REPORT S2-C20-RR-1

Freight Demand Modeling and Data Improvement

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STRATEGIC HIGHWAY RESEARCH PROGRAM

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Freight Demand Modeling and Data Improvement

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TRANSPORTATION RESEARCH BOARD

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FOREWORD

David J. Plazak, *SHRP 2 Senior Program Officer, Capacity*

Freight traffic has been growing faster than passenger traffic on the nation's highway network. As a result, freight bottlenecks have begun to develop at various points throughout the network. These bottlenecks have historically been near ports and other intermodal facilities. However, travel forecasts are beginning to show the effects of growing freight traffic on congestion on urban freeways, urban arterials, and some cross-country routes in rural areas. Being able to understand freight flows and forecast freight demand is taking on greater and greater importance.

The second Strategic Highway Research Program (SHRP 2) initiated two projects (Capacity Projects C15 and C20) designed to improve the nation's ability to plan for increased freight-related traffic and to begin to address the growing issue of freight bottlenecks. Capacity Project C20, which was the first one, assessed the state of the practice of freight demand modeling and freight data as they relate to highway capacity planning and programming. This assessment concludes that the state of freight demand modeling has been relatively stable during the past several decades, unlike demand modeling for passenger travel, which is advancing toward activity-based modeling. The state of the practice in freight data has also been relatively stable; however, promising developments based on new information technologies may greatly improve transportation planners' access to freight data. Examples include global positioning system data from trucks and (potentially) private supply chain data that could be aggregated for public sector planning purposes.

Accelerated innovation is needed so that freight demand modeling and freight data can better serve the needs of public sector decision making regarding highway capacity investments. The C20 research report documents the process used to develop a strategic plan aimed at improving the state of the practice in freight demand modeling and freight data. The strategic plan, published as a separate web document, suggests sample research initiatives that could begin to improve the practice of freight demand modeling and freight data. These initiatives are grouped into themes such as knowledge gaps, modeling, data, and data visualization. Knowledge gaps are a key issue because the perspectives and business planning time frames of the private and public sectors are divergent with respect to freight. The private sector focuses on optimizing short-term supply chains and operations, but the public sector focuses on investments that may take a decade or more to put in place. Bridging this knowledge gap is essential to making progress in freight capacity planning. Visualization technologies are promising for helping freight decision makers and stakeholders understand each other's perspectives.

Since the responsibility for gathering freight data and conducting freight demand modeling is spread among a large number of agencies and organizations, the C20 Strategic Plan suggests a potential model for organizing cooperation to encourage innovation and advancement. One model for advancing the state of the practice in freight demand modeling and freight data is to hold innovation symposia. A pilot effort initiated in September 2010 as part of the SHRP 2 C20 research project, the Innovations in Freight Demand Modeling and Data Symposium, is documented in this report. An online compendium of the papers that were presented is included.

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Executive Summary

Introduction

Research Objective

The SHRP 2 C20 research initiative provides the strategic framework for continuous improvement and innovative breakthroughs in freight transportation forecasting, planning, and data. The stated research objective was to "foster fresh ideas and new approaches to designing and implementing freight demand modeling." This objective recognizes that fundamental change is necessary to better integrate freight considerations into the transportation planning process. Various short-term measures have resulted in marginal improvement to the current state of the practice for freight planning, but they contain many inherent weaknesses.

Fundamental change in freight modeling and data is needed and opportune. Freight is growing in volume, economic importance, and complexity, particularly in relation to sophisticated modal and information technology advances. The effective and efficient movement of goods affects nearly every aspect of life. However, the analytic tools and methods used to forecast freight demand are inadequate to deal with the scale and importance of freight transportation on our multimodal system and our economy.

Historically, travel demand forecasting has been oriented toward the long-standing methods used for passenger transportation. Passenger-oriented forecasting models draw on economic and demographic variables that are insufficient and largely irrelevant for estimating freight demand, which is shaped by a wider range of factors that reflect a complex logistics chain.

By developing better freight demand models and data sources, public and private sector decision makers will be able to make better and more informed decisions related to transportation infrastructure, land use, economic development, and other policies fundamental to prosperity and quality of life. Ultimately, these decisions should consider relevant information such as the current movement of goods, modal mix and variations, shipping costs, time in transit, consumption rates, logistics chains, and other factors critical to the freight industry.

Research Scope and Approach

The Freight Demand Modeling and Data Improvement Strategic Plan was developed through an inclusive process of public and private stakeholders from U.S. and international freight planning communities that culminated in the Innovations in Freight Demand Modeling and Data Symposium conducted in September 2010.

The plan's development focused on collecting information and ideas to

- Determine freight demand modeling and data needs, in part by defining an optimal scenario or desired future state of what the freight planning process should be with all of the model parameters clearly identified and the necessary data available.

- Identify and promote innovative research efforts to help develop new modeling and data collection and processing tools in the near and long-term future.
- Establish and strengthen links between freight transportation planning tools and supporting data, and also consider the relationships between freight transportation and other areas of public interest, such as development and land use, in which freight movement has major implications.
- Leverage and link existing practices, innovations, and technologies into a feasible approach for improved freight transportation planning and modeling.
- Establish a recognized and regular venue to promote and support innovative ideas, modeling methods, data collection, and analysis tools as the basis for informing and sustaining further research.

The Freight Demand Modeling and Data Improvement Strategic Plan identifies a compelling direction for the freight planning community centered on meeting the immediate needs of decision makers. The pragmatic focus on application and results also recognizes the parallel need to foster continued research innovation and breakthroughs. This confluence of steady improvements in practice and continued research focus will be the basis for long-term improvements to freight modeling and data. The SHRP 2 C20 research team focused, therefore, on defining the critical gaps in models, data, and decision making as the means to formulate strategic and cohesive future directions to guide the long-term initiatives identified throughout the research process. For the purposes of this research, *innovations* in the freight modeling and data community are defined as significant (or potentially significant) movements toward the betterment of freight models, tools, data, or knowledge in freight planning practices.

A robust approach was followed to define needs and innovations and to shape the long-term goals. The hallmark of this effort was maximizing input from practitioners and decision makers and considering the current state of the practice. This process entailed a review of research conducted on freight modeling and data improvement, as well as an analysis of current practices within the industry (both domestic and international). The research approach elements, their purpose, and outcomes are shown in Table ES.1.

Findings

Decision-Making Needs

The research and associated stakeholder outreach efforts identified a variety of freight planning and analytic needs. Common threads and recurring themes among the wide array of private, public, and academic participants included the following:

- Freight forecasting and analysis should be enhanced through the development and amalgamation of a recognized and valid inventory of standardized data sources with common definitions.
- There is strong interest in developing a statistical sampling of truck shipment data, similar to the Carload Waybill Sample available for railroads.
- There is a real need for a range of standardized analytic tools and applications to address diverse decision-making needs.
- Behavior-based facets of freight decision making (i.e., the dynamics of shipper and carrier decisions) must be incorporated into modeling, or at least better understood as important context.
- Better information is needed to understand intermodal transfers, particularly the types, volumes, and significant trends. This is particularly important as public policy is promoting systems thinking and intermodalism.
- Industry-level freight data are needed at a subregional level to enable reliable freight analyses at a smaller geographic scale. Similarly, there is a need to better understand the patterns and dynamics of local deliveries in urban areas.

Table ES.1. Research Approach Elements

Approach Element	Purpose	Outcome
Technical Expert Task Group	• Articulate the project and industry vision • Advise project team • Review interim and final findings	• Overall project oversight and direction
Background Research	• Identify domestic and international best practices • Identify historic freight modeling and data challenges • Identify opportunities, innovations, and unique data sources	• Catalog of current and best freight modeling and data collection practices • Determination of potential areas for improvement and innovation • Background in defining strategic needs
Innovations in Freight Demand Modeling and Data Symposium	• Identify domestic and international innovative practices • Discuss applicability and improvements to innovations • Launch a forum for sharing of freight demand modeling and data innovations	• Current innovative initiatives • Brought the data and modeling community together to foster the best thinking on the subject • Venue for future sharing of innovative ideas • Formal structure for rewarding freight modeling and data innovations
Stakeholders Outreach and Workshops	• Validate the strategic directions • Discuss a series of key issues • Review, critique, and validate strategic research initiatives that will affect freight transportation for years to come	• Validation and supporting ideas and discussion on the Strategic Plan • Validation and discussion on research priorities • Ideas for continuing innovations to meet decision-making needs
Strategic Plan	• Frame the long-term direction for freight modeling and data improvement • Foster innovative practices in modeling and data • Set an agenda for short- and long-term research initiatives	• Documented strategic needs and innovative research efforts • Developed a feasible approach to freight transportation modeling and data improvement • Identified short- and long-term strategic research initiatives • Developed a strategic plan and road map

- Freight models should begin to incorporate local land use policies and controls to increase the accuracy and value of freight forecasting at the local level.
- There is a need to better understand the correlation between freight activity and various economic influences such as fuel price, currency valuation, and macroeconomic trends.
- Enhanced tools and processes would be beneficial to measure the accuracy of freight analyses and data forecasts.
- There is an overarching process need to implement a process to routinely generate new data sources and problem-solving methods.
- Attention should be given to using intelligent transportation systems (ITS) resources and related technologies such as global positioning systems (GPS) and IntelliDrive to generate data to support freight planning and modeling.
- There is a recognized long-term need to develop a full multimodal, network-based freight demand model that incorporates all modes of transport to a similar level of detail (vehicle, railcar, vessel, and so forth) for various geographic scales.
- Freight stakeholders emphasize the practical need for benefit–cost analysis tools and methods that go beyond traditional financial measures by including other direct and indirect impacts, benefits, and costs (both public and private).

