_{NA}}(m,n)}\right)^2\right\}^{1/2}$$

Results to Date

Results from this study to date include predicted changes in San Pedro Bay volumes as a function of potential container fees and as a function of potential major infrastructure projects plus container fees. Detailed results in the *Final Report Port and Modal*

Elasticity Study, prepared for Southern California Association of Governments (SCAG), Sept. 8, 2005, are available to the public at www.scag.ca.gov/goodsmove/pdf/FinalElasticityReport0905rev1105.pdf. The following are among the key findings:

- Most efficient supply chain strategy for small or regional importers: Under $46 per cubic foot, direct-ship marine box via nearest port; at least $46 per cubic foot, direct-ship marine box to destinations via least costly West Coast port and landside mode combination available.
- Most efficient supply chain strategies for large importers with nationwide markets: Under $13 per cubic foot, direct-ship marine box via nearest port; $13 to $27 per cubic foot, transload at three or four ports located on both coasts; more than $27 per cubic foot, transload all imports in Southern California.
- For the model that was run with 2004 data, about 17 percent of total Asian imports are most efficiently handled by transloading to domestic vehicles after sorting at warehouses in the hinterlands of the ports of entry (sometimes with value-add or resale).

Figure 2 shows the predicted impact of consolidation.

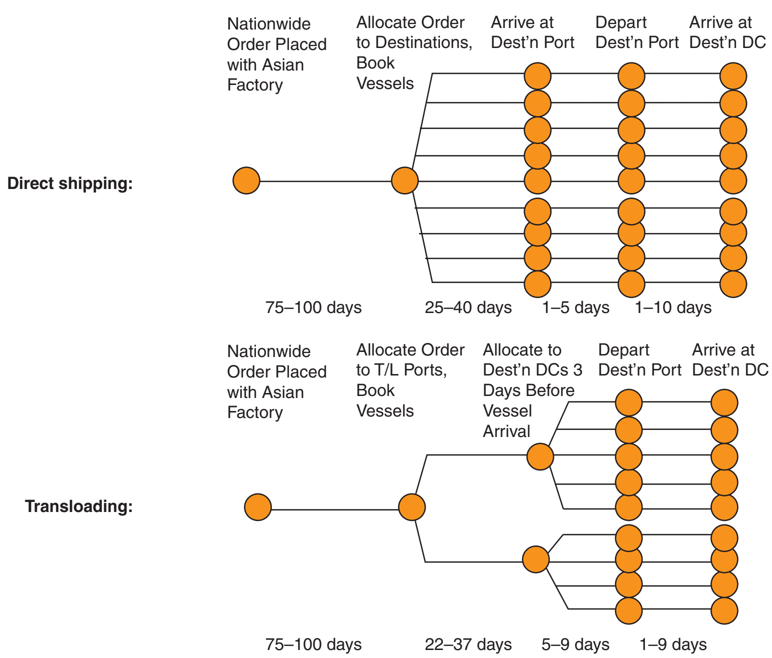

FIGURE 2 Impact of consolidation (T/L = transloading).

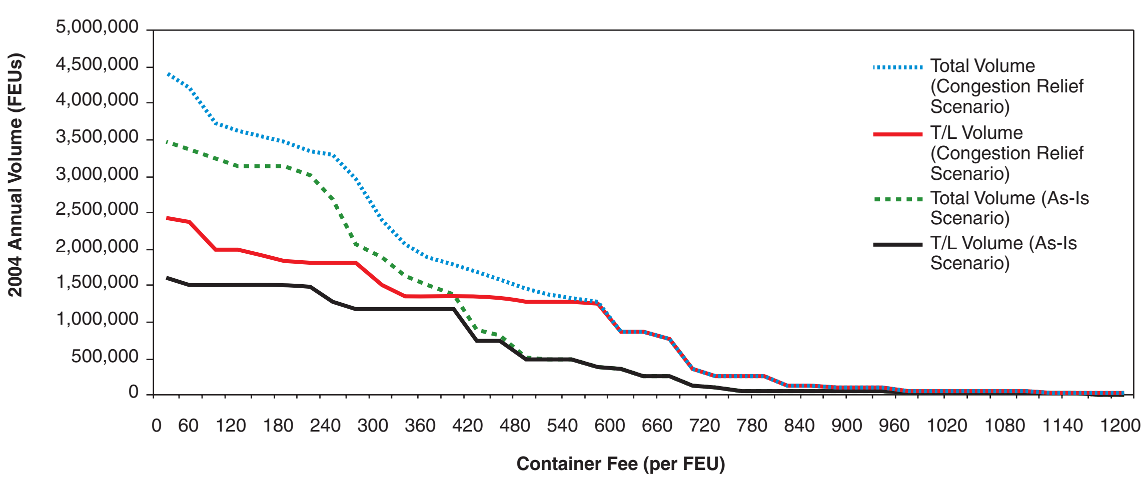

FIGURE 3 Results of SCAG scenario analyses (FEU = 40-foot equivalent unit).

Two scenarios were analyzed for SCAG in this study as outlined below. Figure 3 presents the results of the scenario analyses.

- As-is infrastructure scenario: Container fee on the dock ranging from $0 up
- Congestion relief scenario:
  - Container fee on the dock ranging from $0 up
  - Reduction in dwell/flow times from San Pedro Bay ports (Los Angeles and Long Beach) to transload warehouses (mean and s.d. down)
  - Reduction in variability of rail transit times from Los Angeles basin to all inland points (s.d. down)

In addition, the author has developed a formula for safety stock in the case of direct shipping of marine containers and a formula for pipeline inventory stock. All of these formulas are needed for a proper port and modal elasticity analysis.

Current Work Sponsored by SCAG

Current work for SCAG includes incorporating queuing formulas into the model to predict extensions in container flow times from increased volumes put on fixed infrastructure in the short-run model and updating the model with 2005 data.

This work was sponsored by SCAG.

C. Michael Walton, University of Texas at Austin, moderated this session.

Town Hall Discussion

Gaps and Shortcomings in Current Practice

John T. Gray, *Union Pacific Railroad Company*

Although this conference is focused primarily on public-sector decision making, private organizations also concentrate on the ability to model changes in public policy and related impacts on those organizations.

Recap of Town Hall Discussion

This section provides a summary of the Town Hall Discussion. On the basis of that discussion, the Freight Demand Model Matrix provided in the Appendix was expanded to include the following:

- The effectiveness of tax credits and pricing and the impact of pricing on demand,
- Understanding of the requirements for vehicle size and weight,
- The role of transportation system development versus facility development and understanding the issues and trade-offs between the two, and
- Identification of the responsibilities of various public players.

The following additional issues were raised:

- Understanding the decision-making process of shippers, how shippers behave, how those that are paying for freight behave versus carriers and providers of facilities;
- Connection of transportation to jobs, economic development, quality of life, environmental issues, safety, and security;
- Need for agility in the modeling process, ability to understand the transportation network on a tactical as well as a strategic basis for short- and long-term decision making;
- Ability to identify critical infrastructure and the effect of that infrastructure on nonfreight issues such as environment, security, and energy policy;
- The difference between modeling for planning purposes and modeling for influencing decision making (from the private perspective, the latter is the only reason for modeling);
- The ability of the users of the models to use them more effectively, better training for users, better understanding of the results of models;
- Standardized demand modeling, off-the-shelf modeling versus models structured to meet specific needs, standardized data collection versus data collection structured for specific uses; and
- Political versus economic geography (freight modeling tends to span political units much more frequently than does passenger modeling).

Finally, the following issues are worth emphasizing:

- Understanding what decisions modeling and the results of modeling are going to support. Will the modeling and the data in support of the model support the decisions that are being discussed?
- Understanding the geographic scope of the problem.
- The ability of the available data to support the quality and breadth of the modeling that we want to do

and, conversely, fitting the model to the level of available data.

- The need to model at as simple a level as possible to answer the question while avoiding the loss of necessary complexity.
- Use of private information for public decision making.

Private Information from the Perspective of Union Pacific Railroad

Most private data are collected or maintained only to the extent useful in supporting the transportation transaction (i.e., in pricing or marketing, operations management, or dealing with financial aspects of the transaction). No data are maintained simply for planning purposes. Data may be created for a once-only purpose, but they are not used on a day-to-day basis; they are not maintained.

Thus, when a vehicle comes into the system and is tendered to the carrier, information is obtained on that shipment about origin, destination, shipper, receiver, the type of vehicle it is being moved in, the type of container or trailer it is being moved in, the initials and number of the vehicle, the cost of the movement, the pricing of the movement, and how the revenue for that movement will be settled.

In addition, each carrier movement has an index number (for Union Pacific, the cycle sequence number) that follows it from the first loaded movement all the way through the system until the vehicle is loaded again or removed from the system. This allows the carrier to track the shipment through all the associated movements that take place and identify it with waybill numbers, freight bill numbers, vehicle numbers, pallet numbers, and so forth. This information is maintained under the old Standard Transportation Commodity Code system, not the newer codes that have been established. This is because of the legal document requirements that are recorded in the old codes.

Scale weight of the movement is not always available. The weight that is provided is generally an estimated value or a shipper-supplied value. This could be the maximum weight that the vehicle can carry. Rail carriers do not maintain miles that a shipment moves on the system. Tariff miles are an estimate of what the carrier assumes the shipment moves for revenue purposes. Actual route movement miles are not maintained.

The commodities within containers and trailers are not generally known. They frequently move as freight-all-kinds under third- or fourth-party arrangements. The party who knows what is in them is typically the intermodal marketing company or a broker. The exception is hazardous materials, which are required to be identified by whoever tenders the shipment.

The other information that is available for each movement is known as the "movement tracking data." Tracking data follow the locations through which the movement operated. On average, 30 location messages will apply to each shipment through the Union Pacific system. So effectively, with 9.5 million transactions per year, cars tendered, Union Pacific has close to 300 million locations attached to the shipment data. In short, we know the precise route through the network that a vehicle took.

Union Pacific performed a test by applying a shortest-path algorithm to a subset of the data. At best, this type of model was able to obtain a 60 percent match. Typically, the shortest path is not the cheapest path for a rail shipment. Even with more complete information about the network, only an 80 to 90 percent match between actual and modeled movements was obtained. Reasons for divergence from the shortest path include maintenance, congestion, unavailable resources, and terminal avoidance.

One other limitation is "churn." From year to year, transportation companies do not have the same business profile. An estimated minimum of 10 percent of the business changes every year. A receiver will receive goods from a different supplier. A supplier will have a different set of receivers. Suppliers and receivers will go out of business. They will change carriers. This affects the consistency of the data from year to year.

The following are conditions for release of some of this information:

- Information on shipper or receiver is never released.
- Cost and prices are never released.
- Crude estimates of gross revenue are available through the Carload Waybill Sample.
- Establish a relationship between requester and provider. The private entity has to be confident that the data will be used responsibly and appropriately.
- A strong confidentiality statement is required.
- The provider must receive a clearly defined benefit from sharing the data.

Private companies get several hundred requests each year for information from public agencies. Staff are not available to assemble and distribute data, and filling these requests is a cost to the company, not a revenue generator.

C. Michael Walton, University of Texas at Austin, moderated this session.

State of the Practice
Breakout Session

J. Douglas Hunt, *University of Calgary*

The objectives of this breakout session were to identify issues and potential changes to the state of the practice in freight modeling and to identify potential venues for needed research.

Information from the breakout groups could be generalized into four dimensions. The first was varying levels of geography, which we need to specify as we formulate the next discussion about where things need to go. The geographic levels are

- Urban and regional as a proxy, in general, for metropolitan planning organization and state (some metropolitan planning organizations are bigger than states, so it may be better to think in terms of urban and regional systems);
- National issues; and
- International issues (e.g., Pacific Rim).

The next dimension, or set of issues, concerned understanding of the system—the way the freight system works, what it is like in the real world, what is going on—and our use of this understanding to ensure the development of appropriate decision support tools. An understanding of the nature of modeling is also necessary. Several issues were identified concerning decision makers' lack of understanding of what modeling does, what the role of modeling is in decision making, what is possible, and what is not possible. Finally, issues were identified with regard to understanding the nature of modeling by those of us who are doing the modeling work. Other issues include the role of education of decision makers and modelers and identification of research concerning the nature of the system.

The third dimension is data, and the fourth is modeling techniques.

These are the four dimensions, which could provide a useful structure for the second set of breakout groups to use in organizing their discussions to help extract ideas from participants of this workshop.

Next, with regard to "understanding," think about some elements that would be in an action plan, what the steps would be for research and what the steps would be for education. With regard to data, we are looking for identification of the current situation and the problems with it. Give us your ideas without getting too specific about individual elements, but be specific about the steps that you would see as appropriate to address these problems. Consider the current situation with modeling techniques. The earlier sessions presented what is out there and what is available now, distinguishing the state of the practice from the state of the art and from what might be done in the future. We hope you will work through the matrix to identify some problems with the current situation and steps to address these problems. We are interested not only in what should be done but also in the sequence in which those things should be done.

Emerging Developments and Future Needs

Defining Future Needs

Frank Southworth, *Oak Ridge National Laboratory*
Michael D. Meyer, *Georgia Institute of Technology*
Michael Bronzini, *George Mason University*

The objective of this session was to identify current directions of freight modeling research, future demands on freight modeling, and available data sources.

Defining User Needs: Ongoing Research

Frank Southworth

A heightened interest in freight analysis has generated a number of new and improved directions for estimating the demand for goods movement. Today's state-of-the-art freight analysis models are moving away from the traditional four-step transportation planning model used by many metropolitan planning organizations and state departments of transportation. This presentation summarizes some of the advances and extensions of a demand modeling process that is starting to produce practical, quantitative solutions relating the determinants of freight demand to their physical expressions as traffic flows.

All of the efforts discussed have the following characteristics in common, in addition to their nationwide perspective:

- The need to represent freight activity as a set of place-to-place, notably annual, commodity-specific flow matrices;
- The need for collection and subsequent fusion of a variety of data sources;
- The need to model some noticeable gaps in the freight movement data before analysis; and
- The conversion of commodity flows, measured in either tons or dollars, into suitable mode- and vehicle- or vessel-specific freight movements in support of subsequent impact and infrastructure investment analyses.

National Freight Demand Models

Within the United States a number of regionally and federally sponsored freight movement studies are ongoing. The most ambitious of these studies, in their attention to spatial, modal, and commodity detail as well as geographic coverage, have been the U.S. Department of Transportation's Freight Analysis Framework and the U.S. Army Corps of Engineers' Navigation Economic Technologies program. Innovative national freight demand modeling based on interregional input–output analysis is also under way at the Economic Research Service within the U.S. Department of Agriculture. Collaboration between these various efforts is a promising avenue for future progress.

Freight demand modeling in other countries displays both similarities to and differences from U.S. approaches. Most demand models adopt one of the following approaches to estimation or forecasting:

- Time series–based forecasts, from simple trend analyses based on past freight activity levels or gross domestic product to more sophisticated moving average autoregressive models;
- Traffic zone–based trip rate models, often linked to mode, destination, and route choice within a freight

version of the traditional four-step transportation planning model; or

- National input–output based models linked to interregional spatial interaction models that translate dollar-based economic activity into tons shipped and sometimes into the number of vehicles or vessels used in these movements.

There is a growing emphasis on the evolution of comprehensive modeling systems that link demand forecasts to supply conditions. Of particular interest are hierarchical modeling systems that handle different types of policy and technical issues at different levels of spatial, temporal, and sectoral resolution.

Statewide and Regional Freight Demand Models

Five approaches stand out: modeling approaches based on the traditional four-step planning model; the modeling of freight demands via flexible microsimulation models; disaggregate freight choice models based on econometric analysis of data collected from stated or revealed preference shipper, carrier, or freight broker surveys; the incorporation of supply chain considerations in demand modeling; and the use of flexible combined choice frameworks, including "network-centric" models.

The traditional four-step approach has difficulty in capturing adequately the factors that influence shipper and carrier behavior. In particular, and in contrast to their treatment of physical processes, the modeling of the institutional and decision-making structures that generate these freight flows and costs has received comparatively limited attention to date. A significant improvement in some recent studies has been an increased emphasis on multimodal analysis, including the movement of goods through intermodal cooperation. Hybrid models that combine more than one, and possibly all, of the above approaches are seen as a valuable way forward.

Metropolitan Freight Demand Models

A number of new directions can be identified in recent modeling efforts: the addition of service trips as "freight," the (as yet limited) inclusion of multistop vehicle pickup and delivery logistics, passenger–freight interaction, freight-inclusive land use planning, the modeling of seaport- and airport-based freight complexes and truckload consolidation terminals, and the modeling of truck drays as part of intermodal shipments—especially consolidation of big box companies' high-value containerized freight (a rapid growth sector).

Generic R&D Needs

The following are among R&D needs:

- Models of the behavior of freight agents
- Understanding of the implications of the supply chain for flow volumes and mode selection
- Models of new technology impacts on flows and modes
- Data, data, data (especially on truck activity)
  - Making use of IT data
  - Innovative and targeted survey instruments
  - Better use of existing survey data (e.g., CFS microdata records)
  - Data fusion techniques

Future Modeling Needs

Michael D. Meyer

This is about the future of the decision context of freight modeling, how it will be used, and some of the issues that decision makers in the public sector will be asking about with regard to information from freight modeling. What are the freight-related decisions that public agencies will likely face in the future? How do we produce output that somebody really wants? The focus, in terms of the importance of decisions and looking at models as a decision support system, is a good one.

Much of the discussion focuses on the left-hand side of Figure 1 in terms of freight modeling. What factors influence shipping decisions, market share, technologies, costs, public policy? What factors influence public decisions in determination of what we mean by public good, externalities, economic health (jobs), politics? Of course, those of you who have worked in the public sector know that there are many other factors that influence decisions. This will focus on the right-hand side of Figure 1 because that is what the purpose of this conference is.

The decision-making context will likely change and, in fact, is already changing.

The Meyer framework consists of many contexts in terms of future decisions, including the following:

- Global;
- Multinational, which is different from global (e.g., the North American Free Trade Agreement);
- National and federal;
- Megaregions (multistate, market-oriented trade corridors);
- State;
- Metropolitan; and
- Local.

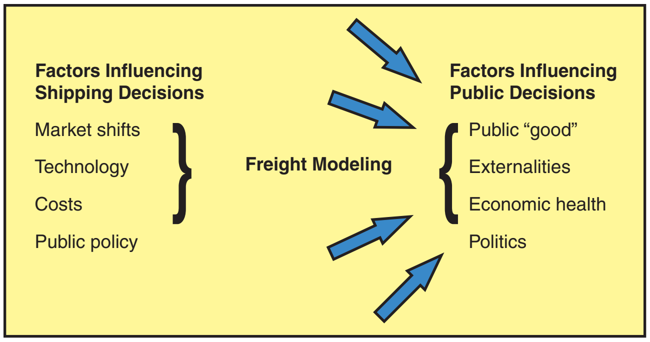

FIGURE 1 Factors influencing decisions.

The middle aspect is the most interesting with the emergence of megaregions in the planning community, which is a revamping of what was done several years ago. Megaregions can be defined as multistate, urban-oriented corridors that are, by themselves, economic units having interdependencies with regard to economic activities and are also market-oriented trade corridors lacking their own jurisdictional boundaries (there is a disconnect between jurisdictional responsibilities and market activity). Recognizing these corridors will be key in the future, with respect both to modeling and to how we make decisions in that particular context.

National

Many activities in this country point to what some of these issues may be. The TRB Freight Transportation Industry Roundtable, which was requested by the U.S. Department of Transportation (USDOT), conducted an extensive dialogue with USDOT about possible elements of a national freight policy. USDOT then developed a draft national freight policy framework with seven objectives. They are listed to illustrate what is being requested from the modeling perspective.

Objective 1. Improve operations of the existing freight transportation system.

Objective 2. Add physical capacity to the freight transportation system in places where investment makes economic sense. Expand capacity if necessary.

Objective 3. Use pricing to better align freight system costs and benefits and encourage the deployment of new technologies. Determine how pricing and pricing strategies can influence private-sector decisions.

Objective 4. Reduce or remove statutory, regulatory, and institutional barriers to improve freight transportation performance.

Objective 5. Proactively identify and address emerging transportation needs. This is the analysis issue.

Objective 6. Maximize the safety and security of the freight transportation system.

Objective 7. Mitigate and better manage the environmental, health, and community impacts of freight transportation.

These issues relate to providing information to people who have to make decisions at all levels of government and to what they will be interested in. It is not just about adding physical capacity to the transportation system.

State

Several state departments of transportation have incorporated freight into their state plans. For example, plan goals from New Jersey include the following:

- Examine key freight and logistics issues from a systems perspective: assess issues, constraints, and opportunities.
- Increase the understanding of goods movement in New Jersey and the supporting infrastructure: tell the "freight story" clearly.
- Recommend policies, strategies, and actions.
- Provide data, analysis, and insight to assist decision makers—not just for transportation but also for land use, economic development, employment, and so forth.
- Improve coordination between public and private entities and build a strong foundation for future collaboration and implementation.

We are going to see more such plans around the country. New Jersey also has a Logistics Council, consisting of both private and public agencies, that has identified issues believed to be important:

- Advance the attractiveness of the state's brownfields for redevelopment and selected greenfields for development of logistics-related uses.
- Optimize use of all modes for freight and goods movement.
- Examine the effects of proposed amendments to truck weight restriction standards.
- Increase the number and strategic locations of truck service facilities and rest stops.
- Examine toll agency pricing structures and make recommendations to increase usage of appropriate Interstate routes, and remain fair to the trucking industry.
- Reduce redundant roadside inspections without compromising safety, security, or pollution control.
- Advance extended hours of operation (off peak).

These are specific types of questions on which information is desired.

Metropolitan

Figure 2 shows Atlanta, Georgia, in 2030. The amount of Level of Service E and F is of concern. Much of it is an artifact of the way our highway system has been defined. One study looked at truck-only lanes in the Atlanta metropolitan area to determine whether they would expedite the movement of trucks. What is happening in Atlanta is symptomatic of what is happening or will happen in other metropolitan areas.

The following are among the issues being considered:

- How do we better manage our transportation system, primarily our highway system?
- How can we use pricing, and dynamic pricing in particular (i.e., how could pricing change over a short period to affect a level of congestion on a particular facility)?
- How will we do public–private financing, in terms of what brings the private (financial) sector to the table?
- What is the importance of the relationship to freight and logistics with regard to economic development, the environment, public health, and quality of life (land use and jobs)?
- How can we remove bottlenecks in terms of congested locations on the highway system?
- How can we jointly use limited rights-of-way?
- How do we allocate costs equitably?
- How do we invest in system technologies on the public side that could be used by the private sector in terms of efficiently moving trucks through the system?
- How do we address separate rights-of-way and lanes?
- How do we address all modes: truck, rail, air cargo, and inland water and short sea shipping?

Rolf Schmitt has a matrix. Meyer also has a matrix, a simpler matrix, which is shown in Table 1. Another column could be added to the matrix to display the type of research necessary.

Under the national/federal level, types of decision support include policy analysis, regulatory assessment, program effectiveness, financial impacts, and investment analysis for certain types of infrastructure for which the federal government is responsible such as inland waterways.

At the metropolitan and local level, the type of decision support structure is much different: multimodal system planning, policy analysis, program effectiveness, project planning, investment analysis, and financial analysis. Different roles are required of models and information systems across the different levels of the decision framework. Table 1 shows an example of the matrix at the metropolitan level. These issues lead to research needs. How do we obtain the characteristics identified in the last column?