- More effective methodologies are needed to apply freight forecasts to funding and financial analyses, such as revenue projections.
- There is a strong interest among highway agencies to develop tools that use freight forecasts to support the agencies' infrastructure design processes.
- Stakeholders consistently emphasized the importance of a concentrated effort to develop the requisite knowledge and skills to support freight analysis and foster greater public and private collaboration and mutual understanding of respective processes and requirements.

Decision-Making Gaps

Table ES.2 highlights freight decision-making needs, the gaps between those needs and the current modeling and data practices, and the data and modeling requirements to meet those needs. This information represents the foundation for the actions that have been incorporated into the Strategic Plan.

Conclusions

The second decade of the twenty-first century will see an even greater emphasis on global trade, technology, innovation, and competitiveness. These megaissues should strongly influence transportation strategy and decisions about system investments; these will, in turn, require capacity building for state departments of transportation (DOTs) and metropolitan planning organizations (MPOs). Responding effectively to these megaissues will also require greater collaboration with the freight industry at every level, including collaboration on the types of freight planning research described in this report.

The long-term ability to effectively and efficiently move goods will depend on the performance of public and private infrastructure, which is key strategic asset to enterprises that ship and receive freight of all types in a fiercely competitive business environment.

Ironically, in this information age when the linkage between goods movement and information technology continues to expand, state DOTs and MPOs lack the kind of data and analytic tools needed to effectively plan for freight transportation. The result is that public decision makers lack the information they need to effectively support freight-related transportation decision making.

By the end of this decade, a vision for improved freight modeling and data will be characterized as follows:

- A robust freight forecasting toolkit has been developed and is the standard for public sector freight transportation planning.
- Forecasting tools and data link dynamically with other key variables, such as development and land use, and their application to local scale, corridors, or regions is also dynamic.
- The challenges associated with the data necessary to support new planning tools have been addressed through a broad-based effort bringing together the varied resources of the public and private sectors.
- The knowledge and skills of state DOT and MPO staff have been methodically enhanced to complement the development of better tools and data.
- Decision makers recognize that transportation investments are to a greater degree being informed by an understanding of the implications, benefits, and trade-offs relative to freight.

Recommendations

A framework or future direction for building momentum beyond the completion of the SHRP 2 C20 report was developed to provide a broad direction and an organizing process for sustaining innovation in freight planning and modeling. The approach is designed to address the range of opportunities and needs that have been identified to date.

Table ES.2. Freight Decision-Making Needs and Gaps

Decision-Making Needs	Gaps Between Needs and Current Practices	Data or Modeling Requirements to Close Gaps
Standardized data sources with common definitions	• Various data sources collected through different programs result in extensive inconsistencies.	• Homogeneous data for ease of incorporation into freight models and for consistency of freight models in different regions. • Reduction in data manipulation to improve accuracy.
Statistical sampling of truck shipments	• Detailed knowledge of truck movements in local areas. • Understanding of current truck activity by different industry segments (long-haul, local, drayage).	• An ongoing standard data-collection program to gather local truck movements. • Compilation of truck data to a level comparable to rail industry data (i.e., Carload Waybill Sample).
Standardized analytic tools and applications	• Range of various tools that require unique data sets.	• Consistency in modeling approaches and data needs for similar geographic scales.
Inclusion of behavior-based elements in freight models	• Current practices use truck movements and commodity flows, but should be based on the behaviors, economic principles, and business practices that dictate the movement of freight. • Current modeling tools do not accurately reflect real-world supply chains and logistics practices.	• Determination of the influencing behavioral factors that affect freight movement and ongoing data collection to inform models. • Behavior-based freight modeling tools to take advantage of newly collected data sets for various geographic analyses. • Incorporation of intermodal transfers, consolidation and distribution practices, and other shipper and carrier practices in modeling tools.
Data development to understand the nature, volume, and trends of intermodal transfers	• Public sector access to intermodal transfer data of containers, bulk material, and roll-on–roll-off cargo is lacking for most transfer facilities other than those of large ports and rail yards.	• Data sets developed through collaboration with the private sector to inform the planning practice knowledge base and models on intermodal transfers. • Protocols to collect data on a regular basis.
Industry-level freight data development at a subregional level and within urban areas	• Freight data are generally not industry-specific, which translates into forecasts that are not sensitive to the unique industry trends that are critical to regions that rely heavily on specific industries.	• Industry-level forecasts that are sensitive to the unique factors of different industries. • Tools and data at a disaggregated level (local) that can be aggregated for larger geographic analyses. • Tools and models to take advantage of the new data sets.
Incorporation of local land use policies and controls for better local forecasting accuracy	• Current freight data and models lack local detail related to the generation of freight activity, which hampers local efforts to effectively plan for the last mile.	• Enhanced understanding of land use decisions and their implications on freight activity. • Resources for local organizations to incorporate land use considerations into freight planning data and models.
Development of a correlation between freight activity and various economic influences and macroeconomic trends	• Freight models are typically based on population-, employment-, and industry-level productivity forecasts, with no consideration for the impacts of other economic factors.	• Enhanced models that incorporate a wide array of economic factors in forecasting freight demand.
Better accuracy of freight forecasts	• Freight models rarely (if ever) are reviewed to check the accuracy of their forecasts, calling into question their reliability and validity.	• A systematic approach for freight model and data owners to review and evaluate forecasts (every 3 to 5 years) and adjust models and data methods accordingly.
Development of a process to routinely generate new data sources and problem-solving methods	• The improvement of freight planning nationally depends on continuing innovation and steady progress in the development of models, analytic tools, and knowledge acquisition.	• A value-adding and sustainable process to generate new and innovative ideas. • Acknowledgment of failed practices that can contribute to the knowledge base of practitioners.
Use of ITS resources to generate data for freight modeling	• Technologies that can be used to collect freight data have not been used to their potential. • Data can provide a wealth of information related to current conditions and diversions as a result of traffic incidents.	• An understanding of the information needed by the modeling community and the standard to which it can be used. • An accessible data bank for freight modeling developed with the cooperation of GPS device providers, ITS infrastructure owners, and other data providers.
Development of a universal multimodal, network-based model for various geographic scales	• The fragmentation of modeling techniques and data means that practitioners typically must develop or improvise data and models for their own applications. • Agencies with fewer resources are not able to adequately analyze freight movements. • Some freight transport modes are analyzed more than others because they have more data available for analysis.	• An open-source data bank and universal freight modeling tool is the ultimate goal. • A level playing field among different modes of freight transportation in terms of quantity and accuracy of data and complexity of modeling tools.
Development of benefit–cost analysis tools that go beyond traditional financial measures	• Analysis of the benefits of project-based scenarios lacks the precision required for those decisions, including direct and indirect impacts, costs, and benefits.	• Tools that incorporate a comprehensive analysis of the factors associated with infrastructure development, expansion, and enhancement specifically related to freight.
Development of funding assessments resulting from freight forecasts	• Transportation funding scenarios and what-if analyses are limited in their ability to forecast revenues associated with freight movement.	• Estimated costs and potential funding sources that can be justified based on credible freight forecasts.
Creation of tools to support the infrastructure design process	• Infrastructure design, unless specific to freight, rarely focuses efforts on how best to accommodate freight movements.	• Incorporation of freight forecasts into infrastructure design related to vehicle size and weight and future freight activity (i.e., tonnage) by mode.
Development of knowledge and skills among the freight planning community as a foundation for improved analysis	• The freight planning community is relatively small and knowledge transfer is challenging. • Talented innovators who can lead new approaches to freight transportation planning are pursuing careers in other industries.	• A comprehensive knowledge base for planning professionals that includes the wide range of subject areas related to freight transportation. • Greater recognition or formal standing of freight planning as a profession with an associated body of knowledge.

Strategic Objectives and Sample Research Initiatives

The SHRP 2 C20 Freight Demand Modeling and Data Improvement Strategic Plan is built on a foundation of seven strategic objectives for future innovation in freight travel demand forecasting and data. The desired direction for enhanced freight planning, forecasting, and data analysis as expressed by the many stakeholders who participated in this project is reflected in these objectives, which are aimed at stimulating innovation through the avenues laid out in the strategic plan.

The seven strategic objectives are

1. Improve and expand the knowledge base for planners and decision makers.
2. Develop and refine forecasting and modeling practices that accurately reflect supply chain management.
3. Develop and refine forecasting and modeling practices based on sound economic and demographic principles.
4. Develop standard freight data (e.g., Commodity Flow Survey, Freight Analysis Framework, and possible future variations of these tools) to smaller geographic scales.
5. Establish methods for maximizing the beneficial use of new freight analytic tools by state DOTs and MPOs in their planning and programming activities.
6. Improve the availability and visibility of data among agencies and between the public and private sectors.
7. Develop new and enhanced visualization tools and techniques for freight planning and forecasting.

Building on the foundation of the seven objectives listed above, the SHRP 2 C20 research effort culminated in the development of 13 research areas. These research areas, called *sample research initiatives,* are shown in Table ES.3. Collectively, these sample research initiatives constitute a programmatic approach for systematically improving freight modeling and data availability and forecasting tools. Each of these initiatives is tied to one or more of the seven strategic objectives, with the ultimate goal of promoting and cultivating innovation through Strategic Objectives 2 and 3, supported by the innovations in data development in Strategic Objective 4 and visualization in Strategic Objective 7.

Each of the 13 research initiatives also relates to one or more of the three main research dimensions identified at the 2010 Innovations in Freight Demand Modeling and Data Symposium:

- *Knowledge* relates to a general understanding of freight transportation issues and the extensive array of elements involved in planning and forecasting freight demand;
- *Models* are the tools used to plan and forecast freight transport–related activities at various geographic levels; and
- *Data* are the underlying information resources for modeling and planning efforts; these data often represent an important limitation of modeling.

The ultimate long-term goal is to build on Strategic Objectives 2 and 3 to promote the development of a full network-based freight forecasting model that incorporates all modes of freight transport and accurately reflects the various factors related to the supply of freight infrastructure and services (Strategic Objective 2) and the underlying demand for these services (Strategic Objective 3). This model will effect a dramatic change in current freight planning and forecasting. It is a highly ambitious endeavor because of the complexity of freight transportation and the numerous elements that are necessary to achieve this long-term goal.

The other five strategic objectives are tied to this goal through the development of the applicable knowledge base needed to further the goal (Strategic Objective 1), the development and

Table ES.3. Sample Research Initiatives

Sample Research Initiatives[a]	Research Dimensions			Strategic Objectives						
	Knowledge	Models	Data	1. Improve and expand knowledge base.	2. Develop modeling methods to reflect actual supply chain management practices.	3. Develop modeling methods based on sound economic and demographic principles.	4. Develop standard freight data to smaller geographic scales.	5. Maximize use of freight tools by public sector for planning and programming.	6. Improve availability and visibility of data between public and private sectors.	7. Develop new and enhanced visualization tools and techniques.
A: Determine the freight and logistics knowledge and skill requirements for transportation decision makers and professional and technical personnel. Develop the associated learning systems to address knowledge and skill deficits.	●			■						
B: Establish techniques and standard practices to review and evaluate freight forecasts.		●		■	□	□				
C: Establish modeling approaches for behavior-based freight movement.	●	●			■					
D: Develop methods that predict mode shift and highway capacity implications of various what-if scenarios.	●	●			■	■				
E: Develop a range of freight forecasting methods and tools that address decision-making needs and that can be applied at all levels (national, regional, state, metropolitan planning organization, municipal).		●	●		■	■	□			
F: Develop robust tools for freight cost–benefit analysis that go beyond financial considerations to the full range of benefits, costs, and externalities.	●	●				□		■		
G: Establish analytic approaches that describe how elements of the freight transportation system operate and perform and how they affect the larger overall transportation system.	●	●				■		□		
H: Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics. Document economic and demographic changes related to freight choices.	●					■				
I: Develop freight data resources for application at subregional levels.			●		□	□	■			
J: Establish, pool, and standardize a portfolio of core freight data sources and data sets that supports planning, programming, and project prioritization.			●				■	■	□	
K: Develop procedures for applying freight forecasting to the design of transportation infrastructure, particularly pavement and bridges.		●						■		
L: Advance research to effectively integrate logistics practices (private sector) with transportation policy, planning, and programming (public sector).	●				□			■	■	
M: Develop visualization tools for freight planning and modeling through a two-pronged approach of discovery and addressing known decision-making needs.	●	●	●							■

Note: Directly Addresses Objective ■; Indirectly Addresses Objective □.

[a] The sample research initiatives outlined as part of the SHRP 2 C20 research project demonstrate how the strategic objectives could be advanced. Each initiative also applies to one or more of the three research dimensions (indicated by ●).

dissemination of data necessary to support it (Strategic Objectives 4 and 6), and the development of enhanced methods for disseminating information from these analytic tools for public stakeholders (Strategic Objective 5) and decision makers (Strategic Objective 7).

The specific research initiatives are initial recommendations for potential research to help move this process forward, but they will likely change as a result of funding availability and industry needs; future developments that spring from some of the other elements of the Strategic Plan, such as the Global Freight Research Consortium (GFRC) and future data and modeling symposia; other data and modeling innovations featured in TRB conferences; and research from the National Cooperative Highway Research Program (NCHRP) and the National Cooperative Freight Research Program (NCFRP).

Innovations in Freight Demand Modeling and Data Symposium: A Foundation for Moving Forward

The successful Innovations in Freight Demand Modeling and Data Symposium held in September 2010 provided a solid foundation for future efforts. The symposium's success rested on several factors:

- The symposium provided a low-cost approach to generating a variety of research concepts;
- The competitive nature of the symposium generated numerous excellent ideas and promising research concepts;
- The symposium brought together academic, private sector, and public sector perspectives; and
- The symposium fostered a greater shared understanding of the issues and requirements for improved freight modeling and planning.

The focus and emphasis areas of future symposia will vary, but the principles of collaboration, competition, and communication represent significant building blocks for successful symposia.

The symposium featured 18 presentations selected to address the challenge of developing the next generation of freight demand models. It was characterized by a combination of modeling data and ideas presented by U.S. and international practitioners and academics, followed by open and direct dialogue and debate. It provided a strong foundation for moving forward in that it:

- Generated ideas;
- Attracted international attention and participation;
- Resulted in the identification of several promising areas of research; and
- Provided a forum for public and private sector stakeholders, as well as university expertise.

Organizing Concept: Global Freight Research Consortium

SHRP 2 C20's project leadership stressed that the future directions should not be burdened with an inflexible bureaucratic organization or cumbersome administration. Rather than establishing a program as part of a government organization, the organizing concept lays out a flexible mechanism—an agile, collaborative framework—for achieving the strategic objectives.

To meet this expectation, a GFRC is recommended. This consortium would promote a body of research through funding agencies and other organizations having a stake in improved freight system performance and decision making, supported by enhanced analytic approaches. Participation would be voluntary, attracting those sectors that have a stake in the achievement of the strategic objectives.

Table ES.4. Illustrative Organizations for GFRC Participation

Agency	Role and Focus Area
TRB cooperative research programs (e.g., NCFRP, NCHRP)	Funding applied research on freight modeling and data; integrating existing separate research tracks with freight
TRB, Second Strategic Highway Research Program (until March 2015)	Sponsoring innovation symposia; funding development of training and outreach materials suggested by the future directions
U.S. DOT modal administrations (e.g., Federal Highway Administration [FHWA], Federal Railroad Administration)	Supporting pilots of advanced freight demand models
U.S. DOT intermodal organizations (e.g., FHWA, Research and Innovative Technology Administration, Bureau of Transportation Statistics)	Improving and expanding freight data resources
Academic institutions and university transportation centers	Funding and conducting basic research on freight models and data collection and fusion; pooled fund consortia
Associations such as the American Trucking Association	Networking work and priorities of GFRC to industry and modal operators and carriers
State DOTs and MPOs	Piloting and application of research
Private sector	Improving and expanding freight data resources; identifying advances in freight transportation technology and business practices for future research

This peer-based consortium would enable, fund, and promote research, supported through national and international public organizations and private organizations whose efforts serve the freight transportation sector.