To close, if we accept the hierarchy described in the Meyer framework, how do we provide consistency among the levels? We have talked about data, and we have talked about models. How do we make sure that what is happening at the national level is consistent with what is happening at the state and metropolitan levels? Finally, we will continue to face, in the public sector, issues of disruption to our transportation system, whether natural or unnatural, and we will have to face serious questions about what happens where we do not have redundancy in the system. One of our challenges in the transportation modeling community is to address how to provide service through a disrupted system.

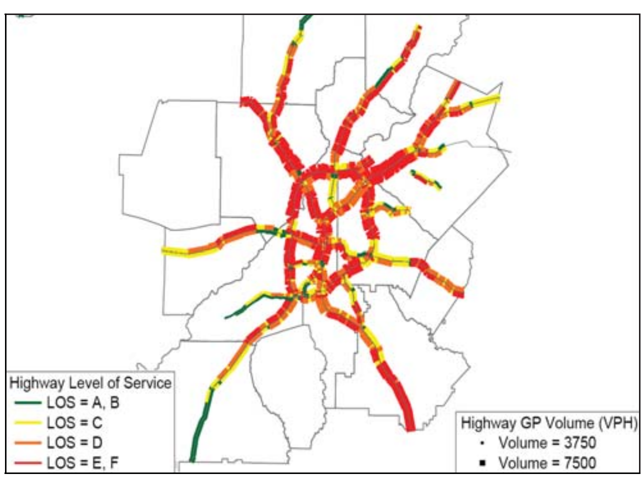

FIGURE 2 Forecast p.m. peak-hour performance, Atlanta's freeway network, 2030 (GP = general purpose).

TABLE 1 Partial Example of the Meyer Matrix

Context	Type of Decision Support	Decision-Making Issues	Desired Analysis Characteristics
National/Federal	Policy analysis Regulatory assessment Program effectiveness Financial impacts Investment analysis (for some types of infrastructure)		
State			
Metropolitan	Multimodal system planning Policy analysis Program effectiveness Project planning Investment analysis Financial analysis	Investments for economic development gain Bottlenecks in the road network Possible modal substitution (and incentives to promote) Joint use of rights-of-way Effect of dynamic pricing on dedicated and separate rights-of-way Potential revenue generation for tolled facilities (investment grade forecasts) Effect of information systems and network systems technology on route choice (assuming there is a choice) Freight land uses Environmental impacts of freight flows	Behavioral response to "real-time" changes in costs Behavioral response to better information on system performance (technology) Better handling of through versus consumer market trips (future) Uncertainty and risk included more substantively into analysis tools Much finer-tuned analysis (spatially and flows) More robust in face of changing market dynamics Linked to "public good" issues

New Data Sources

Michael Bronzini

New sources of freight data must be considered in the context of what is already known. The existing data, mostly from agencies of the federal government, cover freight flows, freight networks, and freight vehicles, for all modes. New data collection technology could be used to enhance some of the traditional data sources, to the point where new approaches to analyzing freight flows may be possible. Some of these technologies include intelligent transportation systems (ITS), especially the archived data user service supported in the national architecture, electronic preclearance systems, X-ray and other sensing methods for inspecting the content of cargo vehicles and containers, and remote sensing.

Much of the interest today is focused on vehicle, container, and cargo tracking through the use of technologies such as radio frequency identification and geospatial positioning systems. A range of companies in the transportation and commercial sectors are implementing such cargo-tracking systems. Some of them in the transportation sector are USPS, UPS, Federal Express, DHL, Ground Express, Union Pacific, J. B. Hunt, SSA Marine, and various trucking companies. Some in the commercial sector are Wal-Mart, Best Buy, Circuit City, CVS, General Motors, Mercedes-Benz, Ford, and Toyota.

There are also government-sponsored initiatives, including the Freight Information Highway Project in USDOT and the proposed Domestic Intermodal Information System in the Department of Homeland Security. Similar activities can be found in other countries, such as the United Kingdom and France.

All of these systems, including the governmental efforts, are being developed to enhance supply chain visibility and efficiency. They are not being designed to yield new data. The private firms, of course, have confidentiality concerns for their proprietary data and have little or no interest in making the data available to the government. Even governmental sources are aimed at operational and security needs. In this respect the freight system is not unlike the situation with regard to ITS applications in urban areas There, also, data are collected for operations and have seen limited use for other purposes.

Can this situation be changed so that freight planners may access data to support public-sector decision making? The answer is not clear, since there have been no known breakthroughs to date. One possibility is to develop public–private partnerships for this purpose. The challenge is in finding benefits for the participating firms so that the data-sharing enterprise can be a win–win situation. Perhaps a way to get started is to develop demonstration project agreements with one or more large firms. Another idea is to find ways to tap into the wealth of data being accumulated for security purposes.

Whatever is done to gain access to new data, it must be recognized that the resultant data set will be incomplete in its coverage of the freight shipping universe. This will require innovative analysis methods to blend the old and new data types.

Bruce Lambert, U.S. Army Corps of Engineers, moderated this session.

Freight Modeling

An Overview of International Experiences

Lorant Tavasszy, *TNO Inro, Netherlands*

Compared with passenger transportation modeling, freight modeling is young, and it is developing quickly in different directions all over the world. The objective of this paper is to summarize the international state of the art in freight modeling, with a focus on developments in Europe. Key issues in freight policy that create a growing demand for freight demand modeling are described briefly. Some of them are common to the freight agendas in many places of the world, and some are more pertinent to the European situation. A conceptual framework of the freight system is sketched first. Three emerging areas of innovation in freight modeling that have been driven by the European transport policy context and are relevant for U.S. freight policy are identified: freight–economy linkages, logistics behavioral modeling, and freight trips and networks. The state of the art in these areas is described, and areas of further modeling work are identified. Finally, the main ideas of the paper are summarized, including the challenge of creating new data sources concerning freight flows.

Compared with passenger transportation modeling, freight modeling is young, and it is developing quickly in different directions all over the world. Since the direction of development has depended on local priorities in freight policy, it is not surprising that freight model development has traveled a slightly different path in Europe from the one traveled in the United States. The objective of this paper is to summarize the international state of the art in freight modeling, with a focus on Europe. Three areas of innovation in freight modeling that have typically been driven from a European context but are relevant for U.S. freight policy are discussed:

- Freight–economy linkages,
- Logistics behavior, and
- Freight trips and networks.

There are numerous reviews of freight transport models in the transport modeling literature. They are not repeated here; most can be found through the Freight Model Improvement Program website. In addition, a complete set of references to all available European Union (EU) work on freight modeling is not provided. The account is limited to a selection of key papers in the literature. Recent freight model literature reviews that include European experiences within an international context can be found elsewhere (*1–4*).

Freight Policy Issues and Modeling Needs

Before the main lines of model development in Europe are described, the key issues in freight policy that have created the demand for freight demand modeling in the first place are discussed briefly. Some of them are common to the freight agendas in many places of the world, and some are more pertinent to the European situation.

The peer review of this paper was conducted by the Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making.

Table 1 indicates that freight modeling within Europe requires (*a*) more detail (vehicle types, logistics, spatial characteristics) and (*b*) an extension of dimensions of freight modeling into the broader transport system (geographically as well as functionally, i.e., linking transport and the economy).

Clearly, the existence of the EU Common Transport Policy has fostered the development of all kinds of EU-level international models where the attempt has been made to satisfy as many of the above requirements for improvement as possible. In particular, the creation of continental models—where domestic freight and global freight are intertwined, all modes of transport are relevant, and borders play a crucial role—has been typical. Priorities of the individual countries have often developed in parallel with EU policy and EU-level research. The remainder of the paper will focus on the main development lines that have emerged from this national- and EU-level research.

Emerging Lines of Model Development

A conceptual framework based on firm decisions relevant to transportation demand is proposed. This frame resembles the four-step modeling approach but allows (*a*) decision problems that firms face related to freight movements to be taken into account and (*b*) extensions to include operations that are typically less relevant to passenger transport, such as storage (see Figure 1).

Since the advent of transport modeling, freight modeling has gone through a number of major development stages. Knowledge in each of these layers has built up individually, and they have slowly become connected to one another.

The first major national attempt in Europe to describe freight transport flows was in the early 1970s (*5*). These models focused on the layer of trade and used gravity modeling as a main tool. A new impetus to freight modeling was given by the use of input/output (I/O) and land use–transport interaction models, since these explained the interaction between trade, transport, and the economy (*6*). As behavioral modeling took up for passenger transport in the 1970s, the first mode choice models became available for freight as well.

The 1980s were characterized by an increased interest in network modeling and extended network models or hypernetwork models, explaining simultaneously trip generation, trade, modal split, and route choice (*7*).

TABLE 1 Key Policy Issues and Associated Modeling Needs

Policy Issues	Modeling Needs
Growth of freight: A doubling of freight flows by 2050 is expected worldwide. Within Europe, international flows are growing at twice the rate of domestic flows.	Forecasting international freight growth. Decoupling freight/economy. Sensitivity to cost changes.
Growing freight shares on the roads: As passenger traffic growth is slowing down and freight is moved by more and smaller trucks, freight is becoming more dominant on the streets.	Truck traffic behavior. Influence of freight intensities on car drivers.
Creation of seamless multimodal networks, new focus on motorways of the sea and inland waterways.	Linking sea and land transport models, EU multimodal networks.
Concerns about international competitiveness of the EU economy, two-way relation between worldwide networks and global trade. "Freight and the economy" discussion: What are costs and (mainly indirect) benefits of freight investments?	Develop suitable worldwide models and continental models. Improve relationship between SCGE and network models.
Pricing: Charging all modes of transport what they can bear (or what is fair, given external costs unaccounted for) is becoming reality. EU and member states have different attitudes and strategies toward pricing.	Situational response to cost changes (truck type, road type, time of day).
Logistic performance: The freight logistics sector is customizing its products and is creating complex, flexible networks by using advanced logistics concepts such as hybrid supply chains, collaborative networks, e-logistics (both business-to-consumer and business-to-business), and return logistics.	Differentiating between goods with different logistics backgrounds; making detailed statistics available.
Changes in vehicle types HGV/LGV: Light vehicle growth figures surpass other categories and appear to be more difficult to capture (in terms of both measurement and public policy).	Forecasting (causes and impacts of) choice of vehicle type.
Local environmental damage: New regulations on noise and emissions require more accurate prediction of freight impacts. New technology requires investments. Citizen involvement is required in freight planning.	Accuracy of forecasts and level of detail (type of traffic, spatial, temporal).
24-hour economy: To deal with congestion, firms are spreading production and logistics over day and night.	Explaining sprawl of flows to different periods of the day.
Security and safety: Traffic must be monitored for degree of risk depending on contents or origin of freight.	Modeling critical global movements: containers, oil, dangerous goods, food.
City distribution: As more stern policies are developed for city access and activities, freight requires new delivery concepts.	Forecasting of tours at urban level, time-of-day dependent.

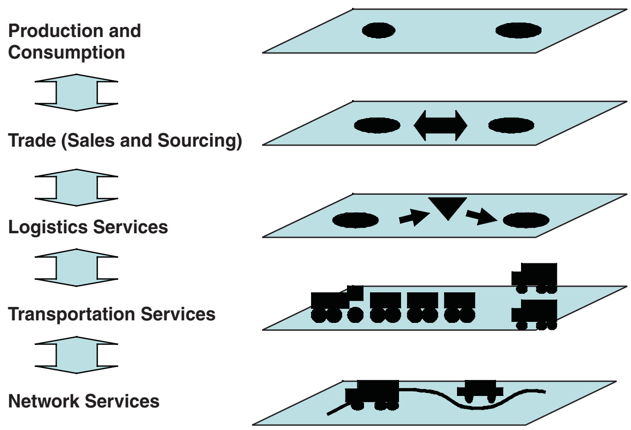

FIGURE 1 Conceptual framework of the freight transport system.

In the 1990s these models were extended by using a multicommodity context (*8*), improved probabilistic choice models, and inventory considerations (*9*). In the past decade freight network simulation has emerged (*10*, *11*). These models have taken up microsimulation and network modeling as approaches to describe the behavior of various agents in the system. Their advantage is that they can describe actors in detail, while their main challenge is their calibration and validation. A closely related new breed of freight models aims to describe agent behavior by including game theoretic considerations (*12*). These models focus on freight exchange markets and serve decision makers in both the private and the public world.

Table 2 summarizes these developments from the viewpoint of the system framework. The general trends are (*a*) increasingly integrative treatment of various decisions that firms make, or layers in the conceptual model, and (*b*) increasing detail of the behavioral content of models, down to the level of simulation in responses of individual firms.

The main developments in freight system models to be discussed in the next section are those indicated by the shaded cells in Table 2 and concern the following categories:

- Improving the representation of freight–economy forward linkages: In freight benefit–cost studies, an important impact to consider is the productivity growth associated with improvements in accessibility. These forward linkages within the economy require models treating the function of transportation in product markets. To this end, spatial economic models are being developed that integrate the first two levels of the framework, trade and production/consumption. The latest addition to this set of models is the spatial computable general equilibrium (SCGE) models, described below.
- Logistics behavior: Freight logistics models aim to describe explicitly the trade-offs between transport and inventory holding. They build a link between origin–destination (O-D) tables for production and consumption locations and O-D tables where warehouse locations are included. This is relevant since it determines (*a*) the spatial patterns for goods flows, changing the usage of infrastructure; (*b*) the costs of freight movements; and (*c*) the (local and global) economic impact of freight policies.

TABLE 2 Summary of Modeling Challenges and Techniques

<table>
<tr><th>Decision Problem</th><th>Typical Modeling Challenges</th><th colspan="3">Typical Techniques Employed</th></tr>
<tr><td rowspan="2">Production and consumption</td><td>Trip generation and facility location</td><td rowspan="3">LUTI (1970s) and SCGE (1990s) models</td><td colspan="2">Trip generation models, I/O (1970s)</td></tr>
<tr><td>Freight–economy linkage
Consumption patterns</td><td rowspan="2">Gravity models, synthetic O-D models (1970s)</td><td rowspan="5">Agent-based simulation models (1990s)</td></tr>
<tr><td>Trade</td><td>International trade
Value to volume conversion</td></tr>
<tr><td>Logistics services</td><td>Inventory location
Supply chain management considerations</td><td colspan="2">Logistics choice models (1990s)</td></tr>
<tr><td>Transportation services</td><td>Choice of mode
Intermodal transport
Light goods vehicles</td><td>Simple trip conversion factors (1970s), discrete choice (1990s)</td><td rowspan="2">Multimodal networks (1980s)</td></tr>
<tr><td>Network and routing</td><td>Routing and congestion
Tour planning
City access</td><td>Network assignment (1980s), simulation (1990s)</td></tr>
</table>

NOTE: LUTI = land use–transport interaction; SCGE = spatial computable general equilibrium.

- Freight trips and networks: In Europe research has been done in the past decade on multimodal network assignment for freight. These models operate at the EU and national levels and have various degrees of refinement, up to stochastic and multiuser-class models. At a more detailed level, however, the data challenge becomes daunting. Models that describe the choice of vehicle type at the scale of a city or region are virtually nonexistent. The main empirical challenges lie in disentangling light goods vehicles from heavier ones and service-sector from freight-only movements.

International Experiences in Three Areas of Innovation

In this section a brief account of the main research in modeling that has occurred in recent years in the areas mentioned above is given. The difficulties in the adoption of these innovations by their users and the challenges for further model development and implementation are described.

Freight–Economy Linkages

SCGE modeling has provided a new tool to model, in a consistent fashion, the first two layers of the system shown in Figure 1. From an economywide perspective, SCGE modeling is a commonly used tool. This model is based on a microeconomic general equilibrium framework that allows for substitution possibilities at the supply side (production) as well as the demand side (consumption) of the economy, via an endogenous price system. It takes account of intersectoral and interregional relationships in an economy and is hence a suitable tool for obtaining insight into economywide direct and indirect consequences of transport policies.

In Europe, the first example of such an SCGE model was the computable general equilibrium Europe model (CGEurope) model developed by Bröcker. He developed this model for 1,300 regions covering the entire European space (*13*). The main purpose of Bröcker's SCGE model is to quantify regional welfare effects of transport-related and financial–economic policies, such as the Trans-European Networks investments and transport pricing.

In the United Kingdom, as well as in the Netherlands, national economic research institutes have worked together in a research program on the economic effects of infrastructure, under the authority of the national government. On the basis of the findings and the work of Venables and Gasiorek (*14*), the Dutch SCGE model RAEM has been constructed and applied (*15*). Furthermore, European SCGE models have been developed in Denmark (the BROBISSE model) (*16*), Sweden (*17–19*), Norway (the PINGO model) (*20*), and Italy (*21*). Recently a Swedish initiative was launched to investigate the possibility of introducing SCGE modeling as part of the national freight model (*22*).

Outside Europe, SCGE models have recently been developed in the United States [e.g., by Löfgren and Robinson (*23*)], where relevant research has also been performed by Lakshmanan and Anderson (*24*). This work described conceptual and mathematical models that identify long-term efficiency effects of improvements in freight and passenger transport infrastructure. In Japan, SCGE models have been used (*25*, *26*) to analyze the potential impact on the Japanese economy of a major earthquake that damaged the high-speed rail network to Tokyo. Miyagi (*27*) has used an SCGE model to appraise the indirect economic impacts of a large expressway project.

A logical step in model development would be to connect such a model to a model of the rest of the freight transport system, replacing conventional I/O and gravity-type approaches. This step involves fitting the two parts of the system together in terms of representation of the transport sector, units of measurement, time scales, study area, spatial resolution, utility formulations, functional forms, and so forth. Examples of consistency issues that arise when SCGE and transport network models are linked are given by Tavasszy et al. (*28*). Clearly, the benefit of such an integrated treatment is the theoretical consistency gained within the freight modeling environment. A second, though related, benefit is an improved ability to assess indirect welfare effects of freight transport policy. Especially if logistics models are used, the economic impacts of changes in the logistics organization of shippers and carriers that occur as a response to changes in transport costs can be quantified. These effects are relevant in cost–benefit analysis of transport infrastructure improvements (*24*).

Since this is a relatively recent development, only a few applications have been made for transport policy purposes. The Dutch SCGE model was applied to several benefit–cost studies related to long-term port and rail development (*15*). The CGEurope model was used to advise the European Commission during the interim assessment of the EU white paper on the common transport policy. It provided new forecasts of sectoral and regional development in the scenario of decelerated development of the Trans-European Network. Despite the claim that these models are data hungry and tedious to calibrate, the fact that many countries have started to investigate these models is a promising sign. The first challenge to solve, however, relates to the preparation of national statistics (a detailed social accounting matrix or multiregional I/O would be sound) on which to base these models.

Logistics Behavior

The introduction of elements of logistics decision making in freight models took off in the early 1990s in the Netherlands. It has taken about a decade for these or similar approaches to become adopted elsewhere. Currently there are at least five logistics-based freight models under development in the world, four of which are in Europe. The most recent one is from the United States; in 2005, a proposal for the Los Angeles County freight model was presented (*29*).

The earliest reference to logistics models was made by Bergman (*30*), who proposed a more detailed spatial representation of logistics processes in freight logistics models. The Strategic Model for Integrated Logistics and Evaluations (SMILE) (*31*) is the first aggregate freight model developed to account for the routing of flows through distribution centers. The model enumerates alternative distribution channels, takes into account freight consolidation possibilities, and calculates the usage of these alternatives on the basis of a logit choice model. The model began operation in 1998 and has been used for many policy studies since then. The introduction of the model helped start a stream of new survey and modeling work in this area, both within the Netherlands and abroad.

At the Delft University of Technology, a model named GoodTrip (*32*) was developed. The model builds logistical chains by linking activities of consumers, supermarkets, hypermarkets, distribution centers, and producers. On the basis of consumer demand, the GoodTrip model calculates the volume in cubic meters per goods type in every zone. The goods flows in the logistical chain are determined by the spatial distribution of activities and the market shares of each activity type—consumer, supermarket, hypermarket, distribution center, and so forth. This attraction constraint calculation starts with consumers and ends with the producers or at the city borders. A vehicle-loading algorithm then assigns the goods flows to vehicles. A shortest-route algorithm assigns all tours of each transportation mode to the corresponding infrastructure networks. This results in logistical indicators, vehicle mileage, network loads, emissions, and finally energy use of urban freight distribution.

Another application that followed the SMILE development is the SLAM (Spatial Logistics Appended Module) (*33*), which was an EU-level spin-off. The model is appended to SCENES, the EU-level transport model. It obtains trade flows (in the form of a matrix containing flows between producing and consuming regions) as an input from SCENES and produces transport O-D matrices for the 200+ zone system in SCENES. These O-D tables incorporate alternative distribution chains. A chain is defined as the combination of distribution centers and transport relations for trade flows between producing and consuming regions. The second O-D table, the output of SLAM, is then fed back into a European freight network model, which uses the modified O-D table to determine modal split and routing of flows. This logistics module was adopted as part of the new standard EU transport modeling suite, TRANSTOOLS.

A slightly more advanced logistics module was proposed for the Swedish national freight model system SAMGODS (*34*). This proposal is now being implemented as a joint Norwegian–Swedish initiative in an even more refined form (*35*). In contrast to the above-described aggregate approaches, this model takes a mixed aggregate-disaggregate modeling approach. Here, aggregate data on trade flows between regions are distributed over pairs of individual firms on the basis of various firm attributes such as sectoral affiliation and size. The resulting disaggregate flows are then spread over different distribution channels (and, possibly, modes of transport) by using a microsimulation approach. In the final step these flows are aggregated again to form interregional transport flows.

In the United Kingdom, following the freight model review, parallel to the above models, the recommendation was to distinguish in the freight modeling framework between two types of spatial interactions: trade and transport interactions. Data describing interactions of the first type were termed production–consumption matrices, the second O-D matrices. The bridge between these matrices would be provided by a logistics module. The first practical result of this recommendation was a logistics model for the trans-Pennine corridor, presented recently at the European Transport Conference (*36*).

Freight Trips and Networks

At the national level, Belgium (*37*), the Netherlands, the United Kingdom, Finland, and Sweden (*38*) have developed hypernetwork approaches for freight network modeling. These network assignment models simultaneously treat mode and route choice; the Dutch model includes choice of vehicle type as well. In addition to the Belgian model, at least two other models—the Strategic European Multimodal Modeling and SCENES—use a multimodal network assignment approach. These models work largely on aggregate data.

Other countries usually treat mode choice and route choice separately. At the basis of mode choice models lie revealed preference (RP) and stated preference (SP) data sets. Recent SP or combined RP–SP work for freight mode choice was carried out in Italy (*39*), the United Kingdom (*40*), and the Netherlands. Network assignment has received relatively little attention, although multiple user class (MUC) assignment for road networks is becoming increasingly important, while truck shares on the road are growing. MUC assignment routines for freight were developed by Bliemer and Bovy (*41*) for road and by Lindveld et al. (*42*) for inland waterways.

The link between mode and route choice is a weak one. The usual approach uses fixed conversion factors from tonnes to vehicles, loading units, ships, or wagons, for each mode of transport and occasionally differentiated by sector or commodity group. Although some literature links shipment size and mode choice (*43*), even once shipment sizes and modes are known, it is difficult to develop models because of data difficulties. Empirical challenges are great since both services and product sectors generate freight movements and vans carry both passengers and freight. Another problematic area is the difficulty in modeling empty trips, since it is difficult to observe empty trips. A practical insight is given by Holguín-Veras and Thorson (*44*) on this matter. Wigan and Southworth (*45*) discuss the challenges in the broader area of modeling commercial, service, and light goods movements.

As to the general state of the art in urban goods modeling, local freight models currently are not much different from regional or global ones. Taniguchi and Thompson present an overview of available models (*46*). City logistics models involve either prescriptive/normative) approaches (for single firms or groups operating as one) or descriptive approaches, where the latter do not take into account the logistics processes behind freight traffic. For the most part the techniques used in descriptive models are direct demand models, which do not take into account explicitly the choice of mode or vehicle type. Some recent work in freight trip generation that takes into account various vehicle types was presented by Iding et al. (*47*) and Steinmeyer and Wagner (*48*).

Especially at the urban level, hardly any transport statistics are available to help in developing freight transport demand models. Where firm-level data are available, interesting possibilities open up, including detailed microsimulation (*49*). Groothedde (*11*) presents a simulation approach that makes use of a mix of public and private data to develop a detailed spatial database of consumer goods movements for purposes of microsimulation of logistics chains.

Concluding Remarks

The aim of this paper was to describe the major lines of freight demand model development that have developed outside the United States. An overview of the key policy issues and the associated modeling needs has been provided. Three major lines of model development have been identified, and the state of the art in these areas was described.

The conclusion is that a number of areas are still not covered sufficiently. In particular, there is insufficient knowledge at the network level of the many asymmetric interactions between freight and passenger traffic. With regard to the three lines of development highlighted in this paper, it is clear that this is a work in progress, despite the fact that the main bottlenecks for their introduction, as well as the early adopters, can already be identified.

A common thread through all three areas of innovation is the challenge to create new data about freight flows. The availability of advanced techniques for data gathering will influence modeling abilities in the future. New observation methods such as cameras and radar will allow a continuous monitoring of freight flows. In addition, new regulations concerning freight security will lead to a better accounting of freight passing certain checkpoints. Until these sources become available, however, a certain amount of creativity will be needed in combining aggregate and disaggregate data sources.

References

1. Burgess, A. The European Transport Model Directory (MDir): Description of Modal Split Modeling in European Transport Models on the Basis of MDir. Presented at THINK-UP Workshop 9, Rotterdam, Netherlands, 2001.
2. *European Transport Modelling and Scenarios: Fitness-for-Purpose Analysis*. TRANSFORUM Consortium, Deliverable D4.3. European Commission, Brussels, 2006.
3. WSP. *Review of Freight Modelling: Final Report*. Integrated Transport Economics and Appraisal Division, Department for Transport, London, 2002.
4. de Jong, G. National and International Freight Transport Models: An Overview and Ideas for Future Development. *Transport Reviews*, Vol. 24, No. 1, 2004, pp. 103–124.
5. Chisholm, M., and P. O' Sullivan. *Freight Flows and Spatial Aspects of the British Economy*. Cambridge University Press, London, 1973.
6. Williams, H. C. W. L. (1977). On the Formulation of Travel Demand Models and Economic Evaluation Measures of User Benefit. *Environment and Planning A*, Vol. 9, pp. 284–344.
7. Harker, P., and T. Friesz. Prediction of Intercity Freight Flows II: Mathematical Formulations. *Transportation Research B*, Vol. 20, 1986, pp. 155–174.
8. Crainic, T. G., M. Florian, J. Guelat, and H. Spiess. Strategic Planning of Freight Transportation: STAN, an Interactive-Graphic System. In *Transportation Research Record 1283*, TRB, National Research Council, Washington, D.C., 1990, pp. 97–124.

9. Tavasszy, L. A. *Modelling European Freight Transport Flows*. PhD dissertation. Delft University of Technology, TRAIL Research School, Delft, Netherlands, 1996.
10. Nagurney, A., K. Ke, J. Cruz, K. Hancock, and F. Southworth. Dynamics of Supply Chains: A Multilevel Logistical/Information/Financial Network Perspective. *Environment and Planning B*, Vol. 29, 2002, pp. 795–818.
11. Groothedde, B. *Collaborative Logistics and Transportation Networks*. PhD Dissertation. Delft University of Technology, TRAIL Research School, Delft, Netherlands, 2005.
12. Thorson, E. *The Integrative Freight Market Simulation: An Application of Experimental Economics and Algorithmic Solutions*. PhD dissertation. Rensselaer Polytechnic Institute, Troy, N.Y., 2005.
13. Bröcker, J. Operational Spatial Computable General Equilibrium Models. *Annals of Regional Science*, Vol. 32, 1998, pp. 367–387.
14. Venables, A., and M. Gasiorek. *The Welfare Implications of Transport Improvements in the Presence of Market Failure*. Report to the Standing Advisory Committee on Trunk Road Assessment, Department of the Environment, Transport, and Regions, London, 1998.
15. Knaap, T., and J. Oosterhaven. The Welfare Effects of New Infrastructure: An Economic Geography Approach to Evaluating a New Dutch Railway Link. Presented at North American Regional Science Association International meeting, Chicago, Ill., Nov. 9–12, 2000.
16. Caspersen, S., L. Eriksen, and M. M. Larsen. *The BROBISSE Model—A Spatial General Equilibrium Model to Evaluate the Great Belt Link in Denmark*. Institute of Local Government Studies, Copenhagen, Denmark, 2000.
17. Hussain, I., and L. Westin. *Network Benefits from Transport Investments Under Increasing Returns to Scale: A SCGE Analysis*. Umeå Economic Studies, Paper 432. Center for Regional Science, Umeå, Sweden, 1997.
18. Nordman, N. *Increasing Returns to Scale and Benefits to Traffic: A Spatial General Equilibrium Analysis in the Case of Two Primary Inputs*. Center for Regional Science, Umeå, Sweden, 1998.
19. Sundberg, M. *Development of a Spatial Computable General Equilibrium (SCGE) Model for Analysis of Regional Economic Impacts of the Öresund Bridge*. Royal Institute of Technology, Stockholm, Sweden, 2002.
20. Ivanova, O., A. Vold, and V. Jean-Hansen. *PINGO: A Model for Prediction of Regional and Interregional Freight Transport*. TØI Report 578/2002. Institute of Transport Economics, Oslo, Norway, 2002.
21. Roson, R. A General Equilibrium Analysis of the Italian Transport System. In *European Transport and Communications Network: Policy Evaluation and Change* (D. Banister, R. Capello, and P. Nijkamp, eds.), John Wiley and Sons, New York, 1995.
22. Williams, I. *Feasibility Study of SCGE Models of Goods Flows in Sweden*. Swedish Institute for Transport and Communications Analysis, Stockholm, 2003.
23. Löfgren, H., and S. Robinson. *Spatial Networks in Multiregion Computable General Equilibrium Models*. TMD Discussion Paper 35. International Food Policy Research Institute, Washington, D.C., 1999.
24. Lakshmanan, T. R., and W. P. Anderson. *Transportation Infrastructure, Freight Services Sector and Economic Growth*. Boston University, Mass., 2002.
25. Koike, A., T. Ueda, and M. Miyashita. Spatial Computable General Equilibrium Model for Passenger Transport Improvement: Evaluation of Japanese New Shinkansen Project. Presented at World Conference of Regional Science Association International, Lugano, Switzerland, May 2000.
26. Ueda, T., A. Koike, and K. Iwakami. *Economic Damage Assessment of Catastrophe in High Speed Rail Network*. 2001. www.sse.tottori-u.ac.jp/keikaku_source/berkeley2001/koi2001.pdf.
27. Miyagi, T. *Economic Appraisal for Multiregional Impacts by a Large Scale Expressway Project: A Spatial Computable General Equilibrium Approach*. Tinbergen Institute Discussion Paper TI-2001 066/3. 2001. www.tinbergen.nl/home.html
28. Tavasszy, L. A., M. J. P. M. Thissen, A. C. Muskens, and J. Oosterhaven. Pitfalls and Solutions in the Application of Spatial Computable General Equilibrium Models for Transport Appraisal. Presented at 42nd European Congress of the Regional Science Association, Dortmund, Germany, 2002.
29. Fischer, M. J., M. L. Outwater, L. L. Cheng, D. N. Ahanotu, and R. Calix. Innovative Framework for Modeling Freight Transportation in Los Angeles County, California. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1906*, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 105–112.
30. Bergman, T. New Generations of Freight Models: More Logistically Oriented Models, Need and Possibilities. Presented at International Meeting on Freight, Logistics, and Information Technology, The Hague, Netherlands, Dec. 1987.
31. Tavasszy, L. A., M. van de Vlist, C. Ruijgrok, and J. van de Rest. Scenario-Wise Analysis of Transport and Logistic Systems with a SMILE. Presented at 8th World Conference on Transport Research, Antwerp, Belgium, 1998.
32. Boerkamps, J., and A. van Binsbergen. GoodTrip—A New Approach for Modelling and Evaluation of Urban Goods Distribution Urban Transport Systems.

Presented at 2nd KFB Research Conference, Lund, Sweden, 1999.

33. Tavasszy, L. A., C. E. Cornelissen, and E. Huijsman. Forecasting the Impacts of Changing Patterns of Physical Distribution on Freight Transport in Europe. In *9th World Congress on Transport Research* (CD-ROM), Elsevier, 2001.
34. Östlund, B., G. Janson, C. Ruijgrok, L. Tavasszy, and M. S. Petersen. *A Logistics Module for SAMGODS*. Swedish Institute for Transport and Communications Analysis, Stockholm, 2003.
35. de Jong, G., M. Ben-Akiva, M. Florian, S. E. Grønland, and M. van der Voort. Specification of a Logistics Model for Norway and Sweden. Presented at European Transport Conference, Strasbourg, France, 2005.
36. Jin, Y., I. Williams, and M. Shahkarami. Integrated Regional Economic and Freight Logistics Modelling: Results from a Model for Trans-Pennine Corridor. Presented at European Transport Conference, Strasbourg, France, 2005.
37. Beuthe, M., B. Jourguin, J. F. Geerts, and C. Koul à Ndjang' Ha. Freight Transportation Demand Elasticities: A Geographic Multimodal Transportation Network Analysis. *Transportation Research E*, Vol. 37, 2001, pp. 253–266.
38. Swahn, H. *The Swedish National Model System for Goods Transport: A Brief Introductory Overview*. Swedish Institute for Transport and Communications Analysis, Stockholm, 2001.
39. Danielis, R. *Freight Transport Demand and Stated Preference Experiments* (partly in Italian). FrancoAngeli, Italy, 2002.
40. Shinghal, N., and A. S. Fowkes. Freight Mode Choice and Adaptive Stated Preferences. *Transportation Research E*, Vol. 38, 2002, pp. 367–378.
41. Bliemer, M. C. J., and P. H. L. Bovy. Quasi-Variational Inequality Formulation of the Multiclass Dynamic Traffic Assignment Problem. *Transportation Research B*, Vol. 37, No. 6, 2003, pp. 501–519.
42. Lindveld, C., S. Catalano, K. Carlier, and P. H. L. Bovy. Supernetwork Approach Toward Multimodal Route Choice Modeling. Presented at 82nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2003.
43. Abdelwahab, W., and M. Sargious. Modelling the Demand for Freight Transport. *Journal of Transport Economics and Policy*, Jan. 1992, pp. 49–70.
44. Holguín-Veras, J., and E. Thorson. Practical Implications of Modeling Commercial Vehicle Empty Trips. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1833*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 87–94.
45. Wigan, M. R., and F. Southworth. What's Wrong with Freight Models and What Should We Do About It? Presented at European Transport Conference, Strasbourg, France, Oct. 2005.
46. Taniguchi, E., and R. G. Thompson. Modeling City Logistics. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1790*, Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 45–51.
47. Iding, M. H. E., W. J. Meester, and L. A. Tavasszy. Freight Trip Generation by Firms. Presented at 42nd European Congress of the European Regional Science Association, Dortmund, Germany, 2002.
48. Steinmeyer, I., and T. Wagner. Using National Behavioral Data on Commercial Traffic for Local and Regional Applications: Experiences from Germany with Data Sources and Gaps, Opportunities, and Limits. Presented at 85th Annual Meeting of the Transportation Research Board, Washington, D.C., 2006.
49. Barcelo, J. Using Microsimulation to Evaluate City Logistics Schemes. Presented at European Transport Conference, Strasbourg, France, Oct. 2005.

DISCUSSION

Inge Vierth, Swedish Institute for Transport

The paper "Freight Modeling: An Overview of International Experiences" is well structured. It describes the major lines and the international experience of freight modeling in Europe well. There are probably more experiences elsewhere, but most of the known experience in Europe comes from the Netherlands and Scandinavia.

The paper focuses on the relevant areas in freight model development:

- Freight–economy linkages,
- Logistics behavior, and
- Freight trips and networks.

The paper analyzes the importance of data as input to models. This was stressed in many other presentations at the conference.

The list of key issues could be extended by

- Direct benefits in cost–benefit analysis (i.e., the impact of improved infrastructure on transport time and reliability for freight transport),
- Regional and global environmental and climate impacts (i.e., the effect of higher or lower carbon dioxide

taxes and trade with emission rights for industry sectors and freight transport),

- Monitoring transport policy (i.e., transport quality as one of six goals in Swedish transport policy), and
- Multimodal corridor strategies including ports and terminals for combined road and rail transport.

A large gap between needs for infrastructure planning, transport policy, and so forth and the existing tools for freight transport is identified.

The remainder of this discussion focuses on the Swedish experience with national and regional freight models.

As in other countries, the need for better tools for forecasting and policy analysis was the driving force for the development of the national freight transport model system in Sweden. The Swedish Institute for Transport and Communications Analysis (SIKA) is responsible for planning methods and developing tools in the transport sector. SIKA develops passenger and freight transport forecast models and forecasts in cooperation with the National Road Administration, the Rail Administration, the Maritime Administration, and the Civil Aviation Authority. A single official transport forecast based on the same planning methods is used by all agencies, so it should be possible to compare road and rail investments with one another.

When national freight development was started in 2001, it was impossible to model all relevant reactions in the private sector with the existing freight model system. This is true for localization of companies, choice of shipment size, consolidation to make use of economies of scale, and so forth. The same development areas as in Tavasszy's paper were identified.

The "freight–economy linkage" and the development of economic forecasts were postponed. The focus was on understanding actual freight movements. Lack of knowledge of logistics behavior was also seen as the main drawback by neighboring Norway. Agencies from the two countries cooperate in the development of a logistics model. The Swedish National Road Administration also requires the assignment of all road traffic in one network.

The Swedish and Norwegian national freight models are traditionally based on the STAN system (an interactive graphic planning tool used for strategic planning of national and regional freight transportation developed by INRO consultants in Montreal). The models include generation, distribution, and multimodal assignment (in tons). To overcome the lack of logistics elements, the future freight model systems in Norway and Sweden consist of base production–wholesalers–consumption (PWC) matrices, a logistics model, and a network model. Normally, wholesalers receive large consignments from producers and send minor consignments to consumers. Some wholesalers perform the same type of services as warehouses and distribution centers.

The base PWC matrices contain zone-to-zone commodity flows. The Swedish PWC matrix consists of PC matrices, PW matrices, and WC matrices. It was decided at this stage not to overload the logistics model with the modeling of wholesale activities. The annual flows to and from the wholesalers are fixed (as part of the base matrix). The base PWC matrices are derived by using all available statistics. In Sweden the Commodity Flow Survey (CFS) is the main source. The development of the CFS, which is based on the same approach as the U.S. CFS, started in parallel with the model development.

The logistics model reads in PWC matrices (in tons) and delivers origin–destination matrices (O-D vehicle matrices) to the network model. The model is based on an "aggregate- disaggregate-aggregate" approach, which consists of three steps: (*a*) disaggregating from zone-to-zone to firm-to-firm flows, (*b*) minimization of transport and logistics costs per firm and year, and (*c*) aggregation of O-D flows by commodity in vehicles. The cost minimization step takes into account the trade-offs between inventory/order costs and transport costs and between high frequencies and economies of scale. Version 1 of the logistics model (from 2005–2006) is a normative cost minimization model to aggregate data. The planned disaggregated model estimation requires more detailed shipment data.

The network model initially produces distance, time, and cost matrices for the logistics model. The new approach requires additional detailed information about terminal or port characteristics (which goods can be handled), infrastructure restrictions (e.g., access to ports), and frequencies for different vehicle or vessel types.

Five regional road transport models are developed for the same regions as the passenger transport models. These models include both freight transport and service/craft transport. For freight transport, a model will be developed starting with the national vehicle O-D matrices. A hierarchic approach is also applied for the data collection. Counties, chambers of commerce, and so forth are offered the opportunity to extend the CFS sample by participating in their regions. For the nonfreight transport correlations, data from a study in Stockholm County, where private and public work units were asked for their incoming and outgoing transport, will be applied to the whole of Sweden.

For more information about the development of the Swedish freight model, see www.sika-institute.se or contact inge.vierth@vti.se.

Oregon Generation 1 Land Use–Transport Economic Model Treatment of Commercial Movements

Case Example

J. Douglas Hunt, *University of Calgary*
B. J. Gregor, *Oregon Department of Transportation*

This paper describes the representation of commercial movements included in the Oregon Generation 1 statewide land use–transport model, a working model with a history of use in practical forecasting and policy analysis. This model is entirely aggregate in nature and establishes short-run equilibrium points in 5-year steps that together constitute a quasi-dynamic long-run equilibrium through time into the future. In the model, the magnitude and spatial distribution of production and consumption activities give rise to flows of commodities that are translated into truck flows. The truck flows are loaded, together with private vehicle and transit vehicle flows carrying people making trips for household purposes, onto road networks, taking account of congestion. The resulting times and distances for truck movements are translated into costs for moving commodities, which influence the magnitude and spatial distribution of production and consumption activities in the next 5-year time point. The model provides an integrated representation of trucks and goods movements more generally within the rest of the economic system—one that has been used in practical applications.

The Oregon Generation 1 (Oregon1) model provides an integrated representation of Oregon's land use, transport, and economic systems and their interactions. The model has been used by the Oregon Department of Transportation (ODOT) in a range of practical applications. Most prominently, it was used to develop a plan for responding to the discovery that more than 500 Oregon bridges were showing signs of cracking problems. It provided a tool for considering the economic, land use, and transport impacts of different investment alternatives that varied in the restrictions on truckloads and thus had impacts on the economy and on land use via the effects on shipping costs.

The Oregon1 model includes a representation of truck movements, incorporating how they arise and how the costs of these movements affect the rest of the system. This paper describes the representation. An overview of the full Oregon1 model, with an indication of the position and role of the goods shipment and truck flow components within the full modeling system, is presented. The goods shipment and truck flow allocations are described in detail, and the result of the calibration of the goods shipment truck flow components is discussed. Conclusions about what has been achieved and what has been learned in this work with regard to the modeling of these movements are given.

The peer review of this paper was conducted by the Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making.

Oregon Statewide Integrated Land Use–Transport Model

Introduction

The Oregon1 statewide land use–transport model is designed for use in assessing the complex long-term effects of policy alternatives on Oregon's transportation, land use, and economic systems and their interactions. It was developed under the Transportation and Land Use Model Integration Program of the Oregon Modeling Improvement Program begun in 1995 (*1*). This is the first stage of work within a larger model development program. It is based on a modified version of the TRANUS software package of an integrated land use and transport modeling system (*2*) and is intended primarily to complement the analysis provided by regionally focused metropolitan planning organization models.

Oregon1 has been successfully applied in the practical analysis of several complex policy issues, including the development of a 50-year planning vision for the Willamette Valley (*3*, *4*), a proposed Interstate running north–south through central or eastern Oregon (*5*), and the extent and staging of a rehabilitation program involving the temporary closure and repair of approximately 550 highway bridges statewide (*6*).

A second-generation model, Oregon2, is under development (*7–9*).

Oregon Overall Structure

The overall structure of the Oregon1 model is shown schematically in Figure 1.

The model works in a series of 5-year steps to simulate changes over time. At the start of each 5-year step, the economic module determines the growth in the full state economy, including exports and final demand totals, by using an input–output model of commodities (measured in dollars of value) that embodies the production and consumption of goods and services and the trading relationships between sectors of the economy within the study area. Exports are adjusted on the basis of consumption costs at external zones.

Quantities of production and consumption activity are passed to a location model, which simultaneously allocates them among model zones by using logit functions that include both price and accessibility terms. Industry quantities by sector are located where land is available with good accessibility to both production (other businesses) and consumption (businesses and households) markets; households by income group are similarly located near labor markets and other goods they consume. This involves a simultaneous solving of production location and transaction equations, with land as a constraint and influenced by land prices.

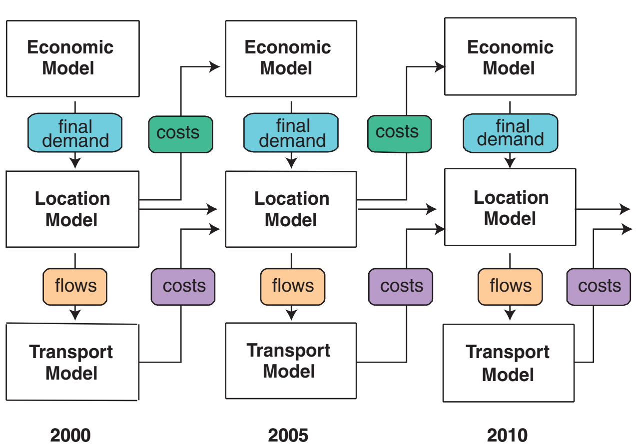

FIGURE 1 Information flows among modules in Oregon1 model.

The spatially disaggregated dollar value flows established in the location model are converted into transport flows of tons of goods moved and numbers of passengers and then into trips that are assigned to vehicles and paths in the statewide network, by operator (vehicle type) on the basis of relative costs, taking account of congestion and handling.

Two feedback mechanisms influence model activity in the next 5-year time point. The congested transport costs affect the locations of activities, including households and employment, and the flows of commodities, in particular where the input (or raw) goods are purchased in the next period. The resulting consumption costs for goods and services at external stations affect the state export quantities and thus the size of the overall state economy.

Representation of Freight Movements

The elements of the Oregon1 model that provide explicit representation of the nature of freight movements and the influences on and impacts of these movements are described below.

Allocation of Goods to Truck Flows

Travel demand is split into transport categories (what most modeling schemes call trip purposes). Economic flows by sector are converted into functional flows by transport category. For example, labor flows in dollars are converted into person flows of home-based work trips. For truck freight, three categories of goods movement are defined on the basis of truck weight classifications:

- Light—goods moved in trucks carrying 64,000 pounds gross vehicle weight (GVW) or less;
- Medium—goods moved in trucks carrying between 64,000 and 80,000 pounds GVW; and
- Heavy—goods moved in trucks carrying more than 80,000 pounds GVW.

This categorization scheme is used so that the effects of truck weight restrictions can be accounted for by economic sector. This, in turn, improves the spatial sensitivity of the model to weight restrictions because economic activity by sector varies across the state.

For each category of goods, a fixed ratio is used to convert flows of goods measured in dollar values per month into flows of goods measured in tons per month. The ratios were computed by multiplying overall ratios of tons per million dollars for each of the eight industry sectors that ship goods by the proportions of tonnage of each sector currently carried by each truck weight class. These proportion values were developed by using ODOT data on truck contents by weight and IMPLAN economic data as a link between commodities and industry. The resulting proportions represent the ”market-desired” allocation of goods between the truck weight classes by industry sector. The highest proportions in the "heavy" category occur in three industry sectors:

- Lumber, pulp, and paper, 43 percent;
- Transport, communications, and utilities, 65 percent; and
- Wholesale, 65 percent.

The resulting distributions of loadings to truck types for the full set of 12 industry sectors considered in the location model are summarized in Table 1.

Truck Types

The Oregon1 model uses a logit model to jointly assign travel to operator and route combinations. For example, commuter travel between two zones may be apportioned between automobile transport on one or more sets of roads, bus transport on one or more routes, and rail transport on one or more rail lines. In the case of truck freight, several operators are specified that permit allocations to be made among truck weight and route combinations. Three operators (heavy, medium, light) are defined for the heavy goods category to allow goods shipments to be split into lighter loads depending on weight restrictions. The GVW thresholds for these operators correspond to the thresholds used to define the freight transport categories. Two operators are defined for the medium goods category to correspond to trucks carrying light or medium loads. Only one operator is necessary to transport light goods.