The member organizations will include public domestic agencies, modal and other associations, universities, and the transportation research entities of other countries. It is also envisioned that the private sector will participate in the GFRC. Table ES.4 summarizes the organizational mix that will potentially represent the core of the consortium.

This partnership will support independent research and reward innovative and compelling investigations and experiments by sponsoring an annual research competition spanning various research tracks and providing a seed-grant award. Establishing and maintaining the GFRC will require careful planning.

- Investigate the appropriate governance model (e.g., foundation, institute, charity) for the GFRC and complete its charter;
- Perform outreach to possible member organizations to promote participation;
- Obtain public and private start-up funding as appropriate;
- Secure the services of a qualified consultant to assist in the early organizing and start-up activities of the GFRC. This could include developing a draft GFRC work program, organizing additional research idea competitions, holding annual competitions for grants, and facilitating the first few GFRC meetings; and
- Regularly restructure and renew the governance model to ensure an entrepreneurial approach and genuine innovation.

Recommended Global Freight Research Consortium Initiatives

The research team recommends that the GFRC address six major initiatives as part of its overall approach to achieving the strategic objectives. The list is by no means exhaustive, recognizing that the ultimate activities of the consortium will be determined by the combined interests and priorities of the participants.

Define Priority Research Issues

The GFRC will periodically issue a list of research priority areas based on submissions to GFRC-sponsored calls for ideas. The actions needed to define priority research issues include

- Establish the initial set of problems or research issues demanding attention;
- Publish and widely distribute a call for ideas; and
- Communicate the submission format standards and the available incentives or awards.

Provide Recognition and Incentives to Spur Breakthroughs

The GFRC should recognize the value in offering awards and recognition, particularly for meritorious research ideas with potentially breakthrough solutions. Nonfinancial recognition is also important. Efforts to promote this process to the greatest extent possible as a way of doing business for the GFRC will include the following actions.

- Establish initial sources for the first call for innovative ideas;
- Consider establishing GFRC following a foundation model, to provide a basis for contributions for funding awards, prizes, and related activities; and
- Over time, as funding for awards increases, establish multiple categories and multiple award winners.

Conduct Regular Innovation Forums

An annual forum should be conducted for presenting innovative research and selecting the most promising ideas in freight modeling and data for further development. Each forum should publish a report that would frame the freight modeling and data research agenda for the following year.

Actions needed for ongoing forums include

- Determine the content, themes, or focus areas for periodic innovation forums;
- Review and incorporate the results of the forums in relation to other GFRC activities; and
- Provide guidance for maximizing the dissemination of forum results and promoting forum participation among colleagues and peers.

Promote Technology Transfer from Other Disciplines

Solutions from other fields that can be transferable or adaptable to freight transportation modeling needs will be promoted regularly and will serve as a focus for a broader outreach to various utilities and other sectors. Transferable solutions will also be a consideration in screening ideas. Effective appropriation and modification of analytic techniques from other disciplines will be encouraged by the following actions.

- Organize a forum that would include presenters from other sectors to consider how their modeling and planning techniques might be adaptable to freight forecasting; and
- Organize a competition devoted to adopting and adapting analytic techniques from other sectors.

Promote an International Focus

Research innovation for freight demand and analysis must necessarily reflect the global nature of freight movement. Implementation must draw on global research and promote participation from all relevant freight sectors and academic institutions worldwide. To encourage an international focus, GFRC organizers could

- Secure public, private, and academic participants from other nations through the contacts and networks of those who have already been involved in SHRP 2 C20;
- Conduct an early GFRC meeting in a strategically selected country; and
- Regularly showcase freight planning and modeling approaches employed in other nations.

Recognize the Application of Completed Research

Another important component of recognition and information dissemination for the consortium will be to periodically draw attention to the impacts and benefits of applied freight modeling and data research. This activity, which will be particularly important for promoting broader implementation of successful freight analytic approaches, could include

- Advance a general tracking activity to capture the benefits and experiences of freight professionals using new research approaches; and
- Periodically publish this information to reflect the long-term benefit of GFRC efforts.

CHAPTER 1

Introduction

Background

Freight transportation in the United States has been a subject of growing interest to policy makers, state departments of transportation (DOTs), metropolitan planning organizations (MPOs), and varied stakeholders, particularly since the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. The overarching policy challenge for transportation agencies is to make informed investments in transportation infrastructure that support efficient freight mobility and access. Long-range transportation plans, transportation improvement programs, corridor studies, and project development need to have a more meaningful freight focus. This need to better integrate freight with transportation planning recognizes the importance of goods movement to economic performance and meeting consumer needs. Progress in freight planning also will require effective communication and coordination with the private sector (shippers and carriers) and local government, particularly with respect to development and land use considerations. Although more than 20 years have passed since ISTEA was enacted, accurate and timely freight planning and forecasting still remain formidable challenges with substantial opportunity for improvement.

Increasingly, the importance of freight data and modeling is being recognized. Transportation investments are capital intensive and represent long-term commitments for taxpayers and stakeholders in the public and private sectors. It is important that transportation planners possess both the tools and the skills to forecast freight demand and to analyze scenarios and investment alternatives as part of the overall transportation analysis. Travel demand forecasting, however, has historically been oriented toward passenger transportation. Passenger-oriented forecasting models draw on economic and demographic variables that are insufficient and sometimes irrelevant for estimating future freight demand, which is shaped by a much wider range of factors as a result of a complex logistics chain.

Freight transportation has undergone dramatic change nationally and globally in recent decades, much of it occurring behind the scenes and outside of the public eye. Population growth, changes in consumer behavior, underlying economic forces (both national and global), and advances in technology have driven major changes in freight transportation. The increasing complexity of the logistics and supply chain process has made it more difficult for public and private decision makers to understand the implications of freight trends for the planning process for capital improvements related to the movement of goods through the U.S. transportation system.

Incorporating freight movement considerations into the transportation planning process has become increasingly difficult at a time when these influences are more critical to the ability to forecast long-term trends and plan for future infrastructure needs. This difficulty is exacerbated by the underlying dilemma faced by decision makers involved in any transportation project or policy decision in which freight transportation is a key consideration: the physical, operational, economic, and political disconnects between the users of the system (shippers and carriers) and those who benefit from the system (businesses and consumers). Some MPOs engage the private sector through freight working groups; however, there are far more regions where these stakeholders may not fully understand the benefits the system provides, the implications of their own decisions on freight transportation, and the real and perceived negative impacts of freight movement.

The standard approach to forecasting freight traffic does not serve decision making well for several reasons:

- Transportation decisions are largely based on passenger movements. Freight movement is far more complex than passenger movement and typically involves multiple travel modes and transportation characteristics at different points in the production and delivery process.

- The impacts of freight movement on the transportation network and the need for decision makers to understand the various elements of the logistics process vary widely depending on geography. Existing data resources are best suited to large geographic scales and do not translate well to local levels.
- Transportation forecasting and modeling practices are usually based on average trip generation rates for various land uses, but freight is heterogeneous in nature and does not lend itself well to average quantities of production, consumption, and movement.
- Freight transportation is carried out by private shippers and private carriers whose impact is often felt on public facilities. However, freight's complex production, transportation, and storage elements are not readily apparent to public decision makers.
- Similarly, the growing role of third-party freight transportation providers and logistics services makes freight less visible to many shippers and receivers. This change makes it more difficult for public agencies to gather information on freight activity through traditional shipper surveys.
- Different commodities often have significant variations in travel modes and logistics patterns for identical origin and destination points.
- Peaking characteristics for passenger travel are typically seen by time of day and day of the week, but freight movement often demonstrates substantial seasonal variations that vary by commodity type.
- Freight typically moves over long distances with modal transfers and changes in freight characteristics at different points in the supply chain (raw materials to components to finished product). Freight movement is also more markedly affected by the unique aspects of international transportation (e.g., customs requirements, security).

Because of the weaknesses inherent in current freight data and modeling practices, public and private decision makers have limited information on which to base critical freight-related decisions. These decisions may relate to infrastructure investment, economic development, business planning, land use, capacity enhancements, and logistics. The implications of poor or ill-informed decision making in the realm of freight transportation are potentially more far-reaching than for passenger transportation in terms of economic costs, environmental degradation, and loss of competitive advantage for a city or region—though perhaps less obvious, except in hindsight.