Truck Operating Costs

The operating costs for each category of trucks are given in Table 2. These costs influence the allocation of goods to truck flow types and feed up to influence the costs of location and of production acting in the location and economic models (in the next time period). Note that while the two medium truck operators have the same parameters, the three light operators are split into two groups that differ with respect to payload capacity. The light operator that normally carries light goods has a lower payload capacity than the light operators that are alternate operators for carrying medium and heavy goods. It is assumed that the alternate operators will carry the maximum loads allowable under the lesser weight limits. The normal light operators carry different commodity mixes and shipment sizes. It is assumed that they carry the average load for the weight class.

Transport Network

A nodes-and-links representation of the transport network is used in the transport model, with all Interstate and state highways included and many major arterial

TABLE 1 Loadings to Truck Types by Industrial Sector

Industrial Sector	Goods Shipment Rate (tons/$ $\times 10^6$ production)	Proportion of Tons Carried by Truck Type, by Weight		
		Light	Medium	Heavy
Agriculture and forestry	6,150	0.06	0.60	0.34
Construction	2,360	0.07	0.49	0.44
Lumber, pulp, and paper	6,000	0.05	0.47	0.48
Printing	1,500	0.34	0.52	0.14
High technology	250	0.26	0.42	0.32
Other manufacturing	2,100	0.12	0.61	0.27
Transport, communication, and utilities	10	0.04	0.22	0.74
Wholesale services	180	0.04	0.22	0.74
Retail services	0	—	—	—
Finance, real estate, and insurance	0	—	—	—
Other services	0	—	—	—
Government	0	—	—	—

TABLE 2 Truck Operating Cost Parameters by Truck Type

	Operator			
Cost Parameter	Light	Light Alternates for Medium and Heavy Goods Transport	Medium and Medium Alternate for Heavy Goods Transport	Heavy
GVW range (lb)	<64,000	<64,000	64,000–80,000	>80,000
Payload capacity (tons)	6.4	14.4	21.3	28.4
Proportion trucks return loaded	.832	.832	.832	.832
Minimum fuel use (gal/mile)	0.165	0.165	0.173	0.183
Maximum fuel use (gal/mile)	0.183	0.183	0.193	0.203
Fuel price ($/gal)	1.18	1.18	1.18	1.18
Time cost ($/h)	19.00	19.00	19.00	19.00
Distance cost ($/mile)	1.56	1.56	1.63	1.67
Load or reload cost ($)	40.00	40.00	40.00	40.00

roadways branching from these highways also included. The heavy truck operators or medium and heavy truck operators are barred from using specific links in the transport network that represent load-limited bridges. In some cases the load limit is 64,000 pounds and in others it is 80,000 pounds, leading to variations in the flows that are not permitted on the links representing these bridges.

Conclusions

The modeling system described here and the work done in its development have demonstrated the practicality of developing a system that provides a representation of the economy, the land use system, and the transport system (including the commercial component) along with the interactions among these systems. The model can be used as a decision-support tool that takes into account commercial movements and associated truck flows, along with the linkages between them and the economy, on a statewide scale. The model can show how policies might affect various economic sectors and regions of the state. It has proved useful in policy analysis and program development. It has also proved flexible and can be modified as needed to address current policy issues.

Both the development and the use of the model in the consideration of policy alternatives were found to help establish a more complete appreciation of the real-world system and the potential impacts of the planning actions being considered. Model results have been a key input to policy decisions in several instances. In particular, the model helped in achieving consensus on the level of funding for a major bridge improvement program and the statewide strategy for carrying out the program. Because the model has proven to be so useful, planners and policy makers at ODOT now expect it to be used to help them in their deliberations.

Although the Oregon1 model has proven to be useful, it has limitations in how it represents the economy, geography, and freight movements. The Oregon2 model will offer substantial improvements in the detail of representation of the economy and geography. Freight movements will be much improved through microsimulation and a tour-based assignment approach. These improvements will greatly enhance the abilities of the model to address freight policy issues.

Acknowledgments

The integrated modeling and analysis work described here was sponsored by the Oregon Department of Transportation. Funding for the Oregon1 development work has largely been provided by the Federal Highway Administration. The development and initial calibration of the Oregon1 model within the larger Oregon Model Improvement Program was completed by a consultant team led by PB Consult, including HBA Specto, Inc., EcoNorthwest, and the University of Washington. The Economic and Bridge Options Team was led by Paul Mather, and the modeling effort was led by Bill Upton and supported by Ben Stabler, Lucia Ramirez, Jan Shearer, and Rich Arnold, all of the Oregon Department of Transportation.

References

1. Oregon Transportation Planning Analysis Unit, MW Consulting, and PB Consult. *Oregon Modeling Improvement Program: An Overview*. Oregon Department of Transportation, Salem, 2002. www.odot.state.or.us/tddtpau/modeling.html.
2. Modelistica. *TRANUS: Integrated Land Use and Transport Modeling System, Version 5.0*. 1995. www.modelistica.com.
3. Hunt, J. D. Willamette Valley Alternative Futures Statewide Model Analysis. Presented at Willamette Valley Livability Forum, Salem, Ore., Nov. 2000.

4. Oregon Transportation Planning Analysis Unit, Parsons Brinckerhoff Quade and Douglas, and MW Consulting. *Oregon Modeling Analysis of Willamette Valley Transportation and Land Use Alternatives*. Oregon Department of Transportation, Salem, 2001. www.odot.state.or.us/tddtpau/modeling.html.
5. Oregon Transportation Planning Analysis Unit. *Study of Eastern Oregon Freeway Alternatives Pursuant to House Bill 3090*. Oregon Department of Transportation, Salem, 2001. www.odot.state.or.us/tddtpau/modeling.html.
6. Weidner, T. J., B. J. Gregor, J. D. Hunt, and M. Wert. Oregon Bridge Investment Alternatives: Using Integrated Modeling in Policy Decisions. *Proc., 10th Transportation Planning Applications Conference*, Portland, Ore., April 2005.
7. Hunt, J. D., R. Donnelly, J. E. Abraham, C. Batten, J. Freedman, J. Hicks, P. J. Costinett, and W. J. Upton. Design of a Statewide Land Use Transport Interaction Model for Oregon. *Proc., 9th World Conference for Transport Research* (CD-ROM), Seoul, South Korea, July 2001.
8. Hunt, J. D., J. E. Abraham, and T. J. Weidner. Household Allocation Module of Oregon2 Model. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1898*, Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 98–107.
9. PB Consult, HBA Specto, and EcoNorthwest. *Oregon2 Transitional Model; Model Description at Finalization: First Draft Report*. Oregon Transportation Planning Analysis Unit, Oregon Department of Transportation, Salem, 2004.

Tour-Based Microsimulation of Urban Commercial Vehicle Movements in Calgary, Alberta, Canada

Case Example

J. Douglas Hunt, *University of Calgary*

This paper describes the representation of commercial vehicle movements in the Calgary region provided by a tour-based microsimulation system, a working model with a history of use in practical forecasting and policy analysis. The model provides explicit representation of vehicle movements for transport and delivery of both goods and services, with for-hire or carrier services included as the transport sector providing the service of moving goods. The lack of an explicit representation of shipments per se allows some of the complexities associated with such representation to be avoided. Yet the model accounts for truck routes and responds to truck restrictions and related policy. It includes all types of commercial vehicles, from light vehicles to heavier single-unit and multiunit configurations. All sectors of the economy are incorporated into the representation, including retail, industrial, service, and wholesaling. The model has been connected with an aggregate equilibrium model of household-related travel, with the trip tables from the two models assigned jointly to the relevant network representations. The microsimulation processes in the model are performed by using external Java applications.

The city of Calgary, Alberta, Canada, has a regional travel model (RTM) that covers the Calgary region. The RTM is used in practical policy analysis and forecasting work by both the city and the Alberta Ministry of Transportation. In recognition of the expected benefits, a system for modeling commercial vehicle movements has been developed to work with the RTM and provide representation of the full range of transport of goods and services. This paper presents an overview of the full Calgary RTM with an indication of the position and role of the commercial vehicle movement component within the full RTM. A detailed description of the commercial vehicle movement component using the tour-based microsimulation approach is given, and the calibration of the tour-based microsimulation component is discussed. An overview of the resulting capabilities of the full model is given, and conclusions about what has been achieved and learned in this work with regard to the modeling of movements are presented.

The peer review of this paper was conducted by the Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making.

Calgary Regional Transportation System Model

The Calgary region is an area centered on the city of Calgary and extending approximately 80 km in all directions to include a hinterland of largely agricultural lands dotted with satellite towns and smaller market centers. In 2001 it had a total population of just over 1 million.

The Calgary RTM has three basic components: the personal travel demand model, the commercial vehicle movement model (CVM), and the joint vehicle assignment process.

The personal travel demand model represents the behavior of travelers making trips for household purposes, covering about 85 percent of the vehicle trips and vehicle kilometers internal to the Calgary region. The CVM represents the movements of light, medium, and heavy vehicles for commercial purposes, including transport and delivery of goods and services, covering about 15 percent of the vehicle trips and vehicle kilometers internal to the region.

The personal travel model is an aggregate equilibrium model. It includes representation of 25 travel segments based on person category and movement type. Various private vehicle and transit modes are considered, along with walking and cycling.

The CVM, the focus of this paper, is a disaggregate microsimulation model. It includes representation of the tours generated by five categories of industrial activity on each of five types of land use. The individual trips on each separate vehicle tour are simulated, providing a vehicle type, an origin, a destination, and a time of trip, among other attributes, for each such trip.

The joint vehicle assignment process loads the trip tables generated by the above two demand models to a nodes-and-links representation of the road networks in the region, establishing a network equilibrium loading taking account of the congestion on links. Five time periods are considered in the assignment process, including the busiest ½ hour (the "crown") and the rest of the 1½ hours (the "shoulders") for the a.m. peak period (from 7 to 9 a.m.), the similar busiest ½ hour and the rest of the 1½ hours for the p.m. peak period (from 4 to 6 p.m.), and the off-peak period covering the rest of the day. The congested travel times from the network for each of these time periods are fed back into these models, and the process is iterated until the travel times used by the models are consistent with those arising from the subsequent loading on the networks, thereby establishing a system equilibrium.

Within each iteration where the congested travel times are fed back, the personal travel model is run once to equilibrium and the resulting trip table output while the commercial vehicle model microsimulation is run 10 times and the results are averaged to obtain expected values for the zone-to-zone trips in the trip tables. In the final iteration of the full modeling system, the microsimulation is run 30 times and the results are averaged to obtain expected values with better statistical properties.

There is a fourth component dealing with vehicle trips with at least one end external to the Calgary region. It is a fairly modest set of singly constrained gravity models considering the exogenously forecast vehicle flows passing through the model external cordon entry and exit points, which account for about 6 percent of the total vehicle trips in the entire region. This generates additional vehicle trip tables for each of the light, medium, and heavy vehicle categories for each time period in assignment, and these trip tables are combined with those from the personal and commercial models before the assignment performed in each iteration.

Structure of the Microsimulation of Commercial Vehicle Movements

The microsimulation of commercial vehicle movements in the CVM considers the tour-based movements by using Monte Carlo techniques to assign the attributes to each tour in a list of tours generated for each zone, including tour purpose, vehicle type, next stop purpose, next stop location, and next stop duration.

Overall Structure

The overall framework of the microsimulation process is illustrated in Figure 1.

First, the number of tours based in each zone is established by using an aggregate trip generation model. This value establishes the length of the list of tours whose specific attributes are identified one after another as the microsimulation progresses. Then, on the basis of Monte Carlo processes, each tour in the list for each zone is considered, one at a time, and the vehicle type and purpose of the tour are identified, followed by the specific tour start time. The characteristics of the stops on the tour are then identified, iterating stop by stop until the tour is finished.

Tours are "grown" incrementally by having a "return-to-establishment" alternative within the next stop purpose allocation: if the next stop purpose is not return to establishment, then the tour extends by one more stop.

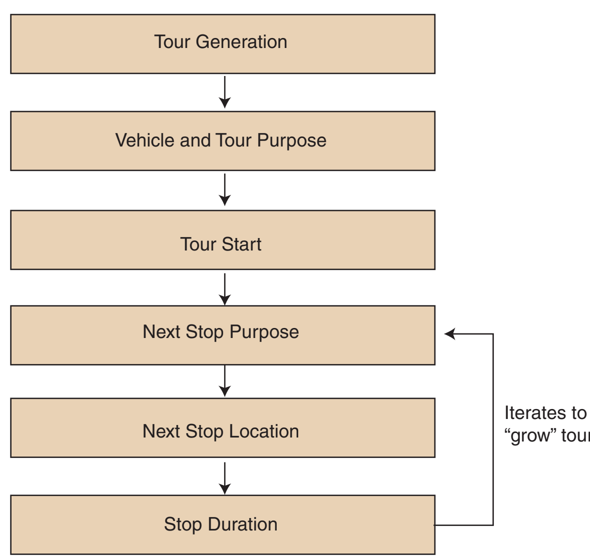

FIGURE 1 Overall tour-based microsimulation framework.

This approach is more consistent with the nature of tour making in urban commercial movements—where there are a comparatively large number of equally important stops in many tours. This is in contrast to the ”rubber-banding” process typically used with household tour-based modeling, where first a primary destination for the tour is established out from the base and then perhaps one or two intermediate stops on the trips between the base and this primary destination are identified—analogous to first stretching a rubber band between two points and then pulling it wider along the lengths in between (*1*). The selection probabilities used in the microsimulation processes are established on the basis of logit models estimated by using the choice data collected in the surveys for different segments of the full range of commercial movements.

Time is treated as a continuum, rather than in discrete periods, and both start and end times are established for each trip and each stop on each tour.

Development Data

The primary source of the data used in development is an extensive set of interviews about own-account commercial vehicle movements conducted at just over 3,100 business enterprises in the Calgary region—analogous to household trip diary interviews—that collected information on tours made on a typical weekday in 2001 (*2*). Sampled establishments provided information on the movements of their entire fleet over a 24-hour period, including origin, destination, purpose, fleet, and commodity information. The resulting sample provided choice behavior information on just over 64,000 commercial vehicle trips for use in the estimation and further calibration of the model components. The data were expanded by industry, size, and location to represent the total population of commercial enterprises, which was challenging in itself because of the uncertainty surrounding the total population of employment at establishments (*3*).

Terms, Categories, and Basic Values

Three categories of vehicle are considered:

- Light vehicles: small four-tire vehicles (cars, vans, pickups, and SUVs);
- Medium vehicles: single-unit trucks with six tires; and
- Heavy vehicles: multiunit trucks with more than six tires.

Four stop and related trip purposes are considered—in much the same way that work and school purposes are considered in personal travel modeling:

- Goods: goods delivery or pickup, including goods-handling and transport activities;
- Services: service delivery, including any incidental materials handling (such as an electrician picking up electrical supplies);
- Others: all nondirect goods and services activities not included in the above or at the point where the tour started, including breaks, meals, vehicle fueling, and so forth; and
- Return to establishment: returning to the starting point of the tour, either at the end of the day or during the day, for any reason.

These different commercial movement purposes relate to different types and distributions of activities, which imply different types of companies with different options, objectives, influences, and choice structures.

The business establishments and the associated employment at these establishments are segregated into five establishment categories on the basis of the two-digit sector-level categories in the North American Industry Classification System (*4*) as follows: industrial, wholesale, retail, transport, and services.

Each of these five categories of establishment is handled separately throughout the microsimulation, each with a largely unique set of coefficients throughout the process, so the results are different, with different behaviors and reactions to policy changes, for these categories. The framework itself is also slightly different for the transport category in particular. The transport category includes what are called “for-hire” or “private” carriers, in essence trucking companies that sell transportation service. These are different in that the goods and services stop and tour purpose categories are combined into a single “business” purpose—in recognition of the fact that transport establishments provide the service of handling goods, which blurs the definitions.

The zones in the model are classified into five land use types on the basis of specific zonal attributes as follows:

- Low density,
- Residential,
- Retail and commercial,
- Industrial, and
- Employment node.

These land use types are used to differentiate coefficient values and resulting model sensitivities at various points in the microsimulation. They work in combination with the establishment categories to separate the blue-collar and white-collar components of given industries, which allows the microsimulation to differentiate between the patterns of commercial movements arising from these components.

Travel utilities that are weighted combinations of travel times and travel distances are used throughout in the representation of travel conditions for movements between zones. The weights used vary by vehicle type and are always negative, consistent with travel having a general cost. In this sense the travel utility for a trip as used here is the negative of the generalized cost of the trip.

Vehicles in the medium and heavy categories are subject to truck route restrictions on the road network in Calgary. Drivers of these vehicles must minimize the distance they travel on the portions of the road network that are not designated truck routes. For links that are not designated truck routes, a large fixed penalty is added to the generalized cost faced by medium and heavy trucks for each additional 50 meters of the link used, so that the network assignment process respects these restrictions. The penalty portions of the resulting travel times are then removed from the network skims so that representations of the actual times and distances are used in the rest of the microsimulation process.

Tour Generation

In this first step, the aggregate number of tours generated by each category of establishment is determined for each time period in each model zone. These numbers are used to form lists of discrete tours considered in the rest of the model.

The tour generation rate (tours per employee) is first determined for the entire day for each category of establishment for each zone by using an exponential regression equation with zonal attributes as the independent variables. This rate is multiplied by the number of employees in the relevant category of establishment in the zone to produce a total number of tours generated in the zone by that industry for the entire day. The attributes represented in the exponential regression equations include the land use type for the origin zone, the percentage of zonal employment in the same establishment category in the origin zone, and accessibilities to total employment for the origin zone.

These numbers of tours for the entire day are then split among time periods covering the day to establish the number of tours in each time period by each category of establishment in each zone. The time periods considered are early off peak, midnight to 7 a.m.; a.m. peak, 7 to 9 a.m.; midday off peak, 9 a.m. to to 4 p.m.; p.m. peak, 4 to 6 p.m.; and late off peak, 6 p.m. to midnight.

The splits among time periods are determined by using logit models, with utility functions that include the same sorts of zonal-level attributes used in the exponential regression equations indicated above.

In each case the resulting number of tours in each time period by each category of establishment in each zone becomes the length of the list of corresponding discrete tours of that type, whose remaining attributes are established in the rest of the microsimulation process.

Tour Purpose and Vehicle Type Allocation

In this second step, each tour in the lists for each zone is assigned both a primary purpose and a vehicle type. A Monte Carlo process is used to assign both simultaneously, where the selection probabilities are determined by using single-level logit models based on establishment category with utility functions that include zonal-level land use, establishment location, and accessibility attributes.

The alternatives for the primary purpose for a tour are

- Goods,
- Service,
- Other, and
- Fleet allocator.

The first three of these categories are consistent with the stop purpose definitions indicated above. The last, fleet allocator, includes tours by vehicles where the data collection process sought indications of more general vehicle use statistics rather than each stop and the travel to and from it, in recognition of the large collection burden that would be imposed, as in the case, for example, of newspaper delivery, postal services, and refuse collection.

The alternatives for the vehicle type for a tour, again consistent with the vehicle category definitions indicated above, are light, medium, and heavy.

Tour Start Time

As described above, in tour generation, lists of tours are allocated to one of five time periods. In this step, each tour in the list for each time period is assigned a precise start time. This is done by using a Monte Carlo process with sampling distributions based on the weighted sample of observed start times differentiated by establishment category and time period. A cumulative percentage distribution function was calculated by industry and time period on the basis of a curve fit to observed data.

These sampling distributions are static, which implies that changes in the temporal distribution for the starts of tours established by the microsimulation in response to changes in travel conditions (or any other potential policy options for that matter) are limited to the changes in the time period allocations in trip generation. But there is further potential for travel conditions to influence the times for the rest of a given tour. The microsimulation keeps track of the precise times for the arrival and departure at each subsequent stop on each tour. This includes using the travel time between each stop. To the extent that travel times on the network change in response to policy inputs (or any other influences), the arrival times at subsequent stops will also change, which can lead to changes in the decision made with regard to the next stop purpose as described below. Further, as tours continue, the microsimulation will allow them to cross into the next time period. For example, a vehicle can start a tour in the a.m. peak and then eventually find itself in the midday off peak, where improved travel conditions can further affect the purposes and locations of subsequent stops.

After the tour start time has been assigned to a given tour, the microsimulation begins the iterative process of "growing" the tour by assigning sets of next stop purpose, next stop location, and next stop duration until the next stop purpose is "return to establishment."

Next Stop Purpose

The purpose for each subsequent stop is assigned from the following alternatives, with restrictions on availability as indicated:

- Goods: available if the primary purpose of the tour is goods;
- Service: available if the primary purpose of the tour is service;
- Other: available if the primary purpose of the tour is goods, service, or other; and
- Return to establishment: if the next stop is not the first stop on the tour.

The term "business stop" is used here to refer to stops that are either goods stops (when the tour primary purpose is goods) or service stops (when the tour primary purpose is service).

Again, a Monte Carlo process is used to assign the next stop purpose, with the selection probabilities determined by using single-level logit models based on a "segment" category. With so many observations of next stop purpose available, it was possible to estimate utility function coefficients for 13 segments of commercial movements based on combinations of industry category, vehicle type, and tour primary purpose, consistent with differences in the influences on next stop choice behavior, as follows:

- S-S-L: service tours by services establishments using light vehicles;
- S-S-MH: service tours by services establishments using medium or heavy vehicles;
- G-S-LMH: goods tours by services establishments using any vehicle type;
- S-R-LMH: service tours by retail establishments using any vehicle type;
- G-R-LMH: goods tours by retail establishments using any vehicle type;
- S-I-L: service tours by industrial establishments using light vehicles;
- S-I-MH: service tours by industrial establishments using medium or heavy vehicles;
- G-I-LMH: goods tours by industrial establishments using any vehicle type;
- S-W-LMH: service tours by wholesale establishments using any vehicle type;
- G-W-L: goods tours by wholesale establishments using light vehicles;
- G-W-MH: goods tours by wholesale establishments using medium or heavy vehicles;
- B-T-LMH: business tours by transport establishments using any vehicle type; and
- O-X-LMH: other tours by any establishments using any vehicle type, including fleet allocator tours.

The utility functions for the next stop purpose alternatives in the logit models include representation of the following attributes:

- Number stops for business purposes made previously in the tour;
- Number of stops for other purposes made previously in the tour;
- Number of stops for any purposes made previously in the tour;
- Elapsed total time for the tour to that point, which is the total time that has been spent on the tour up to that point, including all time spent at stops and in travel between stops up to that point;
- Elapsed travel time for the tour to that point, which is the total time that has been spent traveling on the tour up to that point, including all time spent in travel between stops but not including all time spent at stops up to that point;
- Travel utility associated with making the trip from the current location zone to the zone where the tour began for the vehicle type being used; and
- Accessibility for the current location (zone) to all categories of employment in all zones for the vehicle type being used.

Next Stop Location

After the next stop purpose has been assigned, the next stop location is assigned—if the next stop purpose is not return to establishment. The available alternatives for the next stop location are the 1,447 model zones.

Again, a Monte Carlo process is used, with the selection probabilities determined by using single-level logit models based on 13 "segment" categories similar to those used in the selection of next stop purpose. In this case the 13 segment categories are based on combinations of industry category, vehicle type, and next stop purpose (not tour primary purpose), with the goods, service, and "other" categories still being used, but in this case for the assigned next stop purpose (rather than the assigned tour primary purpose). The 13 category definitions remain the same—apart from using stop purpose rather than tour primary purpose—so the designations for the categories still apply: thus, for example, the S-I-L category in this case indicates "service stops made on tours by industrial establishments using light vehicles" (whereas previously, in the case of next stop purpose, it indicates "service tours made by industrial establishments using light vehicles"). With these 13 segments, different logit models are used for the assignment of next stop location depending on whether the next stop purpose is goods, service, or "other," thereby allowing the appropriate spatial distribution of opportunities to be taken into account, even on the same tour.

The utility functions for the next stop location (zone) alternatives in the logit models include representation of the following attributes:

- Land use type for the possible next zone;
- Accessibility to all categories of population for the possible next zone for the vehicle type being used;
- Accessibility to all categories of employment for the possible next zone for the vehicle type being used;
- A numerical score representing the relative attractiveness of the possible next zone for stops made during tours generated by transport establishments, which is determined as described further below; and
- The "enclosed angle" for the possible next zone, which is the angle (in degrees) enclosed by (*a*) the straight line from the current zone to the zone containing the establishment and (*b*) the straight line from the current zone to the possible next zone (an example of this angle is shown in Figure 2); a value of 0° indicates that the possible next zone is in the same direction as the zone containing the establishment, and a value of 180° indicates that the possible next zone is in the opposite direction from the zone containing the establishment.

Stop Duration Model

In this step, the stop being considered is assigned a precise duration. This is done by using a Monte Carlo process with sampling distributions based on the weighted sample of observed durations differentiated by the 13 segments also considered in the assignment of next stop purpose and next stop location.

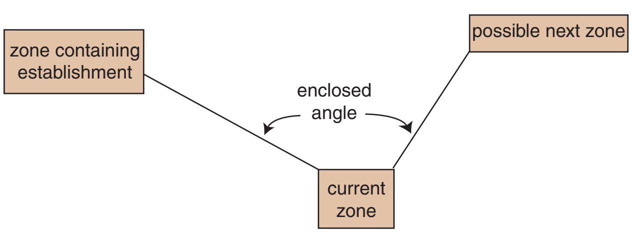

FIGURE 2 Example of enclosed angle for possible next zone.

The microsimulation uses the precise duration assigned to the stop to advance the clock keeping track of start and end times and then begins another iteration for the next stop.

Calibration of the Microsimulation of Commercial Vehicle Movements

After all the elements of the microsimulation process were assembled and the values for the various coefficients established, the entire process was calibrated to match various aggregate targets appropriately.

An iterative approach was used under which the process was run, the match of the output values to specific aggregate targets assessed, and the associated category-specific constants adjusted to improve the match. With Monte Carlo processes like the one described here, in general the results are different with each run. Therefore, multiple runs were done and the results averaged to get values that indicate the central tendencies of the outputs. Initial experimentation showed that in this case averaging over 10 runs provided highly stable results, with variations on the order of 1 percent related to the aggregate targets being considered.

The elements of the microsimulation are interdependent, which means that adjustments to the values of the coefficients in one element can alter the output values for other elements. For example, if the tour generation is adjusted, establishment locations are changed, which affects the decision to return to establishment and therefore tour lengths. This led to the use of an approach in calibration under which the matches to different sets of targets were considered consecutively over a series of iterations until the adjustments to coefficients and the resulting changes in output values were small enough to be of no consequence. The following sets of aggregate targets were considered in the order indicated:

- Tour generation by industry and geographic area;
- Proportions of tours starting in the a.m., p.m., and combined off-peak periods;
- Vehicle type and tour purpose proportions;
- Number of stops per tour by 13 segments;
- Total trip destinations in each of 13 superzones by vehicle type (for example, the proportion of all trips by heavy vehicles that are destined to the southeast industrial area);
- Intrasuperzonal proportions of trips within each of the 13 superzones by vehicle type (for example, the proportion of light vehicle trips with destinations within the

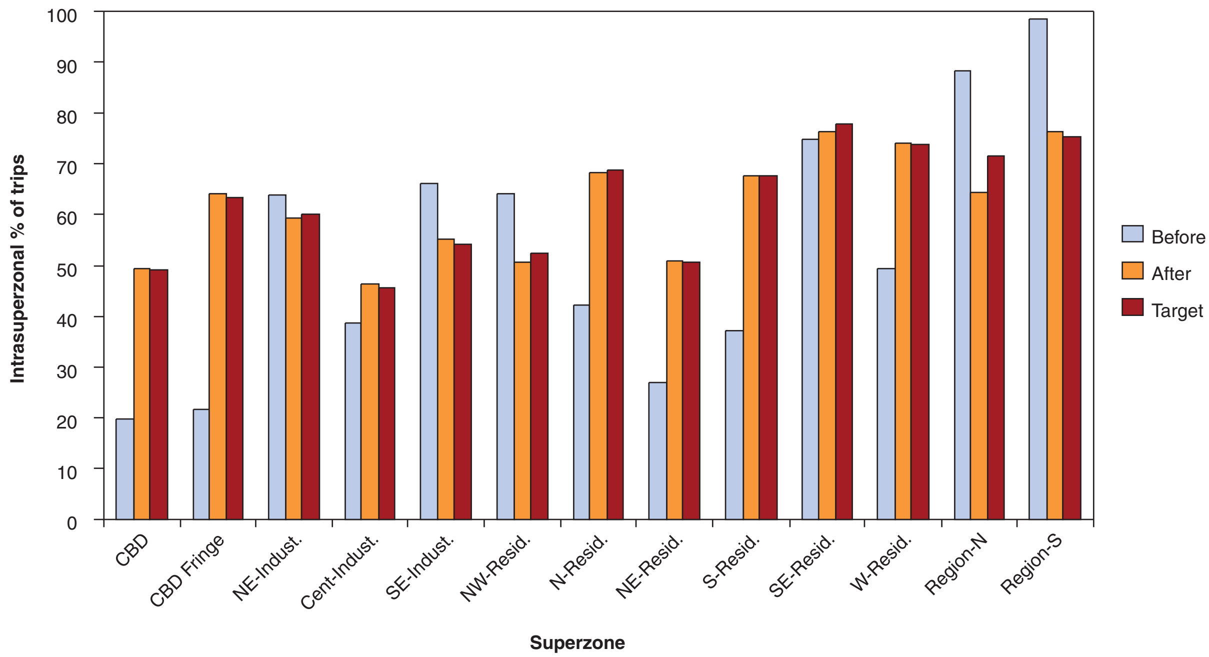

FIGURE 3 Match of tour-based microsimulation results to intrasuperzonal proportion of trip (medium vehicle) targets at start and end of calibration (CBD = central business district).

central business district that also originated within the central business district); and

- Total trips by vehicle type and industry.

The matches to observed aggregate values were within reasonable margins in all cases and within a fraction of a percent in a large majority of cases. Figure 3 shows the results of the calibration with regard to the intrasuperzonal proportions of trips for the 13 superzones. Figure 4 shows the results after calibration with regard to the number of stops for the 13 segments. Figure 5 shows the changes in match for tour purpose and vehicle type proportions by employment category as the iterations in calibration proceeded.

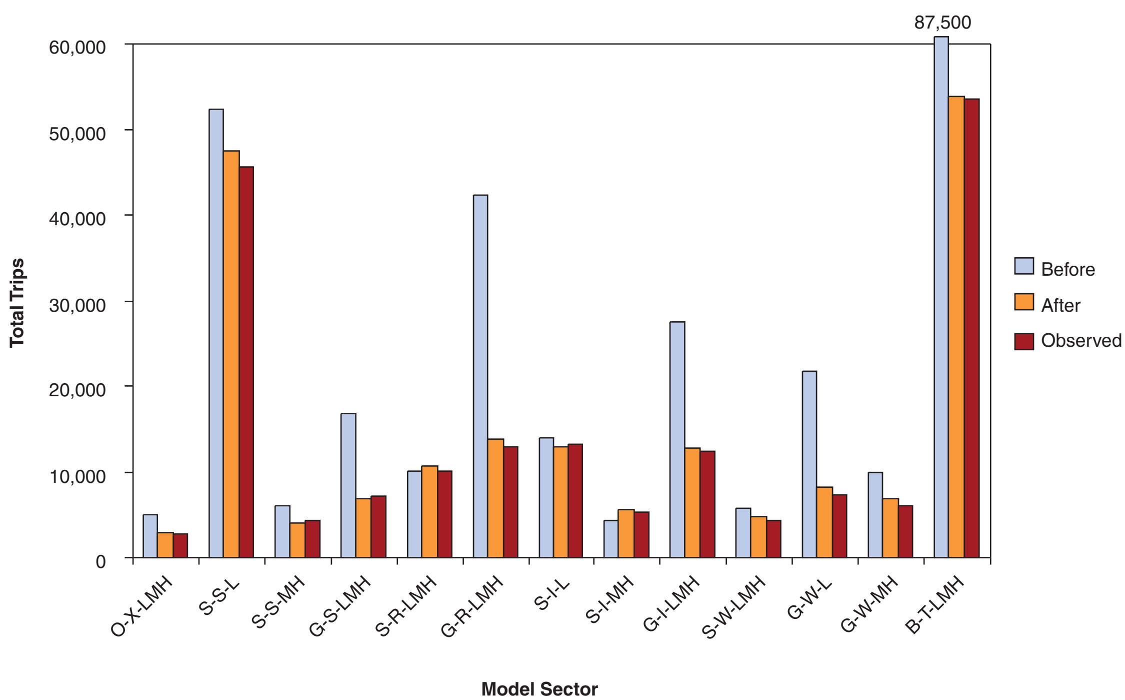

FIGURE 4 Match of tour-based microsimulation results to number of stops by segment at start.

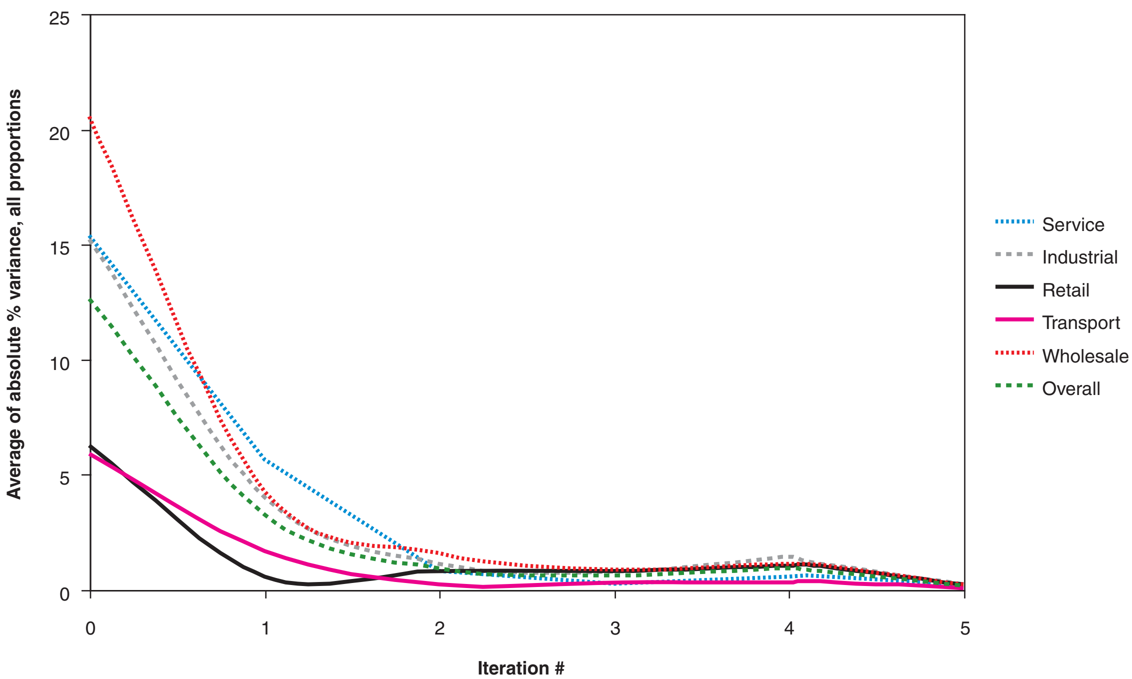

FIGURE 5 Changes in match of tour-based microsimulation results to proportions of tours by tour purpose and vehicle type targets over early series of iterations in calibration.

Figure 6 shows the link-level flows of heavy vehicles only obtained when the full Calgary RTM is run, including the CVM, the personal travel model, and external-internal component, for the model base year. This resulting assignment provides a good fit with observed patterns—closely matching observed flows and displaying a focus on industrial areas (those with darker shade) and an adherence to truck routes.

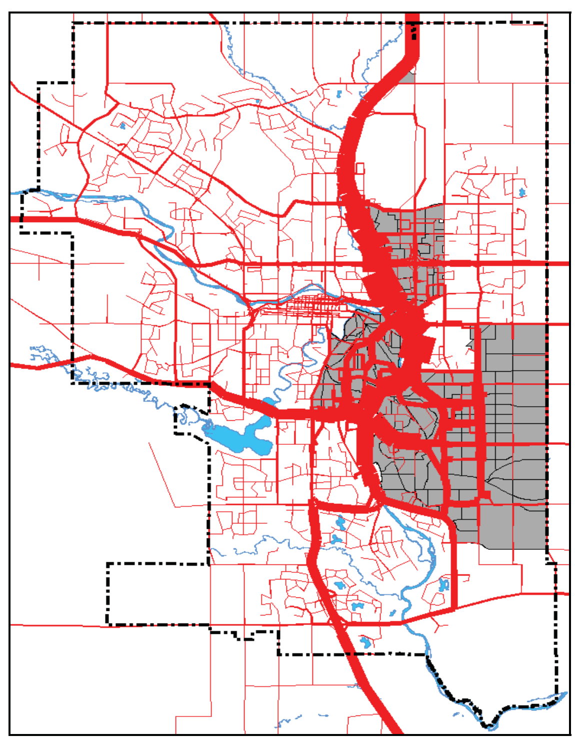

FIGURE 6 Plot of heavy-vehicle flows resulting from full Calgary CVM. Simulated patterns closely match observed flows and display a focus on industrial areas (shown in darker shade) and an adherence to truck routes.

Model Capabilities

The calibrated tour-based microsimulation process for the commercial vehicle movement component, together with the other calibrated components of the Calgary RTM, provide a representation of the transportation system in the Calgary region that can be used in both forecasting and policy analysis. Its application in forecasting requires inputs concerning population, employment, and transport supply conditions similar to those required for the forecasting of household travel alone, along with information concerning truck route policy and vehicle-specific values of time and distance-based operating costs for commercial components.

For the analysis of policy affecting commercial movements, this representation will respond to changes with regard to

- Road network capacities and connectivity;
- Truck route policy;

- Road tolls;
- Fuel taxes;
- Household travel (resulting in changes in roadway congestion);
- Population level and spatial distribution; and
- Employment level, composition, and spatial distribution.

The responses to such changes will occur in multiple elements of the microsimulation. Tour generation, the allocation to start time period, tour purpose and vehicle type choice, next stop purpose, and next stop location all respond to changes in travel conditions. Thus, if travel conditions become more onerous for commercial movements—perhaps because the network becomes more congested or because a key part of the truck route system is removed—commercial vehicles will not merely travel shorter distances; they will also make fewer stops per tour and more tours to fulfill the demand.

Conclusions

The CVM described here demonstrates the practical feasibility of using a tour-based microsimulation approach in the modeling of commercial vehicle movements in a novel way that allows the incorporation of representations of these influences.

The following are some of the notable aspects of the model:

- A tour generation element that includes a response to changes in transport conditions such that (in the short run) more tours arise when travel times increase;
- Variation in tour primary purpose and vehicle choice across a broad spectrum of activities and in response to changes in employment, population, and resulting accessibilities;
- A "growing" of tours more consistent with the nature of commercial movements with potentially larger numbers of equally important stops, as opposed to the "rubber-banding" process typically used in the representation of tours of household movements;
- Representation of the influence of tour duration and, at least partially, the time of day on tour patterns;
- Consideration of the physical shape of tours;
- Responsiveness to changes in truck route policy as well as infrastructure and cost changes specific to three categories of commercial vehicle;
- Separation of the fleet allocator and shipment-focused components of commercial movements;
- A range of interactions among the elements such that changes to the inputs affect the simulated behavior in a variety of dimensions; and
- A set of alternative specific constants for each element that allows calibration of the full microsimulation system to aggregate targets.

One of the advantages of this modeling approach is that it does not rely on any explicit representation of shipments or related transactions. Dealing with shipments, translating from commodity flows to shipment sizes to vehicle allocations, introduces a number of complexities. Some impressive work has been done by others seeking to represent these complexities. The approach used here bypasses much of the need for this additional complexity by focusing on vehicles through the use of generation rates and vehicle allocation models that implicitly take much of this into account parsimoniously. A complete and accurate representation of the full range of factors influencing the translations from commodity flows to shipment sizes to vehicle allocations would provide a model with a more robust policy responsiveness, but in a practical setting, the model described here is in many cases a more realistic solution.

At this point the system is being used in practical policy analysis work. The expectation is that more will be learned about the capabilities of the model and its use as this work progresses and that the need for further improvements will be identified. In addition, the successful implementation of this model in Calgary suggests the potential for successful implementation elsewhere—in fact, models based on this approach and structure are under development for Edmonton in Canada and Ohio in the United States. This has included reusing (with suitable recalibration) the destination choice components in particular—where the greatest amount of data manipulation and work arises.

Even without further improvements, the current system provides a useful tool, taking both the representation and the associated understanding of urban commercial movements well beyond the freight-only, large-truck-only, and regional-level approaches used previously. It permits a much richer treatment of relevant aspects such as the importance of trip chaining and less-than-load hauling, the significance of service delivery as a motivator for travel, and the role of light commercial vehicles. The system points a way ahead in the modeling of the commercial vehicle sector of the urban transportation system.

Acknowledgments

The City of Calgary, the City of Edmonton, and Alberta Transportation funded much of the development work described here, along with the associated data collection. Kevin Stefan of the City of Calgary did much of the work in developing the microsimulation system described.

Dianne Atkins, Ali Farhan, David Kim, Douglas Morgan, and Paul McMillan of the City of Calgary and John Abraham of the University of Calgary also contributed to the work.

Some of the research and the preparation of this paper were funded from grants provided by the Natural Sciences and Engineering Council of Canada and the Institute for Advanced Policy Research at the University of Calgary.

The material presented in this paper in places draws heavily from certain components of a manuscript submitted to the *Transportation Research Record: Journal of the Transportation Research Board* for consideration for publication.

References

1. Jonnalagadda, N., J. Freedman, W. A. Davidson, and J. D. Hunt. Development of Microsimulation Activity-Based Model for San Francisco: Destination and Mode Choice Models. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1777*, TRB, National Research Council, Washington, D.C., 2001, pp. 25–35.
2. Hunt, J. D., and D. G. Morgan. The Calgary Region Commodity Flow Survey. *Proc., 2001 Annual Conference of the Canadian Institute of Transportation Engineers*, Calgary, Alberta, Canada, May 2001.
3. Hunt, J. D., K. J. Stefan, and A. T. Brownlee. Establishment-Based Survey of Urban Commercial Vehicle Movements in Alberta, Canada: Survey Design, Implementation, and Results. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1957*, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 75–83.
4. *North American Industry Classification System—Canada 1997*. Statistics Canada, Ottawa, Ontario, Canada, 1998.

Discussion

Scott Drumm, Port of Portland

This discussion is framed by a view of the Calgary regional travel model from a freight data perspective and from professional experience working with a truck model in Portland, Oregon. Thus, the comments are greatly influenced by both perspectives. The review is organized on the basis of five key themes important for freight modeling:

- Greater coverage of truck types and activities,
- Linkage between freight and land use,
- Connectivity with economic models,
- Ease of data acquisition, and
- Evolution from truck to freight models.

The first theme concerns having greater coverage of truck types, sizes, and activities in freight models, including

- Smaller trucks,
- Interactions with heavy-truck trips,
- Truck destinations, and
- Coverage of nonfreight stops (services).

At the local level, policy makers as well as business leaders are becoming more interested in understanding the movement of not only heavy trucks but also commercial and service trucks. These vehicles generate the bulk of truck trips on a local or regional transportation system. Understanding their role, behavior, and needs will be necessary if freight modeling is to help build an accurate picture of goods movement. The Calgary model leads us in that direction with its inclusion of a broad range of truck types and nonfreight (service) stops. This element of intraregional trips and small truck movements is an area not well covered in most models.

Linkage between freight and land use is becoming increasingly important in public policy and urban planning discussions. Land use is a prime factor in determining where freight moves. As land at key freeway interchanges, near inter- and multimodal facilities, and in zoned industrial areas becomes more scarce, freight models linked to land use have an important role in helping regions and localities determine the trade-offs between various transportation and land use decisions. The Calgary model, as well as the Oregon statewide model (see Oregon Generation 1 Land Use–Transport Economic Model Treatment of Commercial Movements: Case Example), has begun this convergence.

One area where freight models struggle is with connectivity with economic models. The structure and performance of the model area's economy influence traffic volumes generally, modal volumes specifically, and trip geography. Furthermore, the economy and economic models serve as the basis for projections of freight growth. If one is trying to sort out what is happening on the surface transportation system at the present, this tie is not necessary. On the other hand, if a model is to be used to project where trucks are going to be in the future, understanding where the economy is headed is essential. The Calgary model lacks this link, but its use is not as much oriented toward the future as it is toward understanding how the system functions today. The Oregon statewide model, however, is trying to project the future, and it links to economic inputs as its first step.

An important consideration in the development of a model is the ease of data acquisition. If a model is to be kept current, the data supporting it must be readily available and easy to obtain. If this is not the case, updating the model will become costly. The model structure must also be able to accommodate data updates easily. However, there is a trade-off. If one builds a model such that inputting new or updated data is easy and acquiring that data is simple, one likely sacrifices accuracy. This is shown in the Calgary model. The data are detailed and were time-intensive to collect, thus making future updates more challenging. The accuracy, though, benefits from this investment in time and resources. The Oregon model is based on commodity flow forecasts, which are relatively easy to obtain, but because it does not have the level of detail or reliance on primary data, its accuracy is somewhat lessened.

If models are to be truly effective in helping make investment decisions with regard to goods movement, evolution from truck to freight models must occur. Most models, such as Calgary's and the Portland truck model, focus on trucks. Although there are many challenges in developing models such as these, the practice will need to move toward multimodal freight models. This will afford the ability to understand and predict mode shift, determine where investments in nonroad modes will benefit the road and highway system, and understand how changes in one mode or its facilities cascade throughout the goods movement system.

In conclusion, different models serve different purposes, and there are many levels of sophistication in goods movement models. The ultimate objective is to answer the right questions with the right models. Understanding what question is to be answered becomes the primary factor in determining how to build a model or which model to use. Every model has its strengths and weaknesses, and any given model may not meet a specific area's needs. On the basis of an understanding of the questions that the Calgary region needed to answer, the model yielded the kind of outputs that were sought. It also provides ideas that can be applied in other areas. Through its accounting for a variety of commercial vehicle types and activities, the commercial vehicle component of the Calgary regional travel model is moving in the right direction.

The views expressed in this paper are entirely those of the author and do not necessarily indicate the positions of any of the sponsoring agencies. Any errors or omissions are also solely the responsibility of the author.

Ontario Commercial Vehicle Survey

Use of Geographic Information Systems for Data Collection, Processing, Analysis, and Dissemination

Selva Sureshan, *Ontario Ministry of Transportation*

The Ontario Commercial Vehicle Survey (CVS) is part of the National Roadside Study (NRS) conducted by Transport Canada about every 5 years across Canada on major highways and international border crossings. The NRS is a roadside truck driver intercept survey that captures many aspects of the trip, including route, commodity, vehicle weight and dimensions, and driver and carrier profile.