Research Purpose

The SHRP 2 C20 research initiative was developed to provide a strategic framework for continuous improvement in freight forecasting, planning, and data, and in the acceleration of innovative breakthroughs. The stated objective was to "foster fresh ideas and new approaches to designing and implementing freight demand modeling." This objective promotes fundamental change in the integration of freight considerations into the planning process while recognizing that although various short-term measures represent marginal improvement to freight movement planning and current practice, they contain many inherent weaknesses.

Development of better freight demand models and data sources will provide the tools necessary for public and private sector planners and other leaders to make better decisions. These decisions would be based on relevant information regarding the current movement of goods, modal variations, shipping costs, time in transit, consumption rates, logistics chains, and other information that is critical to the freight industry.

Documents produced as part of the SHRP 2 C20 research project include this detailed report, the Strategic Plan, and a speaker's kit. The speaker's kit is available online at www.trb.org/Main/Blurbs/167628.aspx.

Strategic Plan Development

The Freight Demand Modeling and Data Improvement Strategic Plan was developed through a highly inclusive process with stakeholders from U.S. and international freight planning communities. The plan's aim to foster innovation in freight demand modeling and data was informed through previous research, discussion, and outreach at various events throughout the United States, as well as the Innovations in Freight Demand Modeling and Data Symposium conducted in 2010.

The development of the plan focused on collecting information and ideas to

- Determine strategic needs by defining an optimal perspective of how the freight planning process should work in an unconstrained environment, with all of the model parameters clearly identified and the necessary data available. The goal is to promote the development of new tools for modeling and data collection and generate ideas for dramatic changes in freight transport planning practices.
- Identify and promote innovative research efforts that could help develop new modeling and data collection and processing tools in the near and long-term future. These efforts should include different geographic scales, with sound theories and approaches, forecasting methods, and relevant model and data tools for the appropriate geography.
- Establish and strengthen links between freight transportation planning tools and data, as well as other aspects of planning and public policy in which freight movement has major implications.
- Leverage existing practices, innovations, and technologies into a feasible freight transportation planning and modeling approach.

- Establish a venue for promoting and supporting innovative ideas, modeling methods, data collection, and analysis tools; such a venue is critical to sustain further research.

Modeling and Data Issues in Brief

Passenger travel demand models, data, and practices are well defined. Over the past 60 years, these tools (and the supporting data) have been developed through an iterative process among the modeling community. Funding was available to make steady incremental progress. This long-term development allowed the science behind the modeling to continue to evolve. Federal, state, and local requirements focused on passenger travel because these movements represented the majority of the traffic on the roadways. After the four-step trip-based modeling process was adopted as the standard in the early to mid 1970s, which coincided with the fulfillment of the requirements of the Clean Air Act of 1970, there were initial breakthroughs and innovations. From the 1980s to the present, there have been fewer large leaps and more minor process improvements in the state of the practice.

Freight demand models and data have not received the same attention as passenger transportation. This is primarily a result of the highway system being developed to accommodate passenger (and military) vehicles, and the justification for building the highway system required tools to estimate demand (and later air quality impacts). Freight has been difficult to model and freight data have been difficult to collect because

- Data have historically not been available regarding commodities, shipments, demands, and production cycles;
- Freight transportation is primarily a private sector business activity and little has been understood about the supply and logistics chains from a private sector point of view;
- The modeling community has not understood the broad economic influences on local freight movement (and vice versa); and
- Freight model development is driven by the available data, which are lacking in detail for many applications and decision-making needs.

Recently there has been an acknowledgment that freight models and data are critical to assessing national, regional, and local highway capacity; economic development initiatives; and for informing the transportation planning process. Further, it has become clear that the existing tools and data are limited primarily to national-level and larger urban areas. Even these have limited application in informing decision makers, and recent pressures on state and local budgets have scaled back freight modeling and data improvement initiatives and training.

In recent years global positioning systems (GPS), weigh in motion (WIM), and other electronic data collection methods have been used to inform models on an ongoing basis. These methods provide good truck movement data, but they do not provide commodity flow information or data associated with the movement of goods via rail, water, or other freight modes. Having access to and understanding these data can assist planners and decision makers, whose aim is to reduce congestion, increase efficiency, promote economic development, and make informed land use decisions.

Need for Freight Modeling and Data Innovation

The historic inadequacies of freight modeling and data are now juxtaposed against the need for better freight decision making. The planning, economic development, and freight communities now require that substantial leaps in freight modeling and data innovation occur in the near and long-term future.

In 2007, $11.7 trillion worth of goods were transported via the U.S. transportation infrastructure (Research and Innovative Technology Administration 2009), and truck miles (94 billion) accounted for 7.5% of the total vehicle miles traveled that year (U.S. Census Bureau 2009). Considering the capacity impact that freight has on transportation infrastructure, planners must be able to account for freight movements and potential shifts to adequately plan for the future.

It is widely acknowledged within the modeling community that existing tools are inadequate for most regional and local freight planning applications. The existing methods are typically oriented toward national data; local applicability of national data is limited, so tools are typically not robust. In addition, there is growing recognition that tools should incorporate land use, economic trends, and freight activity. Current innovations are trending toward electronic data collection tools such as GPS and WIM rather than advancement of the models themselves.

To achieve the necessary advances, the freight modeling and data community must understand the unique characteristics of freight and the modeling and data challenges associated with the development of needed tools. A brief overview of these topics is presented below.

Unique Characteristics of Freight

Freight forecasting and modeling are challenging because the transportation of freight involves unique transportation processes and is subject to highly complex and variable external influences. Goods movement is affected by short-term changes in the conditions that drive supply and demand for various products and raw materials. These variables are not easily quantifiable in long-term forecasting. As a business activity that is inextricably tied to the behavior of producers and consumers, freight transportation is reactive by nature and meets the classic economic definition of a *derived demand* (i.e., demand for freight transportation and affiliated services occurs as a result of demand for products and raw materials).

The derived nature of freight transport activity renders traditional transportation planning tools and methods unsuitable for accurate forecasting. Important factors that make freight demand difficult to quantify and predict include

- Transportation activity, including transport modes and equipment, varies widely for different types of commodities. A load of coal shipped from a mine to a power plant 50 miles away, for example, would likely be moved by rail because of the efficiency of the rail system in accommodating heavy loads moved in large quantities. The same quantity (measured by volume or weight) of household electronics, on the other hand, would likely be moved by truck over any distance shorter than several hundred miles.
- Time sensitivity is a major factor in the decision-making process for shippers of many commodity types. Materials of low unit value that are moved in large quantities, such as coal or aggregates, are likely to be moved via slower modes such as rail or barge for domestic transport or by ship for international transport. Conversely, high-value products, especially products with a limited shelf life, such as pharmaceuticals or fresh food, are more likely to be delivered by truck for domestic moves or by air for international transport.
- Unlike passenger travel, for which peak periods of activity tend to occur in predictable patterns by time of day and by day of the week, freight transportation is more heavily influenced by seasonal variations. For example, peak demand for consumer products tends to occur in the months and weeks before the December holiday season, while demand for materials used to produce energy fluctuates by energy type (e.g., the heaviest use of gasoline occurs in the summer months, while home heating oil is used almost exclusively in the winter).
- Freight corridors in the United States go beyond jurisdictional boundaries and link MPOs, states, and subregions within the United States and may also be connected to Canada and Mexico. Corridors like I-95, I-29/I-35, and I-5 have begun crossing jurisdictions in their planning, and although they all have different characteristics, they struggle with similar passenger, freight, and congestion issues.
- The supply and demand for any commodity imported to or exported from the United States is influenced heavily by international trends and economic considerations that are difficult to forecast. This trend has become more important over time, and is likely to continue, as the global economy has become more interconnected. The types of commodities moved around the world and the countries where these commodities originate and are consumed are influenced by factors such as currency exchange rates, political stability, demographic changes, and technological development in emerging economies. These factors are often subject to rapid change, which makes them extremely difficult to predict over long time periods.

Modeling Challenges

The complexity of the private freight transportation business model poses challenges to the predictive capabilities required by the public sector. Supply chains are global; however, impacts to the transportation system are felt locally. Simulating freight movements to the level of detail that is useful for regional, corridor, or local planning is challenging with the tools available because the geographic scale of models and data used in the planning process needs to be refined.