In the past 10 years, significant improvements have been made in data collection, processing, and reporting techniques to enhance the accuracy of the survey data. The direct data entry method was introduced in 1995, followed by data processing and reporting techniques based on geographic information systems (GIS) in the 1999–2001 survey. The ongoing 2005–2007 survey software includes a GIS-based routing component that will enable the surveyor to confirm the route with the driver and modify it, if required, to get an accurate profile of the highways used for the trip.

Currently the CVS is the most detailed source of intercity commercial vehicle characteristics and commodity flow information available to the Ontario Ministry of Transportation (MTO). The data have been used by various levels of government and private-sector consultants for studies to prioritize multiyear strategic investments.

GIS Platform

TransCAD is the primary GIS platform used by MTO at various stages of data collection, review, and analysis and reporting of CVS data. In addition, an ArcGIS-based reporting product has been developed to generate reports in a predefined format.

Data Collection

In the 1999–2001 survey, no GIS component was used in the data collection phase. Surveys were conducted with direct data entry software on a tablet computer using a DOS-based application. No routing-based validity checks were performed. Drivers were asked to list the highways used in the trip to confirm the route during the data processing phase.

Data Processing

The primary assumption in the CVS is that a survey is not only a sample at the site where it was collected but also a secondary sample for all sites along the route of the projected trip. Therefore, each record must be reviewed for accuracy and cleansed as much as possible to ensure that the survey is assigned to the sites that are appropriate to the sequence of trip legs.

Both GIS and non-GIS techniques had been used to review each record for the following issues:

- Handwriting recognition—incorrect interpretation of entries,
- Incorrect jurisdictions,
- Missing border or provincial crossings, and
- Drivers' interpretation of the definition of "trip."

During the survey, up to 11 geographic points directly related to the trip were collected, in addition to another

The peer review of this paper was conducted by the Committee on Freight Demand Modeling: A Conference on Tools for Public-Sector Decision Making.

four location-based data points indirectly related to that trip. An application, ROCMOD, ran in the TransCAD environment and provided all this information on a single screen to process the surveys on a record-by-record basis.

Every time a route was generated, the application compiled a list of predefined points of interest (POIs) along the route. At the data processing stage, the POIs were limited to the survey stations and provincial crossings. More points are being added later to enable assignments and traffic analysis, as required. Currently, there are more than 1,000 directional POIs on the network across Canada and the United States. They play a pivotal role in the expansion of the database as control points to eliminate double counting associated with combining surveys from more than 150 sites captured over several months, and they aid in future analysis by acting as select link analysis points.

Data Assignment and Analysis

There are no zone systems in the CVS model. Because TransCAD does not restrict the number of zones for an assignment, origin–destination (O-D) matrices are created on an on-demand basis by using the nodes closest to trip stops as centroids. A trip is broken down into several subtrips to accommodate all the intermediate stops. It was found that about 15 percent of the truck trips did not follow the shortest path between the origin and the destination. Breaking down of the trips was found to be necessary to trace the path of these trips correctly.

The use of dynamic generation of O-D matrices provides MTO with tremendous flexibility to assign trips. Any subset of the database can be selected and assigned to the network by simply specifying the condition for the selection.

Another advantage of compiling the matrices on demand is that it allows the user to perform robust select link analyses compared with traditional select link analyses based on a predefined matrix. In fact, in MTO's model, a select link assignment is treated the same way as any other assignment. It also allows the user to perform multilink analysis, where trips common to multiple highway links can be assigned to the network. For example, all trips that passed both Ambassador Bridge between Ontario and Michigan and Peace Bridge between Ontario and New York can be easily selected and assigned to the network.

Reporting

MTO has recently launched a new application to create a three- or four-page report containing commonly requested charts, graphs, and maps that summarize various characteristics of the truck traffic. Most reports are three pages long with the exception of data collection sites (DCS), for which a four-page report is produced. In addition to the standard report, DCS reports contain summaries of site-specific data, such as information on the sample collected at the site and average traffic characteristics.

The CVS reporting system was developed with the ArcGIS platform to utilize corporately available resources within MTO. A report can be created for any predefined POI on the highway system. It also allows users to perform area- or corridor-type analysis by using several POIs and examining trips that passed any one or all of the selected POIs. A POI may be selected by using a search list or the map.

The reporting system takes the select link analysis a step further by allowing the user to study the truck characteristics in detail at any point on the highway system. In addition, like the CVS assignment procedures, the custom report feature of the system allows the user to produce reports based on any subset of data (e.g., all international trips, trucks with dangerous goods).

Lessons Learned and Innovations Under Development

Between 1999 and 2001, a significant amount of time was spent on data review that resulted in delays in releasing the data. It was recognized at the time that the accuracy of the data can be ensured only by minimizing errors and omissions during data collection, but because of the limitations in technology, comprehensive validity checks would have resulted in a sizable increase in survey time.

With the availability of affordably priced routing software, such as Microsoft MapPoint, and advances in computer technology, it became possible to incorporate the routing component in the 2005–2007 NRS during the face-to-face survey. An off-the-shelf consumer-based routing product was included, and the survey software is now able to harness the power of locating detailed addresses on the map to project the accurate route of the trip. In previous surveys, except for some major urban areas, for the most part only municipal-level information was collected. Surveyors had no ability to check the validity of the address given to them and cross-reference zip or postal codes with address and place name information provided by truck drivers.

Validating addresses and routes used for the trip during the survey is expected to improve the quality of the data collected in the 2005–2007 survey, and it promotes consistency in the collection of detailed trip end data.

Other Innovative Commercial Vehicle Tracking Methods

Roadside interviews are the most suitable avenue for collecting data about intercity movements. However, the use of roadside surveys in an urban environment is impossible because of safety issues. In addition, emerging privacy concerns are making the conduct of roadside interviews more difficult. It will be almost impossible to conduct roadside surveys in about a decade.

MTO is investigating the use of nonintrusive Global Positioning System (GPS) data to supplement, and eventually replace, data collected from roadside surveys. The number of trucks equipped with GPS receivers, which record the location of the vehicle every few seconds, has been increasing steadily over the past few years. Besides providing detailed O-D information, the GPS technology provides many other potential benefits:

1. Coverage of urban freight movement with detailed route origins and destinations and performance indicators;
2. Link-level congestion analysis, including travel time and speed;
3. Near real-time international border transit time monitoring;
4. Tools and reporting systems to measure economic impacts of delays due to incidents;
5. Fuel consumption and pollution analysis using GPS units that include engine data retrievers; and
6. Impacts of high-occupancy-vehicle lanes on general-purpose-lane traffic.

State of the Art—What's Needed?

Breakout Session

Michael D. Meyer, *Georgia Institute of Technology*

The objective of this breakout session was to identify ideas for freight modeling that consider new approaches, applications, coordination, data, model standards, and framework and that the U.S. Department of Transportation, researchers, and the vendor community can pursue.

Ideas that emerged from this conference could generally be grouped into four categories:

- Understanding of the system, the nature of modeling, and the role of modeling in decision making;
- Geography;
- Data; and
- Decision support tools (modeling techniques).

Understanding: Observations

Understanding, in all its ramifications from personnel skills to freight behavior, was a major concern. Specific research areas were not identified, but several areas of understanding were enumerated:

- Basic knowledge about logistics and business decision making under varying conditions by industry, sector, mode, season, and so forth
- Role of logistics in freight modeling and understanding of cost and pricing
- Accounting for dynamics of changing world
- Important relationship between public and private decision makers (e.g., on-land development)
- Relationship between freight movements and land uses and impacts on
  - Economic activity (jobs)
  - Income
  - Environment
  - Community land use
  - Value added of freight activities
- System performance measures, the role of freight movements, and operational goals
- Modal operational characteristics and network effects, with a focus on actual movement on the network
- Relationship between economic development and transportation agencies
- Better understanding of what is happening in other countries
- Personnel skills—training and education

Geography: Observations

Two aspects were identified relating to geography. First is the need for understanding, data, and decision support tools at different physical geographic levels as shown in Figure 1. Second is the need by decision makers to be able to move between these levels, as shown in Figure 2.

- Different geographic levels have different implications for data, modeling, and the use of results.
- The transportation system is being asked to do things it was not originally designed to do (e.g., ports are

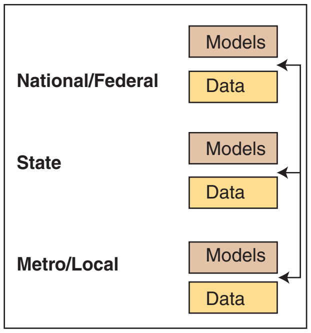

FIGURE 1 Physical geography.

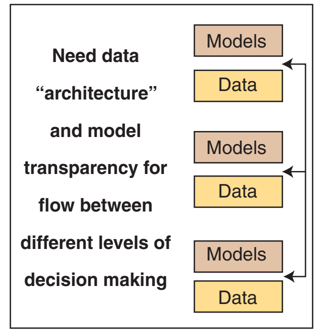

FIGURE 2 Movement between geographies.

traditionally local, but many now have national impacts). We need tools to deal with this phenomenon.

- There are important differences between jurisdictional boundaries and market boundaries. The latter are the key focus for freight modeling (megaregions).
- Public decisions vary by geographic level (e.g., policy development, financial analysis, regulatory issues, investment analysis, operational strategies).

Geography: Research Needs

Many of the items listed under the data and decision support tools sections have different requirements depending on the level of geography being considered and would best be considered separately at those levels. One interest is in a robust national freight flow model (prototype).

Data: Observations

How do we feed the beast? A recurring theme throughout the conference was for more, better, and more reliable information.

- We need to do a better job of monitoring system performance (e.g., accuracy of classification count equipment).
- Intelligent transportation system (ITS) technologies provide important opportunities for data collection.
- We need an organizational structure for shared data collection between public and private sources, recognizing concerns of the private sector. Is there a role for trade organizations and universities?

Data: Research Needs

- National data on through movements in metropolitan areas to complement metropolitan area decision tools
- Development of a freight data architecture and application scenarios for different geographic decision contexts
- Systematic and linked approach toward data collection and use
- Leadership in using available public and private databases
- Assessment of viability of ITS technologies for providing data for analysis, along with associated limitations
- Public Use Microdata Sample equivalent for freight geographic information
- Approach to capture raw trend data on a routine basis and industrywide
- Move from traditional paradigm of periodic, 5-year data collection to continuous flow of data and use in models
  - Subsample updating of Commodity Flow Survey (CFS)
  - Bayesian decision networks
  - Sample size increase of CFS
- More surveys when conducting decennial census, with homogeneous architecture
- Case studies of collaborative data efforts
- Transfer of data conclusions and underlying relationships from one location to another
- Better understanding of the transfer of methodologies and data use from one application and context to another
- Best practices of truck origin–destination collection methodologies and classification count matrices
- Additional guidance like *Quick Response Freight Manual* for data
- Information about "logistics for public receivers" (e.g., government buildings, schools)
- Relationship between land use and freight data
- Improvements and survivability of CFS and Vehicle Inventory and Use Survey

Decision Support Tools: Observations

- Decision support can take many forms, which begs the question of whether we need a model. Other options include Delphi, focus groups, and so forth.

- The most important factor in determining the type of decision support tools is the types of decisions that are being made.
- Different time scales exist for public- and private-sector decision making, which should be incorporated into decision support tools.
- How do pieces of models fit together?
- The current trend is to apply our professional expertise and analysis increasingly in a "real-time" world, yet many of the models are not robust enough to examine phenomena in this way (e.g., dynamic pricing).
- If we agree that experience has shown freight models to be important and useful, is the issue a need for better tools or that we have not communicated to the profession at large that the tools are adequate?
  – Maybe both . . . we have not answered all the questions.
  – We need to educate those who develop and use models and those who use the results.
- Applying the four-step modeling process to freight planning is dubious, and we need a different paradigm that incorporates the components shown in Figure 3.

Decision Support Tools: Research Needs

- Freight Model Improvement Program
- Key variables and relationships among variables for shipping decisions along with how to incorporate them into freight models

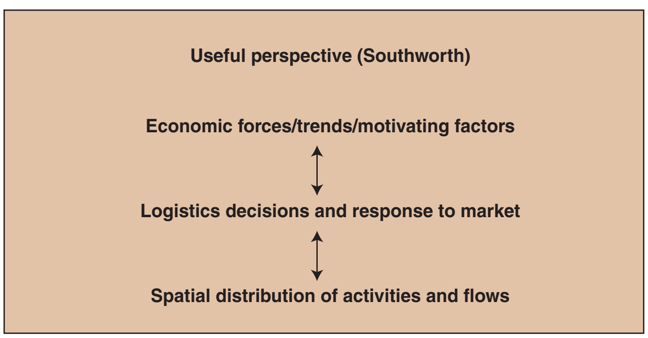

FIGURE 3 Perspective in modeling freight.

- Additional guidance like *Quick Response Freight Manual* for tools
- Strategies to communicate applicability and value of various decision tools, in particular, models
  – Role of governments
  – Vendors
  – Universities
  – Transportation Research Board
- Safety module as postprocessor of freight modeling
- Decision tools that link econometric and transportation models
- Decision tools that incorporate logistics
- Comparison of state-of-the-art models used in different contexts and for different purposes
- Freight operational models within decision analysis framework
- Multimodal and intermodal understanding, including short sea shipping, inland water, air cargo, and so forth
- Analysis tools that show environmental and land use effects of different investment and operational strategies at metropolitan area and local levels
- Decision support tools that incorporate uncertainty and risk associated with unknown future conditions
- Linkage to modeling regimes at more disaggregate geographic levels from national models that produces broad freight flows
- Proof of model's value and viability to be made available and disseminated . . . feedback loop

General: Research Needs

Several research needs identified during the breakout sessions applied more generally to the overall topic:

- Best practices in modeling and other techniques and data for different decision-making contexts;
- Performance standards, but no mandates, on "how to get there"; and
- Research digest that synthesizes the current state of knowledge.

Where Are We Going?

Industry Perspectives

Jim McClellan, *Woodside Consulting*
Bob Costello, *American Trucking Associations*
Bob James, *Port Authority of New York and New Jersey*

Railroad Perspective

Jim McClellan

Freight railroads are an important part of the transportation network, though not as important as trucking. Trucks dominate the movement of freight in terms of both tons carried and revenues. But railroads generate more ton-miles than trucking and account for more than 40 percent of freight ton-miles.

Utility coal, intermodal, agricultural products, and industrial products (automobiles, steel, chemicals, etc.) dominate the rail traffic mix. Growth has been especially strong in utility coal and Asian imports.

While intercity and commuter rail passenger services are operated, intercity services are largely irrelevant outside of the Northeast and certain Midwestern and West Coast markets. But commuter rail, once limited to the nation's oldest cities, is expanding as current systems add routes and new cities establish commuter rail networks.

Overall, railroads are in good financial and physical condition. Success has been driven by two major factors: decades of rigid cost control and a growing volume of freight traffic coupled with higher freight rates.

Railroads Face Two Major Challenges

First, service quality is fair to good but seldom as good as truck service. As a complex network business, high-quality rail service is hard to deliver, but if railroads are to play a greater role in the transportation scheme of things, they must provide better service.

Service quality is directly related to capacity, which is the second major challenge for the rail industry. Capacity is tight in many markets; any image of an industry awash in capacity is at least a decade out of date.

The capacity crunch is not a crisis; railroads are continuing to invest in resources needed to meet rising demand. But the system is crowded, and any disruption (weather related, an accident, etc.) can have a serious impact on the network.

Adding Capacity Is Complex and Costly

Available capacity depends on a number of components: motive power, cars, track, terminals, people, and control and maintenance systems. A shortage in any area will limit the capacity of the network.

And railroads are "site-specific." Crews are trained for specific routes; cars to handle Product A cannot handle Product B. Obviously, tracks and terminals are location-specific and are usually commodity-specific as well.

Capacity is costly. A locomotive can cost $2 million, a controlled siding $10 million, and an intermodal terminal $100 million or more. And it can take from a couple of years to up to a decade to put the assets in place.

The challenge is to have the right asset at the right place at the right time. Too much idle capacity almost ruined the rail industry in the 1960s and 1970s, and railroads cannot afford another cycle of too many assets.

But if assets are put in place too late (or not at all), congestion mounts (as do operating costs) and some revenues are lost.

Capacity and Demand Modeling

Railroads use demand models to project what kind of capacity is needed and where and when it will be needed. But most demand forecasting is imperfect when it comes to the kind of specific projections needed for what is often a microlevel investment decision. Customer projections (which are often wrong) as well as experience are used to supplement demand forecasts. Still, getting it right all the time has turned out to be an impossible dream.

Trucking Perspective

Bob Costello

Since trucks haul nearly 70 percent of the freight transportation tonnage in the United States, there is no single economic indicator that will provide a forecast of the demand for trucking services.

1. Real gross domestic product growth in the long run is correlated well with truck transportation, but on a quarter-to-quarter basis it may not be.
2. Manufacturing, retail, wholesale, and housing, among other things, are all important to gauge when demand for trucking services is being assessed. Among the various modes, trucking is the most balanced between bulk freight and general freight. The modes are split as follows: trucking, 54 percent bulk, 46 percent general; rail carload, 69 percent bulk, 31 percent general; rail intermodal, 6 percent bulk, 94 percent general; air, 0 percent bulk, 100 percent general; and water, 88 percent bulk, 12 percent general.
3. What you want to measure in trucking will determine what types of statistics you will look at and what government data you will use to forecast changes. We run into problems with standard government statistics because they are value based, not weight based. Estimates of the number of trucks needed have to be adjusted for weight or number of shipments or both.
4. The American Trucking Associations has developed a truck tonnage–weighted manufacturing production index that helps adjust for the differences between manufacturing value and weight. Production of higher-value, lower-weight goods has been growing faster than production of lower-value, higher-weight goods.
5. The shrinking of the size of consumer products also is not reflected in government data but is clearly affecting the growth rate of trucking volumes.

You have to be careful of structural trends in assessing trucking volumes for the following reasons:

1. Supply chain changes (shorter hauls, more frequent deliveries, and smaller inventories relative to sales),
2. Driver shortages (this is changing how the supply chain works, at least in some markets),
3. Modal shifts (some long-haul is going to intermodal, where it makes sense),
4. Prebuying of trucks due to government regulations (but are they all on the road?), and
5. The shrinking of freight (e.g., TVs and computer monitors are mostly flat panel now, which reduces the number of truck movements).

Port Perspective

Bob James

The Port of New York and New Jersey (PONYNJ) consists of heavy data users and collectors—and sometimes model users—for operations, planning, and education purposes. We must be engaged with others in beyond-the-gates planning and projects, a novelty for port commerce. We and our partners have a lot to do to make decisions that fit. It is broadly recognized in the region, especially in New Jersey, that the port is a key asset in maintaining and growing its prosperity, and thoughtful and sometimes dollar-full projects have emerged. Good models will help, but we need good data and the means to bring partners together to link and extend the beneficial impacts of our resources.

Background

PONYNJ is a landlord port, and we support or directly construct major facilities for our tenants. Facility planning models strongly inform our decision making. Our business imperative indicates that we must meet a triple bottom line:

- Provide efficient, effective, safe, and secure mobility through our facilities;
- Support and spur environmentally sustainable economic development; and
- Do so from our own fee-based resources.

Figure 1 shows a schematic of the port facilities.

The trade distribution for all of 2005 consisted of 4,792,922 total 20-foot equivalent units (TEUs), 2,803,447 total containers, 3,385,003 loaded TEUs, and 1,407,919 empty TEUs. Figure 2 provides a breakdown by geography.

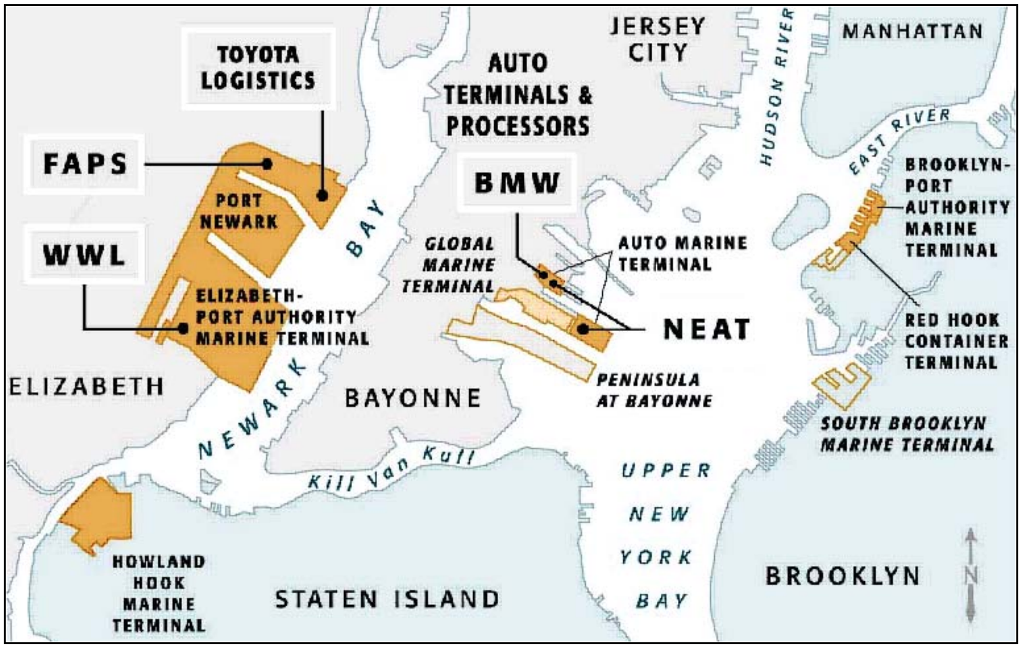

FIGURE 1 Port facilities and auto terminals.

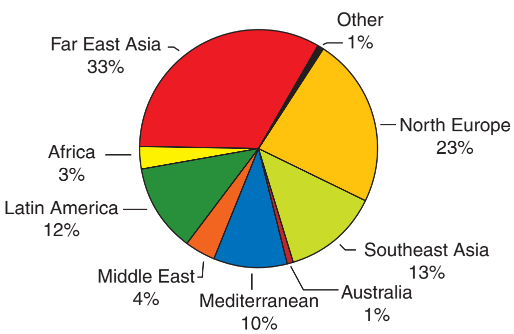

FIGURE 2 PONYNJ trade distribution for 2005.

FIGURE 3 Reach of PONYNJ.

PONYNJ handles about 12 percent of the nation's overseas cargo by volume. The airport and seaport complex is entrusted with more than 11 percent of the nation's total over-the-borders trade by value. We are operating in a demand-driven environment, and port volume has been growing by about 10 percent per year. In response, PONYNJ has an aggressive redevelopment program that includes channel deepening, expanded rail infrastructure, and terminal modernization.

The port's marine terminal highways handle an average of 9,632 trucks every day, with an average turn time of 1½ hours.

PONYNJ is within 700 miles (1,127 km) of most major cities and population centers in the northeastern United States and Canada, as shown in Figure 3. Cargo can be shipped easily to or from the port within 1 to 3 days by road, rail, or barge. The Northeast is the largest U.S. market, as indicated in Figure 4.