Sound planning tools must be developed in line with important foundational principles. Because incorporating some of these principles into useful planning tools requires a great deal of effort, it is important for the freight modeling community to understand the challenges associated with them. Some of these challenges include

- Formulating a relationship between planning tools and data at different geographic levels (aggregate versus disaggregate);
- Developing commodity-based tools at refined geographic scales;
- Using resources to review and evaluate the results of past projections in order to refine the tools and data used for better forecasting;
- Bridging the vexing gap between long-range public sector planning horizons and near-term private sector decision cycles;
- Developing freight movement activity in the context of land use decisions at all steps in the process (production, delivery, and consumption);
- Presenting opportunities to use freight planning data and tools to support ongoing transportation planning processes (special studies, development of transportation improvement programs and long-range transportation plans, freight corridor identification) and other efforts (e.g., bridge and pavement design); and
- Ultimately, developing a standard and universally accessible toolbox of freight planning data and tools.

Only by addressing these challenges effectively and systematically will the results required by freight modelers, decision makers, and the general public be achieved. Creating effective and useful freight planning models will depend on improving the data that support those models, while simultaneously improving the knowledge of the planning community regarding the workings of private industry and the resulting impact on the freight transportation system.

Data Challenges

Current practices in modeling have been developed based on the data available. If new and more robust data sets become available, then freight models will evolve to better reflect the practices that drive the demand for freight and the resulting impact of that demand on the nation's transportation infrastructure.

Data advances in recent years have come from enforcement and tracking measures (such as WIM and GPS) that were not originally intended to be used by the freight planning community. Although these data sources are more accurate and less time consuming to use than their predecessors, they require manipulation for modeling and forecasting use. Freight models require data that are specifically collected for freight modeling and contain the detail needed to make decisions at various geographic levels. Some of the challenges to achieving freight-specific data include

- Perceived or real difficulty in obtaining proprietary data from private sources;
- Difficulty in quantifying the touring (i.e., local delivery) component of truck traffic in metropolitan areas;
- Lack of clarity in the relationships between land uses and freight generation and attraction (which are less clear than for passenger travel);
- Difficulty in quantifying the role and implications of empty and partially loaded freight vehicles (trucks, rail cars, ships) in the freight transportation process;
- Inconsistency of data across different modes of transport (rail versus highway versus air cargo versus intermodal);
- Need to manipulate data collected for other purposes in order to incorporate or expand the data for modeling purposes;
- Limitations in the local applicability of national data, which typically result in less than robust tools;
- Discontinuation of certain current data collection processes (e.g., the Vehicle Inventory and Use Survey) that could provide critical data at various geographic levels;
- Inaccurate or nonexistent local-level commodity flow data;
- Different characteristics of long-haul trucks and local deliveries, as well as empty movements for all modes (especially truck);
- Lack of data regarding the growing role of small-package and overnight freight relative to traditional freight movement; and
- Matching the type and format of local and national data collection efforts.

These modeling and data challenges can be overcome with the proper use of technology and resources. Modeling and data will need to be advanced simultaneously to enable the best data to be used with the best tools at a given time for a specific geography. To achieve these simultaneous advances, another category of challenges must be addressed: knowledge.

Knowledge Challenges

There is a present disconnect between data collection and model building that can be surmounted with the technical knowledge within the planning community, as it was during the advent of passenger travel demand models. There is, however, a fundamental gap in the knowledge between those who build freight demand models and those who make freight-related decisions that is harder to bridge. This knowledge challenge involves many disparate stakeholders among the freight community, such as modelers, state DOT programming staff, elected officials, economic development agencies, trucking companies, shippers, receivers, railroads, port terminal operators, and local planners. To bridge this knowledge gap, data and modeling initiatives must work to create a collective understanding among the many stakeholders of the issues related to freight movement. Steady progress to close the knowledge gap will be a springboard for many other advances. Within this overarching challenge are smaller, more discrete challenges, which include

- Developing a thorough understanding of real-world supply chain processes, including the broad economic influences on local freight movement;
- Clarifying the role of terminal operations and intermodal load transfers on mode selection in freight transportation and the impact on the surface transportation system;
- Understanding the role of the backhaul in service options and pricing;
- Quantifying the potential for public–private and public–public data sharing arrangements;
- Understanding the potential local impacts of major national and international economic changes;
- Identifying environmental justice and community issues associated with freight movement;
- Addressing the dynamic nature of freight movement in capacity assessments;
- Expanding the understanding by decision makers of system throughput and its effect on freight system management; and
- Demonstrating to the private sector the tangible benefits of their participation in the planning process.

These knowledge challenges are the most important and foundational because they give the model and data improvements their purpose. The disconnect between the interests and knowledge of the various stakeholders should be acknowledged as innovations in freight demand modeling and data continue so that these innovations may be directed toward bridging this knowledge gap.

CHAPTER 2

Research Approach

The challenge in developing the Freight Demand Modeling and Data Improvement Strategic Plan was to identify a compelling direction for the freight planning community—including meeting the immediate needs of decision makers—while continuing to foster innovation among researchers for making long-term improvements to freight modeling and data. To meet this challenge, the research team focused on defining the gaps in models, data, and information for decision makers and formulating future directions to guide the long-term initiatives identified throughout the research process.

A robust approach to define needs, innovations, and long-term goals centered on input from practitioners, decision makers, and past practices. This approach involved a review of research conducted on freight modeling and data improvement and an analysis of current domestic and international practices within the industry. Practitioners were engaged through an Innovations in Freight Demand Modeling and Data Symposium and competition. Involvement of freight stakeholders fostered discussion for validating research priorities and strategic directions for the freight modeling and data improvement community. The approach elements, their purpose, and outcomes are shown in Table 2.1.

Defining the Strategic Needs

Understanding and defining needs requires asking specific questions. The first and most critical question for defining the depth of this research was, "Whose needs?" Many public and private entities with a stake in the efficient movement of goods are involved in freight modeling, data collection, and decision making. Public sector groups such as freight planners, policy makers, safety officials, and regulatory officials require freight modeling and data to maximize capacity, increase safety, and target the best use of funding to make the maximum impact on the transportation system. Public sector interests function at various geographic levels; to achieve their individual goals and mandates, each group has specific freight data and modeling needs.

Private sector interests seek information to maximize efficiency throughout the logistics chain, part of which is moving goods on public infrastructure. Within the private sector are companies and service providers with unique characteristics and needs relative to freight demand modeling and data. For example, trucking companies require different freight data than third-party logistics providers, whose needs are different from those of railroads, port terminal operators, suppliers, and manufacturers.

The identification of the strategic needs of these freight demand modeling and data stakeholders has been systematically considered in this research. Both the public and private sectors have important data and analytic needs. Each sector also has something to offer for the benefit of all. The key is to identify the data and tools available, note where there are overlapping needs, and address how to fill any remaining gaps that may benefit the freight community as a whole.

Public sector and private sector strategic needs were identified through an outreach campaign that included workshops with private sector representatives and officials from DOTs, MPOs, toll authorities, and county planning agencies. These workshops and outreach sessions took place in Newark, New Jersey; Tacoma, Washington; Tempe, Arizona; New Orleans, Louisiana; Irvine, California; Minneapolis, Minnesota; Columbus, Ohio; and Washington, D.C.

Identifying Innovative Research Efforts

Identifying innovative research is imperative to SHRP 2 C20. Innovations are what led to the development of today's travel demand models for analyzing passenger movements, air quality, congestion, corridors, and other factors. Identification of those innovations specifically aimed at freight demand modeling and data improvement will provide the building blocks for the freight analysis tools of tomorrow. As depicted in Figure 2.1, the SHRP 2 C20 Freight Demand Modeling and

Table 2.1. Research Approach Elements

Approach Element	Purpose	Outcome
Technical Expert Task Group	• Articulate the project and industry vision • Advise project team • Review interim and final findings	• Overall project oversight and direction
Background Research	• Identify domestic and international best practices • Identify historic freight modeling and data challenges • Identify opportunities, innovations, and unique data sources	• Catalog of current and best freight modeling and data collection practices • Determination of potential areas for improvement and innovation • Background in defining strategic needs
Innovations in Freight Demand Modeling and Data Symposium	• Identify domestic and international innovative practices • Discuss applicability and improvements to innovations • Launch a forum for sharing of freight demand modeling and data innovations	• Current innovative initiatives • Brought the data and modeling community together to foster the best thinking on the subject • Venue for future sharing of innovative ideas • Formal structure for rewarding freight modeling and data innovations
Stakeholders Outreach and Workshops	• Validate the strategic directions • Discuss a series of key issues • Review, critique, and validate strategic research initiatives that will affect freight transportation for years to come	• Validation and supporting ideas and discussion on the Strategic Plan • Validation and discussion on research priorities • Ideas for continuing innovations to meet decision-making needs
Strategic Plan	• Frame the long-term direction for freight modeling and data improvement • Foster innovative practices in modeling and data • Set an agenda for short- and long-term research initiatives	• Documented strategic needs and innovative research efforts • Developed a feasible approach to freight transportation modeling and data improvement • Identified short- and long-term strategic research initiatives • Developed a strategic plan and road map