Access goals for the port include moving cargo through the gates to the first point of rest quickly and in

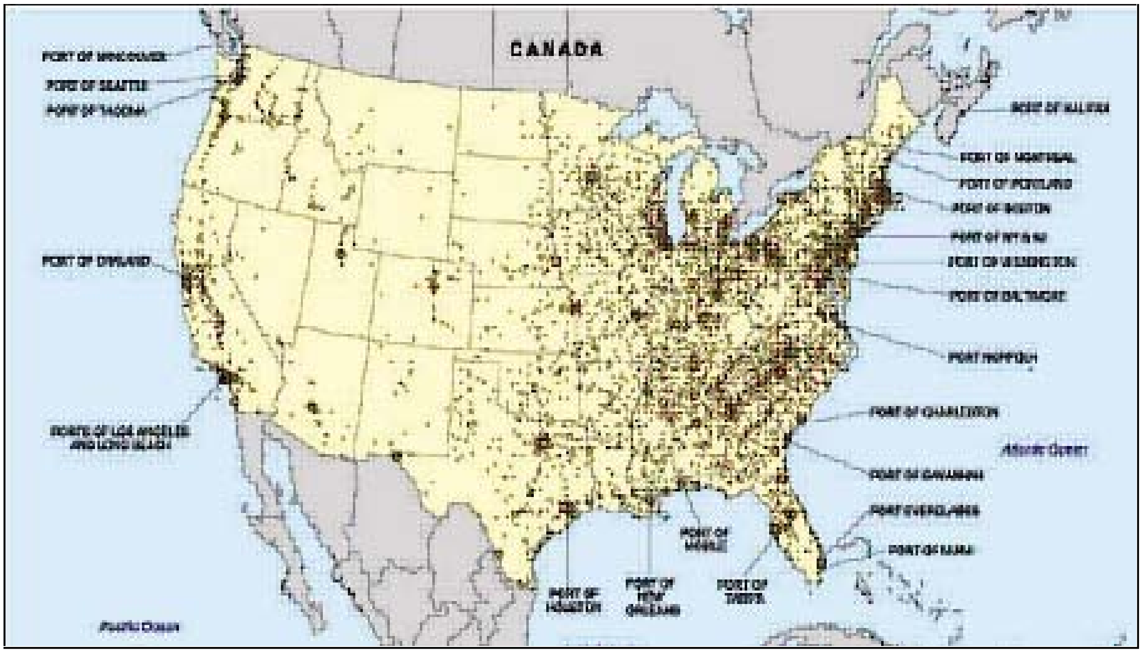

FIGURE 4 Cargo origins and destinations.

an environmentally sustainable manner while contributing to regional prosperity and quality of life.

Logistics

The traditional notion that port success can be almost solely based on the efficiency of its transfer platform is long gone. A port is part of a logistics chain that can stretch for thousands of miles across links that are strongly interdependent. As indicated in Figure 5, the chain of service needs limber links. The port must be concerned and active—subject to the reasonable bounds of its resources and influence with access beyond its gates.

To strengthen the links, the port must share logistics chain responsibilities with several partners and work with them to make the logistics chain stronger and environmentally sustainable. This means understanding the customer, public- and private-sector partners, and our own operating environment. To do this, we need data and planning tools, with modeling as part of this arsenal. We need to be able to answer the questions "How much can the system handle?" and "Can we achieve intermodal connectivity?"

In general, multimodal hubs and corridors consist of complex institutional arrangements. They tend to concentrate on local impacts but have highly distributed benefits. Chokepoints impede freight efficiency and freight security. Significant capital needs supersede traditional capital resources.

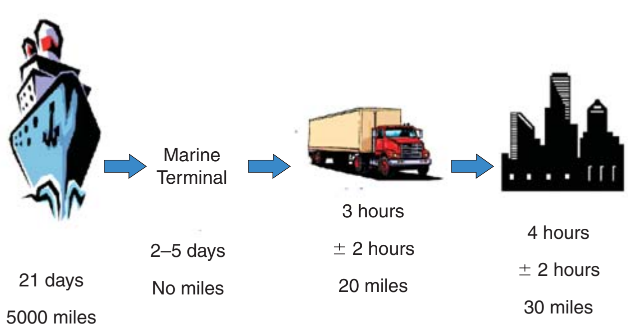

FIGURE 5 Chain of service.

Port Origin and Destination Study

Approximately 75 percent of all trucks arriving and 79 percent of all trucks leaving the port are coming from or going to New Jersey destinations. Four counties—Essex, Hudson, Middlesex, and Union—account for 66 percent of the origins and 70 percent of the destinations. New York State is next with 10 to 11 percent, of which 7 to 8 percent go to New York City's five boroughs. Figures 6 through 9 provide results from the origin and destination study.

Effective access will take teamwork with the New Jersey Department of Transportation, local communities, the North Jersey Transportation Planning Authority, the federal government, and the private sector.

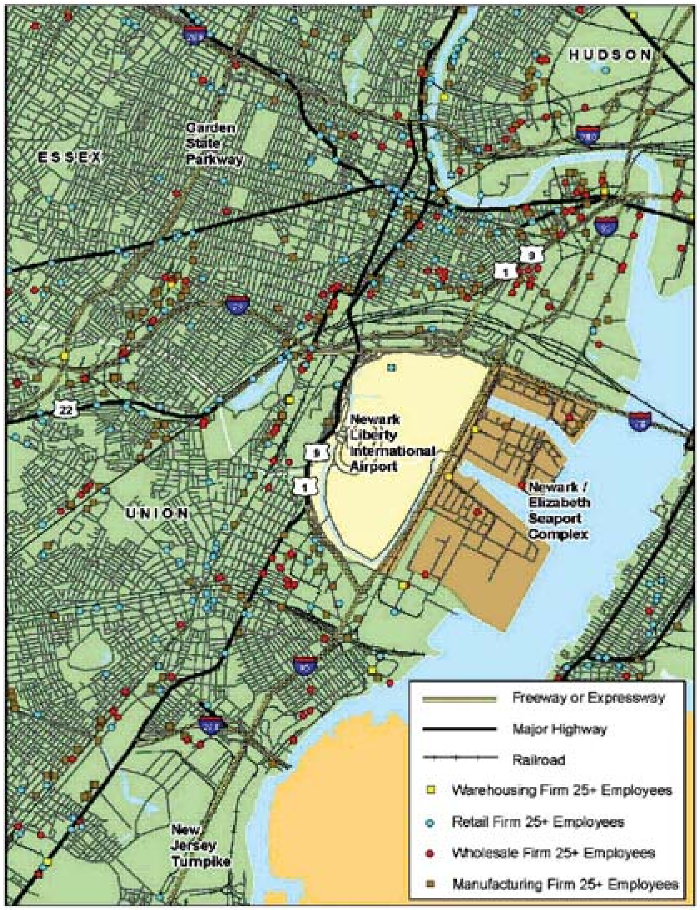

FIGURE 6 Local freight nodes in the Newark, New Jersey, area.

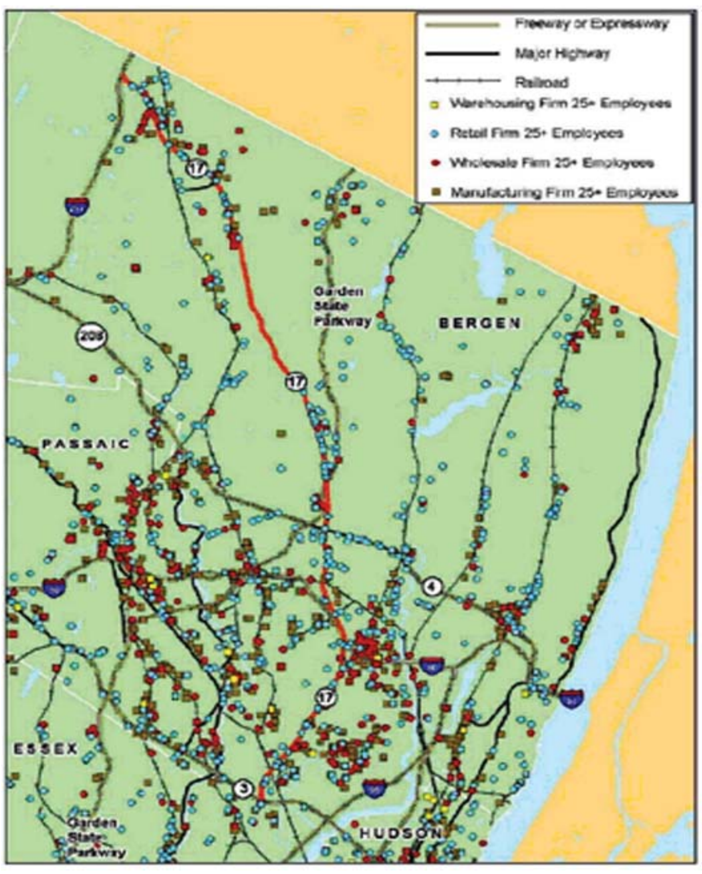

FIGURE 7 Local freight nodes (north).

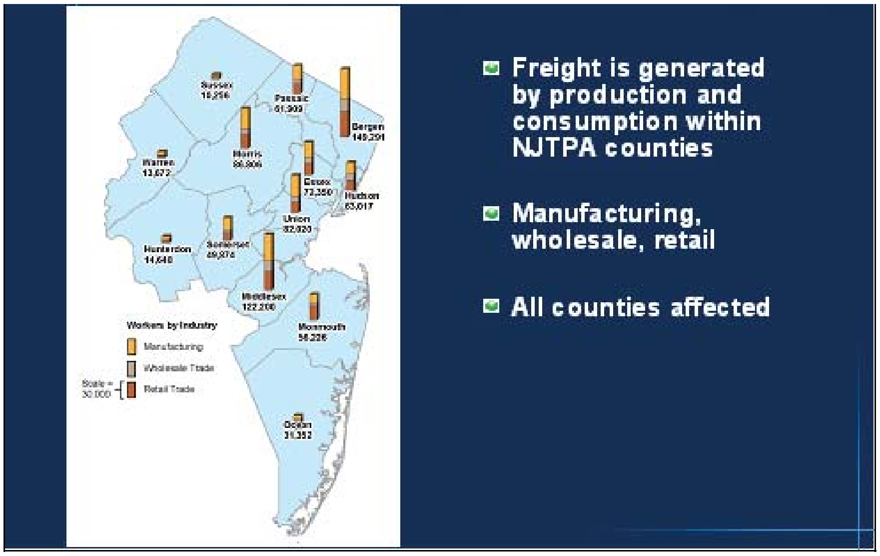

FIGURE 8 Freight generators from the *Current and Future Conditions Report* (NJTPA = North Jersey Transportation Planning Authority).

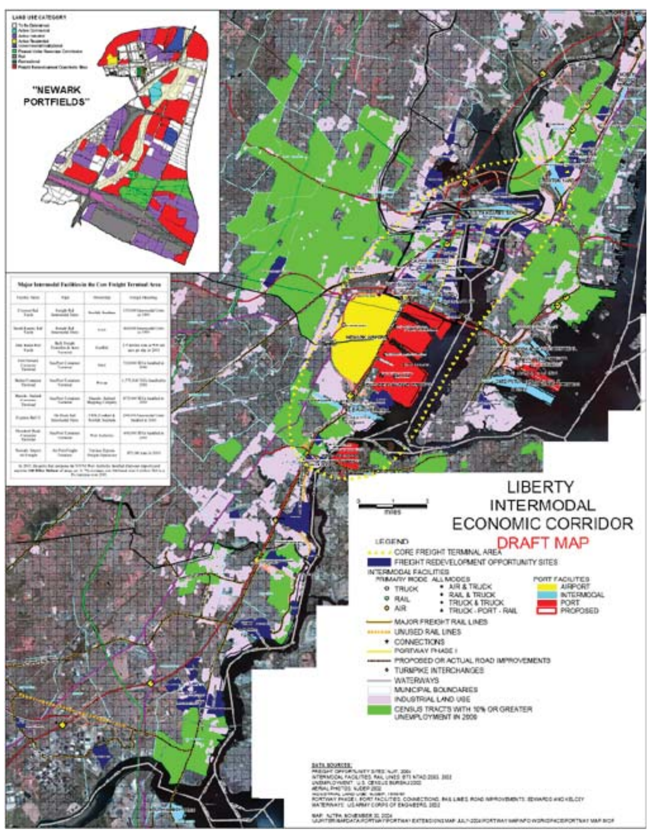

FIGURE 9 Liberty Intermodal Economic Corridor.

So Where Should Models Be Going?

What has been presented is not the Southern California picture or the picture for Portland, Savannah, or Seattle. In terms of space and land use constraints for port activities, right-of-way will figure heavily in our planning. Modeling tools must draw heavily from the reality of the differing locales and cannot substitute for local and regional data that are necessary to power them. The organizational capabilities and the ability to bring assets to the table will differ. To assist ports, follow the logistics chain.

Final Thought

Freight, like love, will find a way. The way that it finds can produce bliss or dysfunction. When you build your freight models, strive for a result that brings harmony (order to the freight path), if not eHarmony.

J. Susie Lahsene, Port of Portland, moderated this session.

Next Steps in the Public Sector

Rolf Schmitt, *Federal Highway Administration*
Jane Bachner, *Federal Railroad Administration*
Bruce Lambert, *U.S. Army Corps of Engineers*

View from the Federal Highway Administration

Rolf Schmitt

Several proposals currently resonate in the Federal Highway Administration (FHWA):

- To create a national freight flow model,
- To provide data more timely than once every 5 years, and
- To create a freight version of the Travel Model Improvement Program.

The Freight Analysis Framework (FAF) is a partial answer to the first two proposals. The FAF is a national model that provides a comprehensive picture of freight flows by commodity, mode, origin, and destination for 2002. It integrates the Commodity Flow Survey with other public data sources and estimates missing values. The methods and data are available and transparent. As currently planned,

- FAF flows will be converted to truck payloads and assigned to the highway network;
- FAF will include provisional annual updates by mode, origin, and destination, providing estimates for the years between the quinquennial Commodity Flow Surveys; and
- FAF will include forecasts based on economic trends to 2035, and the original FAF will be redone for 1997 with new methods to provide trend data.

The FAF is not a full-fledged national freight policy model. As a "what-if" policy analysis tool, FAF can reassign flows on the basis of exogenous changes to sources of demand, mode split, available highway links, and so forth. It will feed other models (e.g., the Highway Economic Requirements System, size and weight, cost allocation) to analyze the consequences of policy changes.

The FAF is definitely not a regional or local freight flow model. While it provides national context and external flows for states and localities, it does not provide detail inside its 114 regions and 17 additional international gateways. FAF flows can be disaggregated to county or smaller levels with econometric or spatial interaction models, but the likelihood of any local flow being accurate is minimal.

The FAF and the Commodity Flow Survey have both been criticized for not providing greater geographic detail. The data and modeling challenges become overwhelming given an origin–destination matrix with six modes, 40 commodities, and

- 50 states (600,000 cells);
- 114 Commodity Flow Survey regions (3.1 million cells);
- 172 Bureau of Economic Analysis areas (7.1 million cells);
- 370 metropolitan statistical areas (32.9 million cells);
- 3,141 counties and equivalents (2.4 billion cells);
- 33,000 zip codes (approximately) (261.4 billion cells); and
- 65,000 census tracts (approximately) (1.0 trillion cells).

Several strategies are used in transportation and other fields to collect or estimate small-area data nationwide: national census, nationally required local data collection (e.g., Highway Performance Monitoring System, unemployment data), national architecture for local data collection (e.g., Intelligent Transportation Systems Architecture, National Spatial Data Infrastructure), national control totals guiding local data collection [e.g., FAF in conjunction with the Freight Model Improvement Program(FMIP)], and commercial sources (e.g., Dunn and Bradstreet, TRANSEARCH). In choosing among these approaches, we should consider financial realities, respondent burden, and institutional challenges. In addition, we should consider the following questions:

- If we cannot meet all local planning needs with national data, how do we keep overextended national data from becoming a substitute for local knowledge?
- How do we support the development of local freight data within the context of national freight data among state and local agencies, "mom and pop" consultants, academic researchers, public interest groups, small shippers and carriers, and so forth?

FHWA is responding to these challenges by launching the FMIP, consistent with the proposal to create a freight version of the Travel Model Improvement Program. FMIP is intended to improve the state of the practice and the state of the art in analysis methods and data collection so that states and localities can fill in their parts of the FAF picture with local information. Comments from this conference will be considered by FHWA in its agency research and development agenda; ideas for university transportation centers, cooperative research programs, and other venues and partners; and training initiatives through the Freight Professional Development Program. The following are among FHWA's concerns:

- How should FMIP build on the successes of the Travel Model Improvement Program?
- What pitfalls of the Travel Model Improvement Program should FMIP avoid?
- What should FMIP try to accomplish in the next 3 years?
- What should FMIP try to accomplish over the longer period covered by the next reauthorization?

Other topics warranting consideration include defining a freight architecture, identifying commodity classifications, identifying ways to use intelligent transportation system (ITS) data, defining and using performance measures, determining the relationships and trade-offs between supply chains and geography, exploring alternative futures, and identifying key questions that are likely to be posed.

Freight Architecture

Several conference attendees called for development of a freight architecture. What do we mean by architecture, and what data will the architecture organize or produce? The FAF provides one form of architecture in the way it integrates data with models. TRB's *Special Report 276* proposes an architecture built on a series of coordinated surveys. ITS architecture includes elements to share data on vehicles, drivers, and payloads across agencies at the border. The International Trade Data System establishes data requirements for shipments through international gateways. Can one architecture fit all?

Commodity Classification

We have multiple classification systems for multiple purposes, and crosswalks are imperfect. The Standard Classification of Transported Goods and Harmonized System are based on trade, while the Standard Transportation Commodity Codes and Census product codes are based on industry of shipper. Can these systems be linked with or absorbed into the North American Product Classification System now under development by the United States, Canada, and Mexico?

While commodity, product, and industrial classification systems can be related, nothing currently links with land use classification. Land use classification is used by local agencies to represent observed economic activity and is not standardized. It also does not necessarily represent freight well (e.g., not all warehouses are the same, especially with respect to truck trip generation). Few theoretical or practical bridges have been developed between land use classification and industrial, product, or commodity classification systems.

Use of ITS Data

ITS data are more precise, more timely, less expensive, and less intrusive or burdensome than surveys but cover narrower slices of transportation and often involve poorly documented quality. How do we filter spurious observations without losing serendipity? How do we integrate ITS data with other data? Should ITS data be incorporated into standard models and other analysis tools or are new tools needed to use these data?

Freight Performance Measures

In an 1848 speech in favor of public improvements to transportation, Abraham Lincoln said, "Statistics will save us from doing what we do in wrong places" and "that which is produced in one place to be consumed in another; the capacity of each locality for producing a greater surplus; the natural means of transportation, and their susceptibility for improvement; the hindrances, delays, and losses of life and property during transportation, and the causes of each. . . . These statistics might be equally accessible, as they would be equally useful, to both the nation and the states."

How can we use models to generate performance measures and set performance targets? Conversely, can performance measurement systems become a new source of data for models? One example is making use of data on speed and reliability on intercity highway networks based on tracking 250,000 trucks, collected through a partnership between FHWA, the trucking industry, and a communications vendor.

Supply Chains Versus Geography

Economic relationships are supported by supply chains, and supply chains create freight flows on the transportation system between geographic areas. Public agency decision makers are responsible for economic health, transportation, and other concerns in geographic areas. Most transportation and commodity flow data are geographic, most economic data are interindustry and aspatial, and most data on supply chains are anecdotal. It is not clear from the presentations that we have effective models and data to link economic transactions among industries with supply chains and supply chains with commodity flows among regions. Links between economic and commodity flow forecasts typically depend on stable value-to-weight relationships. If we forecast in 1976 the exact amount spent in 2006 on prerecorded music, how many tons of vinyl and eight-track tapes would we forecast to be shipped today?

Alternative Futures

Forecasts are typically the what-if-trends-remain-unchanged scenario with high/optimistic and low/pessimistic alternatives. Alternatives should include shifts among trading partners, geographic concentration versus diffusion, and other types of major change. One approach is to identify, monitor, and build scenarios around conditions that would trigger major change (Peter Schwartz, *The Art of the Long View: Planning for the Future in an Uncertain World*, 1991).

Key Questions for Possible Data Collection or Model Development

Before we undertake the development of new data or models, we should consider two key questions. Would decisions be different with no data or the wrong data from observations or from models? How much geographic and other detail, accuracy, and timeliness are required for the observed, estimated, or forecast data to make a positive difference in public and private decisions?

View from the Federal Railroad Administration

Jane Bachner

The form sent to all the speakers for this conference asked us to list our credentials with respect to modeling. I was at somewhat of a loss, since I am not a modeler. I am an economist, but not an econometrician. So, I somewhat facetiously wrote that my "credential" was over 30 years experience working on policy issues at the U.S. Department of Transportation (USDOT). In retrospect, however, I think that is a key qualification for talking about modeling. I may not create models myself, but I use their results to help shape recommendations on rail and intermodal issues.

The models we are interested in are those that provide input for major policy decisions; they help us determine the likely consequences of action—or inaction. This is particularly important when the action is controversial, such as tolled truck lanes. Is it worthwhile going through a difficult political fight to have a change implemented if, when you are all through and you have won, the outcome is not what you expected? Not only have you not solved the problem, you have lost whatever credibility you had.

Transportation policy makers at the federal level are facing a wide range of issues that must be resolved if the freight network is to function properly and keep the economy strong. At USDOT, we need to develop options and recommendations for our own proposals and assess ideas proposed by others. I can think of several examples of the types of issues that we are dealing with now, or will be in the next few years, where we need good modeling capabilities to help the analysis.

We all want to ensure that hazardous materials are carried in the safest way possible. Some cities are trying to ban these shipments—by rail and by truck—through populated areas. Good models can help determine whether rerouting would make the shipment safer or actually more dangerous because of circuitousness, terrain conditions, and other factors.

There are proposals to increase truck size and weight limits, boost productivity, and help mitigate congestion by carrying the same level of traffic in fewer trucks. Good mode split–shipper choice models can assess the effect of these changes on traffic currently moving via intermodal service—would shipments now moving long distance by rail switch back to highway? Would that exacerbate congestion rather than mitigate it?

We all know about the crisis in highway funding. Many states are looking to tolling to fund investment in new highway capacity. Policy makers need models to give us a good picture of what the likely effects are. Would freight pay the extra cost, or divert to other routes, or other modes, leaving an expensive white elephant? Would tolling on existing roads cause shifts to other routes as well?

The increasing trend of using public–private partnerships to fund large infrastructure investments calls for increased use of modeling to help guide the decision process. Capacity models can help us assess, on a network or regional basis, whether the investments will have the desired results. They can also help us determine whether the transportation system is robust enough to cope with changes in export and import patterns. If foreign manufacturing centers shift to locations where the Suez Canal to East Coast ports is the most efficient water route, will our surface network be adequate to carry the traffic? How do we plan investments now that will give us the flexibility to weather these shifts?

We also need to be sure we are building the right type of models. At the federal level, we need flexible models that can be adapted to help assess all types of questions. Elaborate models are not necessarily the best. The more difficult it is to obtain—and maintain—data, and the more complex the model, the less useful it can be. That is not to say that we should not always be working to obtain better data, but we should make the best use of what we have.

Someone said that it is not models we need—it is knowledge. Models are only useful if they help us make better decisions, and to do that, they need to be grounded in the real world. We must have a good understanding of how shippers, carriers, and receivers act now, to figure out how they would react to policy changes. That is the only way we have a chance of making sure our changes have the desired outcome.

View from the U.S. Army Corps of Engineers

Bruce Lambert

The awareness of freight mobility is rising. We perceive an urgency, in part, because everyone is now a "traffic engineer" experiencing congestion. The numbers of trucks operating on the nation's roads, balanced against increasing economic–environmental concerns for existing and new projects, threaten to overwhelm the ability of the system to sustain operations and make improvements. If we assume that large infrastructure projects, with the exception of railways, are financed by public agencies, these agencies are facing challenges to respond effectively, either because of funding shortfalls or program inflexibility. Often, we understand that we should focus on the overall system. However, because of funding and program management, the project perspective continues to move us away from programs that serve the broader system perspective. These and other national-level discussions about freight mobility will continue, but we are challenged with the paradox of effectively understanding a complex transport system and articulating the associated needs to decision makers in both the public and the private sectors.