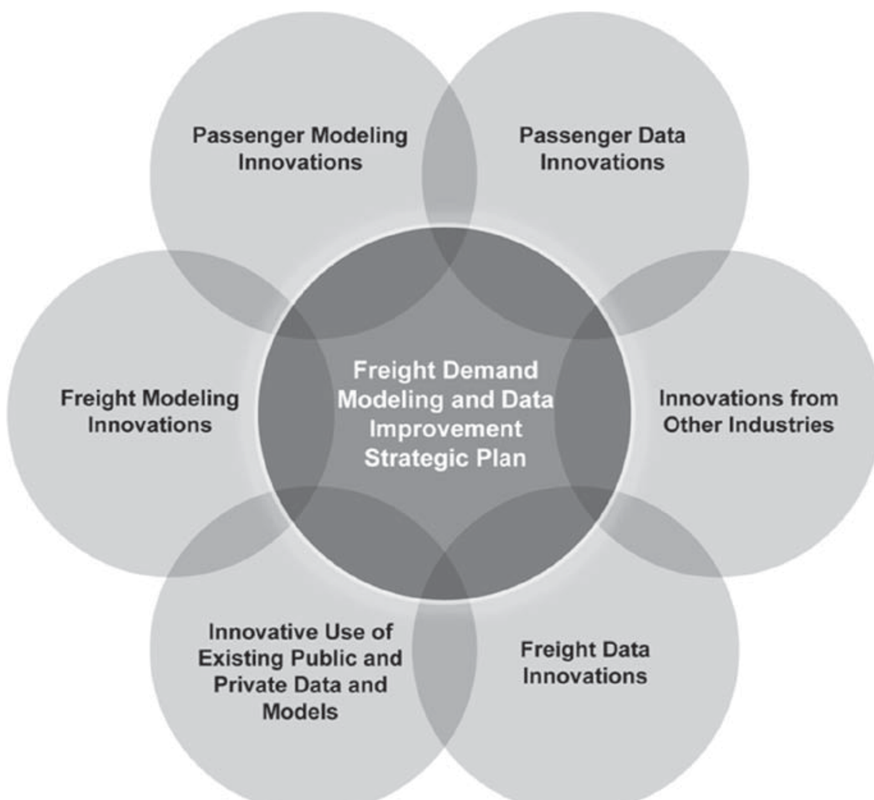

Figure 2.1. Innovations considered in the SHRP 2 C20 Freight Demand Modeling and Data Improvement Strategic Plan.

Data Improvement Strategic Plan incorporates these elements as part of the strategic future directions and research initiatives to glean fresh ideas and identify and fill the knowledge and data gaps that remain relative to freight analysis and decision-making needs.

The innovations shown in Figure 2.1 were identified through various efforts. Research provided a perspective on past innovations, specifically the history of the development of passenger travel demand models and data. Outreach meetings and interviews with private sector practitioners revealed several modest and recent innovations that, if combined with existing practices or new innovative practices, should foster the development of better freight planning tools. The primary source of innovative practices was the 2010 Innovations in Freight Demand Modeling and Data Symposium, which was a pilot initiative to assist the freight community in the identification of such innovations.

The two-day symposium was organized into six sessions based on six areas of research interest as determined by the topics of the papers that were submitted:

1. Regional freight model development;
2. Alternative techniques for modeling freight transport;
3. The application of econometric and statistical methods;
4. International perspectives on modeling freight;
5. Data collection and visualization techniques for analyzing freight travel patterns; and
6. Microsimulation approaches to freight forecasting.

Each session comprised two or three 20-minute presentations, followed by a 15-minute question-and-answer discussion involving the entire audience and the presenter. As a participation incentive, the freight modeling presentations competed for a $1,000 prize. The symposium attracted a diverse audience representing academia, public sector practitioners, and private industry. Participants examined, evaluated, and promoted innovative and promising advances in freight demand modeling, data collection, and freight forecasting research methods. Local, state-level, regional, domestic, and international models were presented.

Developing a Feasible Approach to Freight Transportation Modeling and Data

Issues related to freight transportation link closely to other relevant issues such as land use planning, economic development (economic growth, employment, funding sources), environmental protection, infrastructure planning and development (including both transportation and nontransportation infrastructure), and energy considerations. Moving forward, a key element of the freight planning process will be its ability to link pertinent information and collaborative analyses with these other planning efforts to the maximum extent possible.

Feasible implementation of freight travel demand modeling and data innovations requires additional and ongoing data gathering, technological advances, incentives, funding, collaboration, and coordination. The efforts of the freight community—public and private—must be involved in framing the pertinent questions that need to be answered, and in developing the data required for analysis, the tools needed, and the sources of funding that will enable the development and implementation of versatile freight travel demand models.

The research team worked strategically to craft the approach to pursue short-term and long-term freight demand modeling and data improvements. These complex issues were considered by developing pertinent information obtained from workshop discussions, one-on-one discussions, and research publications. The collaboration and coordination necessary to develop new freight planning tools and data were pursued throughout the SHRP 2 C20 outreach effort. The results are incorporated into the research initiatives and future directions described in Chapter 4.

Establishing a Venue for Supporting Innovation

Freight demand modeling is more dynamic and heterogeneous than passenger demand modeling because of the many complex interactions between international and domestic flows, public and private interests, and logistics behavior. The inadequacy of freight modeling and data for many of the pressing issues facing decision makers and freight planners makes it is important to create a venue in which the freight community can share innovative ideas and discuss ways to apply and improve them. This effort is critical to sustain further research efforts. Ideally, this venue would involve a collaboration of public and private interests that share a common goal of improving freight transportation planning efforts and can secure access to financial resources, innovative ideas, and extensive data to support these efforts in the future.

The 2010 Innovations in Freight Demand Modeling and Data Symposium served as a pilot for future symposia with the intent of establishing a venue and format for the sharing of innovative freight modeling and data ideas. This collaborative, multisector symposium was intended for a diverse audience of academia, public sector practitioners, and private industry interested in furthering the science and application of freight demand modeling and forecasting. The participants were tasked with examining, evaluating, and promoting innovative and promising advances in freight demand modeling, data collection, and freight forecasting research methods.

The 2010 symposium centered on discussing how current freight models fall short and identifying data needs that can bridge the gap between a traditional freight model and a valid real-world tool that can be used with confidence for day-to-day planning and operations. Featured presentations addressed the challenge of finding the next generation of freight demand models.

Future symposia should be tailored to the seven strategic objectives described in Chapter 4, provided there is sufficient research interest in those areas expressed in future responses to calls for papers. Potential topics to be discussed in future symposia include the accuracy and dynamic requirements of valid freight models and forecasting; data collection, data quality, and data relevance; energy and environmental impacts (including mode shifts, pollution reduction technology penetration, and fuel prices); creation of local-level dynamic modeling data outputs in response to national events; public and private sector funding impacts on local freight traffic and logistics; and relevant performance measures to determine a model's usefulness for investments and public sector funding decisions.

Participation in freight symposia will continue to bring freight modeling practices closer to real-world, practical, and relevant freight model generation and outputs, and importantly, further the science.

CHAPTER 3

Findings and Applications

Passenger models have advanced throughout the past five decades, but freight modeling and data are still in their formative stages. However, freight is critical to the national, regional, and local competitiveness of the United States. Accommodating, or at least considering, freight within everyday planning practices at the federal, state, regional, and local levels is necessary to benefit the public as consumers, employees, and business owners.

The findings within this chapter reflect extensive research and outreach to freight stakeholders. The following sections lay out the current state of freight demand modeling and data, as well as potential innovations to advance the state of the practice.

Freight Industry Trends Overview

The past several decades have been marked by major changes in domestic and global freight transportation. These changes have been driven by population growth and other demographic changes, adjustments in consumer behavior, dynamic market and economic forces, changing business practices, and advances in transportation and information technology. Public and private decision makers responsible for understanding the implications of these trends for the transportation infrastructure planning process must contend with the influence of increasingly complex supply chains and logistics processes.