For every significant challenge, several items must be addressed that raise the awareness of the unique needs of freight movement and provide mechanisms to examine possible solutions. One of the challenges is that we, as a profession, are unable to fully articulate our needs concerning system improvements. If we simply built or programmed all the proposed improvements across the nation, the cost would be astronomical, and frankly, not a good use of resources. This "total" ignores a number of relevant trends that shape long-term demand for transportation infrastructure. Transportation is a dynamic industry that generates additional capacity, both physical and operational, by leveraging information on shipments, location, and supply chain elements. Furthermore, institutions remain critical to making improvements or imposing new restrictions through new policies and procedures. We also have to assume that changes in operational structures and shipment types and quantities will increase productivity. We are already building new infrastructure (either hard concrete or ITS) that will change future system capacity. The reality is that other users will come into the system, changing the level of demand for transportation services. What, then, is the real need we are trying to program for the future? On the basis of these trends, it may be lower than initially proposed, depending on the response to the perception of future system capacity and demand.

For freight mobility improvements, we, the practitioners and data providers, must understand both the data and the modeling challenges when we answer the questions of decision makers. For data, we must first ask whether we have the necessary data elements in place to meet the challenges facing us today. What we know and what we can evaluate from the current data are important in understanding what additional information is needed. In this context, we can properly evaluate our current programs and identify future data programs to improve system coverage. Furthermore, we should consider the possibility of working with nontraditional data sources or forming public–private partnerships. The work of FHWA and the American Trucking Research Institute on the Travel Time in Freight Significant Corridors is a good example of marrying the needs between the public and private sectors to understand operational issues.

With regard to models, we must be able to explain what our models tell us consistently and reliably, particularly if others attempt to answer the same question. We also must recognize that decision makers are often unable to fully comprehend what we present to them about the nature of traffic and the economic linkages of a project across the system. To make improvements to this system, we must rely on models that answer legislative mandates, but these models must also pass the "smell test" and be accepted by both other practitioners and academicians. One approach is to link nested hierarchical models into a decision framework. These models provide different answers, depending on the level of the economy as defined by some combination of industry type, political or economic geography, and the physical transportation network. This approach should recognize that each level possesses unique data and modeling needs that are not necessarily shared among other levels but that broad elements should be exchangeable. This approach allows us to link operational and planning models while allowing us to recognize that we do not have models to answer every question in the same manner. While models are important, they are only as good as their application by practitioners. Ignoring training and staff development continues to be as glaring a failure as not using the correct data or model.

A key linkage between data and models is often misunderstood. We find ourselves in meetings like this one asking, "Why does no one love us?" Addressing this challenge remains critical in sustaining or expanding data and modeling efforts for freight studies. The question centers on two different elements of the freight data and modeling profession: the data provider and the analyst.

The data provider is confronted by not necessarily knowing all the users or the uses of the data once released. Generally, any feedback mechanism is fairly flawed because usually only "power users" will take the time to comment on or critique the data program. This feedback may overstate the need for improving a given data set for a wide variety of users while also requesting additional data elements or formats resulting in increased costs. Furthermore, data providers often seek a level of data purity that may never be sustained on the basis of the challenges of capturing transportation information. While data providers seek to release defensible, replicable, and reviewable data, they may not possess the industry knowledge to evaluate properly the information being released.

The analyst generally operates with a different time frame, answering questions on the basis of specific requests. Analysts tend to see knowledge of transportation and the transformation of data into information as their means of providing value-added services. Furthermore, they tend to highlight their transformation of the data, often to the detriment of the original data source. Analysts also tend to assume that the data will always be available and formatted according to their needs. With respect to statistical purity, analysts seek to answer the question at hand and may not be concerned with a public review, particularly when they can cite the original data source.

The largest challenge remains with institutions, both public and private, and their real concerns about freight mobility improvements. Can we, as public agencies, get beyond freight being only a checklist on a scorecard? Can we, as data providers and analysts, accept the different levels of intelligence that decision makers need and even the differences among the decision makers themselves? Finally, can we transform decision makers into agents for change, so that we have internalized the debate on infrastructure improvements?

The answers depend on many items, but clearly a public-sector perspective must focus on developing a federal framework. Because people expect the federal government to participate in this dialogue, initial steps could involve the following:

1. Define common goals within the federal system (including working with states and local planners, etc.). We need to recognize that we cannot solve all problems at all times, but we should prioritize the data and modeling needs that will return the greatest benefit to the nation as a whole.
2. Identify multiagency data sets and models within the federal government that support these goals. Today, most projects are multidisciplinary, so the government should recognize that most agencies should look for similar data and models on certain projects. There should be a national discussion on trying to coordinate and share research activities among interested stakeholder agencies.
3. Identify research gaps in current programs, data, and models to ensure sound guidance on these goals. The same shared research agenda should also allow agencies to discuss and share data and modeling elements. Often, regulations do not include the needed oversight, resulting in mixed data programs and the inability to fully answer the needs articulated by the regulations or policy guidance.
4. Allow agencies to perform the research to identify what they must know—specifically developing a framework for sharing data, models, and analyses. This requires an understanding of the guidance calling for these required items. In some areas, institutional procedures become the linchpin for promoting change. But institutional leaders must be educated on the need to identify what they currently collect and use and encouraged to explore new data and modeling efforts on transportation issues.
5. Promote federal leadership in collecting, sharing, and promoting findings, with the caveat that users must recognize that not all items can be shared. The federal

government must maintain confidential agreements to ensure that sensitive data elements continue to be collected and that it has the best data available for answering its own questions. Finally, it is not fair to transform the federal government into a de facto national planning agency if everyone depends only on federal data elements and models without local insight.

I remain confident that meetings such as this one are steps in the right direction. However, my overarching concern is that once we identify the "medicine" necessary to bring about the desired change, can we (as practitioners and data providers) fully commit to taking the steps to critique and transform data and model development? Can we have a dialogue in which hard choices can be discussed concerning the strengths and merits of existing and necessary data and modeling programs for specific users? Only in this way can we actively engage in a realistic review of data programs and models for the decision makers who are depending on us.

J. Susie Lahsene, Port of Portland, moderated this session.

Closing Comments

Key Observations and Suggested Areas for Research

Michael D. Meyer, *Georgia Institute of Technology*

Michael Meyer summarized his perspective on some key observations that had been presented and discussed by attendees at the conference. Meyer also summarized areas for research.

Key Observations

- Freight and logistics sectors are critically important to the national, state, and metropolitan economies, and there is a need for leadership.
- Political and jurisdictional boundaries do not define market interrelationships, although they do have a predominant influence on funding.
- The decision hierarchy suggests the need for different decision tools for different contexts and a need for linkage and transparency, as shown in Figure 1.
- Public agency decisions are broad, ranging from system improvements to land use to environmental considerations, as shown in Figure 2.
- The four-step model paradigm is an artifact of passenger demand modeling and does not fit the freight–logistics decision process.
- Freight cannot be represented by just one type of model because decision makers need to capture logistics, supply chain, network flow, microsimulation, econometrics, hybrids, and so forth. Maybe a model is not even necessary.
- The breadth of freight suggests an approach that is a marriage of different disciplines (e.g., regional economics, industrial engineering, civil engineering, urban geography, logistics, management, and business), which further suggests a truly multidisciplinary approach to research.

FIGURE 1 Decision-making context.

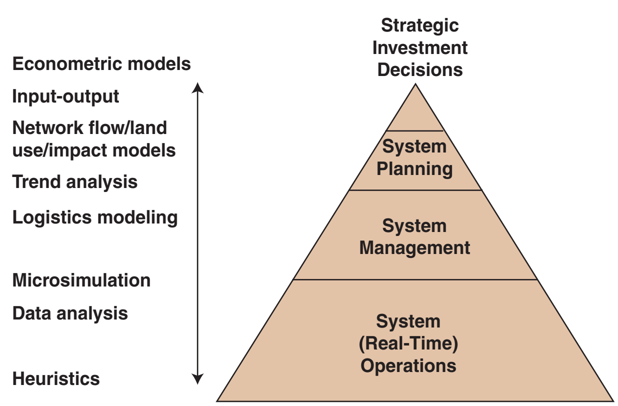

FIGURE 2 Decision making and corresponding tools.

- Because of uncertainty in determinants of market conditions, there is a need to incorporate risk explicitly into decision tools and models, in particular.
- The traditional data collection paradigm of periodic updates is outdated, and a need exists to examine methods for continuous data input.
- The "harsh dose of reality" about data (and especially data held by shippers and carriers) is the necessity of building relationships and identifying what the public sector has that might be of interest to private firms.

Suggested Areas for Research

Ideas that emerged from this conference could generally be grouped into four categories—understanding, physical geography of decision making, data, and decision tools—as outlined in the breakout session summaries. Participants provided a variety of suggestions for research needs related to geography, data, and decision tools as outlined below. Several of these ideas applied more generally to the overall topic and are listed first.

General

- Best practices in modeling and other techniques and data for different decision-making contexts.
- Performance standards, but no mandates, on "how to get there."
- Research digests that synthesize the current state of knowledge.

Geography

Many of the items listed under the data and decision tools sections have different requirements depending on the level of geography being considered and would best be considered separately at those levels. One specific interest is in a robust national freight flow model (prototype).

Data

- National data on through-metropolitan area movements to complement metropolitan area decision tools
- Development of a freight data architecture and application scenarios for different geographic decision contexts
- Systematic and linked approach toward data collection and use
- Leadership in using available public and private databases
- Assessment of viability of intelligent transportation system technologies for providing data for analysis, along with associated limitations
- Public Use Microdata Samples equivalent for freight geographic information
- Approach to capture raw trend data on a routine basis and industrywide
- Movement from traditional paradigm of periodic, 5-year data collection to continuous flow of data and use in models
  - Subsample updating of Commodity Flow Survey (CFS)
  - Bayesian decision networks
  - Sample size increase of CFS
- More surveys in conducting decennial census, with homogeneous architecture
- Case studies of where collaborative data efforts have occurred
- Transfer of data conclusions and underlying relationships from one location to another
- Better understanding of the transfer of methodologies and data use from one application and context to another
- Best practices of truck origin–destination collection methodologies and classification count matrices
- Additional guidance like *Quick Response Freight Manual* for data
- Information about "logistics for public receivers" (e.g., government buildings, schools)
- Relationship between land use and freight data
- Improvements in and survivability of CFS and Vehicle Inventory and Use Survey

Decision Support Tools

- Freight Model Improvement Program
- Key variables and relationships among variables for shipping decisions along with how to incorporate them into freight models
- Additional guidance like *Quick Response Freight Manual* for tools
- Strategies to communicate applicability and value of different decision tools, in particular, models
  - Role of governments
  - Vendors
  - Universities
  - Transportation Research Board
- Safety module as postprocessor of freight modeling
- Decision tools that link econometric and transportation models
- Decision tools that incorporate logistics

- Comparison of state-of-the-art models used in different contexts and for different purposes
- Freight operational models within decision analysis framework
- Multimodal and intermodal understanding, including short sea shipping, inland water, air cargo, and so forth
- Analysis tools that show environmental and land use effects of different investment and operational strategies at metropolitan area and local levels
- Tools that incorporate uncertainty and risk associated with unknown future conditions
- Linkage to modeling regimes at more disaggregate geographic levels from national models producing broad freight flows
- Proof of model's value and viability be made available and disseminated—feedback loop

Challenge: The Four C's

In conclusion, Meyer's challenge to the conference attendees and readers of the proceedings is to develop a *constituency* for the results of freight planning that is led by *champions* on the basis of *collaborative* undertakings that respond to *customer* (of the information) needs. The fifth C is, of course, *cash*.

APPENDIX

Freight Model Use Matrix

The committee developed the following matrix, on pages 102–103, to focus the conference program content and provided it to the breakout groups to facilitate their discussions. This version of the matrix incorporated updates from the committee after the breakout session related to the state of the practice and provided further guidance for breakout groups discussing the state of the art in freight modeling.

Freight Model Use Matrix

What Decisions in the Public Sector Would Benefit from Understanding Freight Demand?	Examples of Applications	Analyses and Forecasts Are for Whom?	What Variables Do We Need to Analyze and Forecast?
Establish a common understanding of freight trends and issues	Trade and transportation forecasts for policy studies	Public officials, private industry executives, the public	Total tons and value, vehicle/vessel volumes, vehicle/vessel use, operating costs
Transportation system development for capacity, agility, redundancy	Traffic forecasts for long-range transportation plans and investment needs studies	Federal, state, and local executives, planners, legislators	Commodity flows by system, vehicle/vessel volumes, vehicle/vessel use
Identify organizational responsibility for action	Traffic forecasts for long-range transportation plans and investment needs studies	Federal, state, and local executives, planners, legislators	Commodity flows, vehicle/vessel volumes, vehicle/vessel use by local versus long distance
Transportation facility design	Set number of lanes and interchange geometrics to accommodate expected traffic, set dimensions of inland waterway locks	State and local planners, project engineers	Commodity flows by facility, vehicle/vessel volumes, vehicle/vessel use
Effectiveness of pricing, tax incentives, and operational strategies for capacity improvement	Mode split analysis, demand elasticity studies	Federal, state, and local executives, planners, legislators	Commodity flows by mode, vehicle/vessel volumes, vehicle/vessel use
Allocation of resources for capacity management (construction, maintenance, operations, abandonment)	Traffic forecasts for long-range transportation plans and investment needs studies	State and local executives, planners, legislators	Commodity flows by facility, vehicle/vessel volumes, vehicle/vessel use
Set tax rates, tolls, and so forth to meet expenses and pay off debt	Statewide revenue forecasts from trucking fees, toll road revenue forecasts	State legislators, bond rating services	Vehicle/vessel volumes, vehicle/vessel use
Cost allocation to establish equity among users or identify sources of costs	Traffic loads for infrastructure damage estimates, vehicle miles traveled and fuel consumption for revenue forecasts	Federal and state officials who set tax rates, tolls, and tariffs	Vehicle/vessel volumes, vehicle/vessel use
Set vehicle size and weight limits and enforcement strategies	Traffic loads for infrastructure damage estimates, vehicle miles traveled and fuel consumption for revenue forecasts	Federal and state officials	Vehicle/vessel volumes, vehicle/vessel use
Manage exposure and risk, plan responses to security and safety threats	Hazmat route designation	Federal and state transportation officials, state and local police, state and local planners	Commodity O-D, commodity flows by facility, vehicle/vessel volumes, vehicle/vessel use, vehicle/vessel O-D
Identify crash reduction and mitigation strategies	State safety plans	Federal and state transportation officials, state and local police, state and local planners	Vehicle/vessel volumes, vehicle/vessel use, crashes
Manage environmental, community, and energy consequences (air quality, noise, invasive species, energy consumption, and demand for transport of energy)	Air quality conformity analysis, land use impact studies	Federal and state officials who approve projects, federal and state legislators	Vehicle/vessel volumes, vehicle/vessel use, vehicle/vessel O-D
Promote economic development (transport as a direct employer, transport to serve logistics and keep or attract employers)	Port impact studies	State and local executives, planners	Commodity O-D, commodity flows by facility
Identify opportunities to expand markets of places, companies, and technologies	Marketing studies	State and local executives, corporate executives, land developers	Commodity O-D, commodity flows by facility
Understand trade and transportation policy (can we deliver when deals are made?)	Bilateral negotiations	Federal executives and legislators	Commodity O-D, commodity flows by facility

NOTE: O-D = origin–destination.

What Kinds of Models Are Used for Analyses and Forecasts?	How Well Do Models Forecast Trends?	How Well Do Models Forecast Responses to Policy (What-If) Scenarios?	What Are the Issues or Difficulties with These Models?	What Are Potential Changes or Improvements?	Value of Getting the Forecast Right, Costs of Getting It Wrong
					Public acceptance of problems and solutions, loss of credibility if wrong
					Underestimates of future volumes result in inadequate system capacity, delay, and general economic costs
					Rational basis for establishing public interest, federal role, and so forth
					Inadequate designs result in future congestion, high cost of replacement
					Public and industry acceptance of noncapital capacity enhancement strategies
					Spend too much on little-used facilities, too little to accommodate future congestion
					Credit rating, financial solvency
					Subsidies that result in efficient facility use
					Subsidies that result in efficient facility use
					Unnecessary loss of life and property
					Unnecessary exposure of public to risk
					Freight-oriented projects disallowed because freight inappropriately represented
					Public support gained for freight-oriented projects
					Lost revenues to local businesses from missed opportunities
					U.S. transport system was overwhelmed by Russian grain deal in 1970s

Participants

Jaime Allentuck, *U.S. Government Accountability Office*
Victor Aragones, *U.S. Department of Transportation*
Jane Bachner, *Federal Railroad Administration*
Paul Bingham, *Global Insight, Inc.*
William R. Black, *Indiana University*
Rob Bostrom, *Wilbur Smith Associates*
Alex Bourgeau, *Southeast Michigan Council of Governments*
Michael Bronzini, *George Mason University*
J. Richard Capka, *Federal Highway Administration*
Harold Cerveny, *Tioga Group*
Garland Chow, *University of British Columbia*
David Cipra, *Wisconsin Department of Transportation*
Bob Costello, *American Trucking Associations*
T. Randall Curlee, *Oak Ridge National Laboratory*
Jessica Davis, *Tennessee Department of Transportation*
Scott Dennis, *Research and Innovative Technology Administration*
Charles DeWeese, *HDR Engineering*
Rick Donnelly, *PB Consult, Inc.*
Scott Drumm, *Port of Portland, Oregon*
Jay DuMontelle, *Federal Highway Administration*
Chandler Duncan, *Wilbur Smith Associates*
Ronald J. Duych, *Bureau of Transportation Statistics*
Bill Eisele, *Texas Transportation Institute*
Liyang Feng, *Southeast Michigan Council of Governments*
Michael Filippov, *Global Insight, Inc.*
W. Gordon Fink, *Emerging Technology Markets*
Kim Fisher, *Transportation Research Board*
Juan Flores, *American Association of State Highway and Transportation Officials*
Karin Foster, *Baltimore Metropolitan Council*
Frederick Frank, *Knoxville Regional Transportation Planning Organization*
Anthony Furst, *Federal Highway Administration*
H. Oliver Gao, *Cornell University*
Gordon Garry, *Sacramento Area Council of Governments*
Gregory Giaimo, *Ohio Department of Transportation*
Dan Goldfarb, *UHB*
James R. Gosnell, *Southern California Association of Governments*
John T. Gray, *Union Pacific Railroad*
Scott Greene, *Federal Railroad Administration*
David Grier, *U.S. Army Corps of Engineers*
Xi Guo, *Canadian Pacific Railway*
Jesse Gwilliams, *Michigan Department of Transportation*
Youssef Hajoui, *MTQ, Canada*
Kathleen L. Hancock, *Virginia Polytechnic Institute and State University*
Keith Hofseth, *U.S. Army Corps of Engineers*
Sammy Holcomb, *Mississippi Department of Transportation*
José Holguín-Veras, *Rensselaer Polytechnic Institute*
Dennis Hooker, *Metroplan Orlando*
Hamid Humeida, *Metropolitan Washington Council of Governments*
John Douglas Hunt, *University of Calgary, Canada*
Bob James, *Port Authority of New York and New Jersey*

Eric Jessup, *Washington State University*
Raphael Kedar, *U.S. Department of Transportation*
Elaine King, *Transportation Research Board*
Vimal Kumar, *Baltimore Metropolitan Council*
Richard LaFerriere, *Transport Canada*
J. Susie Lahsene, *Port of Portland, Oregon*
Bruce Lambert, *U.S. Army Corps of Engineers*
Virgil Langdon, *U.S. Army Corps of Engineers*
Frank Law, *California Department of Transportation*
Robert Leachman, *University of California, Berkeley*
Justin LeBeau, *University of Oklahoma*
Akshay Mani, *Cambridge Systematics, Inc.*
Pablo Manterola, *Sectra, Chile*
Gary Maring, *Cambridge Systematics, Inc.*
James McClellan, *Woodside Consulting Group*
Karen McClure, *Federal Railroad Administration*
Elizabeth McNally, *U.S. Government Accountability Office*
Arnim H. Meyburg, *Cornell University*
Michael D. Meyer, *Georgia Institute of Technology*
Cristobal Miller, *Transport Canada*
Ali Mohseni, *New York Metropolitan Transportation Council*
Curtis Morgan, *Texas Transportation Institute*
Freda Morgan, *Transportation Research Board*
Kevin Neels, *Brattle Group*
Roy Nunnally, *Indiana Department of Transportation*
Joel Palley, *Federal Railroad Admininistration*
Thomas Palmerlee, *Transportation Research Board*
Alain Paquet, *Transport Canada*
George Parrish, *Mississippi Department of Transportation*
David Pearson, *Texas Transportation Institute*
Eric Pihl, *Federal Highway Administration*
George Pinal, *El Paso Metropolitan Planning Organization*
Jeremy Raw, *Virginia Department of Transportation*
Eva Reid, *Cambridge Systematics*
Joseph Reseland, *W.R. Coles, Division of Hanson Professional Services*
Paul Ricotta, *Caliper Corporation*
Benjamin Ritchey, *Battelle Memorial Institute*
Julie Rodwell, *Oregon Department of Transportation*
Matthew Roorda, *University of Toronto, Canada*
Jakub Rowinski, *New Jersey Institute of Technology*
Mark L. Schlappi, *Maricopa Association of Governments*
Rolf Schmitt, *Federal Highway Administration*
Brie Schwartz, *Transportation Research Board*
Huiwei Shen, *Florida Department of Transportation*
Lubna Shoaib, *East–West Gateway Council of Governments*
Ari Sirkiä, *VTT Technical Research Center of Finland*
Howard Slavin, *Caliper Corporation*
Megan Smirti, *University of California, Berkeley*
Steve Smith, *Indiana Department of Transportation*
Frank Southworth, *Oak Ridge National Laboratory*
Bruce Spear, *Federal Highway Administration*
Michael Sprung, *Bureau of Transportation Statistics*
Selva Sureshan, *Ontario Ministry of Transportation, Canada*
Tianjia Tang, *Federal Highway Administration*
Rob Tardif, *Ontario Ministry of Transportation, Canada*
Lorant Tavasszy, *TNO, Netherlands*
Russell Thompson, *University of Melbourne, Australia*
Trung Trinh, *Mississippi Department of Transportation*
Linda Turnquist, *California Department of Transportation*
Mark A. Turnquist, *Cornell University*
Donald Vary, *Cambridge Systematics, Inc.*
Inge Vierth, *Swedish Institute for Transport*
Olegario Villoria, *IDS Group*
Gregory Waidley, *Wisconsin Transportation Center*
C. Michael Walton, *University of Texas, Austin*
Jason West, *University of Texas*
Wade White, *Citilabs*
Demin Xiong, *Oak Ridge National Laboratory*
Supin Yoder, *Federal Highway Administration Resource Center*
Hsin-I Yu, *Des Moines Area Metropolitan Planning Organization*
Yinghua Zhan, *HNTB*

TRB

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

www.TRB.org
ADDRESS SERVICE REQUESTED

Non-profit Org.
U.S. Postage
PAID
Washington, DC
Permit No. 8970

THE NATIONAL ACADEMIES™

Advisers to the Nation on Science, Engineering, and Medicine

The nation turns to the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org

ISBN 978-0-309-11307-6