Several key issues related to the changes and increasing complexity in freight transportation in the United States include the following:

- The decline of manufacturing occurring in Northeastern and industrial Midwestern states, accompanied by the growth of industry and manufacturing in the Sun Belt, and a shift in manufacturing activity for many products from the United States to other locations around the world.
- Lower population growth in the Northeast and Rust Belt states, with higher growth rates occurring in Southern and Western states.
- A gradual shift in location advantage for traditional industries. The need for access to inland waterways (including the Great Lakes system) and freight rail connections to domestic sources of raw materials and subassembly locations has diminished in importance, while deep-water ports and Class 1 rail connections to ports and North American Free Trade Agreement trading partners have played a bigger role in freight transportation.
- Minimal capacity additions to the highway system. Since the establishment of the U.S. Interstate Highway System in the 1950s and its development and expansion in the following decades, there has been little expansion in the highway system in the past 15 to 20 years.
- The growing use of the shipping container as a standard means of moving many forms of freight has made freight transportation across multiple transport modes increasingly modularized and improved transportation efficiencies over longer distances.
- The deregulation affecting the railroad, trucking, and airline industries.
- Consolidation in all sectors of the freight transportation industry (particularly rail) has resulted in longer supply chains and driven the development of massive economies of scale that have reduced transportation costs on a unit (ton-mile) basis.
- The application of advanced information and communications technology in many areas of manufacturing and freight transportation has enabled shippers and carriers to increase efficiencies at multiple steps in their supply chains.
- The increasing dominance of the service sector emerging in the mature economy of the United States, along with online retailing and the resultant implications for overnight shipping, small-parcel deliveries, and terminal-based truck activity within smaller geographic regions.

The various factors described here, coupled with the increased complexity of supply chains and logistics processes, have resulted in an environment in which incorporating freight movement considerations in the transportation planning process has become increasingly difficult at the very time that these considerations are more critical to the ability to forecast long-term transportation trends and plan for future needs. This situation is exacerbated by the inherent political dilemma faced by decision makers involved in almost any freight-related aspect of the transportation system: the widespread disconnect between users of the system (shippers and carriers) and those who benefit most from the system (the general public). Taxpayers can be more attuned to the real and perceived negative impacts of freight movement than to the broad benefits they receive from freight movement.

The significant changes that the freight industry has undergone over the past two decades and the key trends influencing freight transportation fall into four general categories (Kuzmyak 2008):

1. Globalization of trade—Freight movements range in geographic scale and scope, and the supply chains that span the entire globe can often have very localized impacts.
2. The economy—The cyclical nature of economic trends results in changes in freight transportation characteristics over time.
3. Private sector inventory practices—Many of today's national and international businesses rely on manufacture-to-order and just-in-time inventories to meet customer demands, which makes reliability, speed, and flexibility crucial to both maximize efficiencies and maintain industry profit margins.
4. Warehousing—Freight transportation processes have become cost-efficient across different transport modes over time, and the close physical proximity of supply points (e.g., raw material sources, production facilities) to consumers no longer offers the advantages it once did. The traditional warehouse, which was primarily used for storage of raw materials and finished products, has been replaced by a distribution center whose primary functions include efficient consolidation and distribution activity aimed at reducing shelf time for materials and enhancing the efficiency of the overall logistics process.

Current Practices

As a result of these major changes in freight transportation, the planning process for freight-related capacity needs has become increasingly complex. However, public sector transportation decision making remains relatively uninformed with respect to freight transportation due to the limits of the current models. These models are unable to accurately replicate current conditions or forecast the impacts of freight on future transportation systems, thus limiting the possibilities for policies and improvements to solve expected problems and address future capacity needs.

The practice of freight demand forecasting has received greater attention with the growing recognition that efficient freight and commercial truck travel is essential to national, state, and local transportation infrastructure planning and the economic well-being of the nation as a whole, as well as the prosperity of individual states and regions. Incorporating freight movement considerations in the transportation planning process is difficult, but these considerations are increasingly critical to the ability to forecast long-term transportation trends and plan for future needs.

Current practices in freight modeling and data development used by various organizations and planners in the United States are documented in the following sections. This review of the practice addresses stakeholder and user needs along with the strengths, weaknesses, opportunities, and threats regarding critical issues and the knowledge, data, and tools that should be addressed through innovation and further research. This review includes descriptions of various types of freight demand models, the methods of freight demand forecasting currently in use, and promising methods of freight forecasting emerging from research. This review also summarizes the variety of public and private data sets commonly used by model developers and practitioners to estimate, validate, and apply state-of-the-practice forecasting methods for freight movement. A basic understanding of the current state of the practice provides an important foundation for future improvement.

Models

Freight planning practitioners use different models and analysis tools depending on the purpose of the analysis and data availability. These tools assess a range of measures, from commodity flows to economic impacts. It is important to understand existing tools in order to determine whether using them as building blocks, components, or discrete tools is feasible and advantageous to advancing innovations in the state of the practice.

Each model is described below, along with its strengths and weaknesses.

Economic Flow Models

Economic flow models estimate the flow of goods and services between households and firms, balanced by the flow of payments made in exchange for them. Economic flow models are built on four economic activities:

1. Production—The use of economic resources in the creation of goods and services;
2. Consumption—Consumer or raw materials purchasing;
3. Employment—The use of economic resources for labor in production or economic activity; and
4. Income generation—Maximum amount an individual can spend during a period without being worse off (Valdehueza 2008).

Economic flow models are used in freight modeling to estimate the flow of goods based on these economic activities and then applied to estimate modal flows through a network. This estimation can be completed for national, regional, and local geographies, depending on data availability.

Strengths
- Estimates goods movement from the origins of freight activity;
- Estimates the volume of physical goods while considering other economic indicators and influences that may affect current and future movements; and
- Could be used to better estimate local freight touring trips, as well as regional truck flows, depending on the level of detail in the supporting data.

Weaknesses
- Requires significant data collection for disaggregated inputs; and
- Requires an understanding of markets for both goods and services, as well as monetary policies.

Land Use and Economic Input–Output Models

Input–output analyses are used to understand an economy by describing flows to and from industries and institutions. These models are best suited to predict changes in overall economic activity as a result of changes in underlying economic forces. They can be applied to freight trip generation models by using input–output data (with employment and population data) to estimate the zonal level of commodity production and attraction. Input–output models have three basic components:

1. Transactions—The monetary flows of goods and services in a local economy for a given time period, including goods and services purchased and used in the production process, purchases for consumption, and payments for factors or inputs outside intermediate production processes.
2. Direct requirements—The purchases of resources (inputs) by a sector from all sectors to produce one dollar of output based on a multiplier effect. This measures the total change throughout the economy (output, employment, and income) from one unit change for a given sector.
3. Total requirements—The relationships between the different input and output requirements, recognizing that if output for final demand increases, not only must purchases of indirect inputs increase, but firms supplying those direct inputs must increase their purchase of inputs. This analysis is done through a relational table of all industries being examined.

Input–output models (depending on the software package) have comprehensive and detailed data coverage of the entire United States by county and the ability to incorporate user-supplied data at each stage of the model-building process. These options provide a high degree of flexibility for both geographic coverage and model formulation.

Strengths
- Estimates changes to various industries as a result of consumer spending, raw materials consumption, and other economic indicators or scenarios; and
- Offers flexibility to change various parameters for scenario-based analyses.

Weaknesses
- Requires significant effort to translate results into goods movements and commodity flows and modal movements; and
- Requires significant effort to generate accurate multipliers in order to yield accurate truck volumes.

Commodity-Based Models

Commodity-based models estimate the amount of freight moved by weight. This method simulates the economic basis for freight movements, focusing on commodity attributes (e.g., shape, unit weight), and includes the following steps:

- Generation—An estimate of total tons produced and attracted by zone;
- Distribution—An estimate of goods exchanged between origin–destination (O-D) pairs;
- Mode split—An estimate of the weight moved by the various modes; and
- Assignment—Loaded, partial, and empty trips applied to origin–destination matrices by mode and assigned to a network (Jack Faucett Associates 1999).

This approach yields a region-to-region commodity tonnage table based on economic forecasts and historic trade patterns. Flows are then disaggregated to zones based on historic and forecasted activity levels of production and consumption within each zone for each commodity. The disaggregated flows are converted into trucks and assigned to a network (Holguín-Veras et al. 2001).

Strengths

- Provides sound estimations of national, statewide, and regional movements; and
- Provides a more robust method for estimating truck trips than a vehicle-based model.

Weaknesses

- Provides low-quality local commodity flows as a result of lack of data; and
- Uses a similar method to the four-step passenger modeling process, which does not consider the entire logistics chain in its estimation.

Trip-Based Models

Trip-based models focus on modeling vehicle trips, which implies that mode selection and the vehicle selections have been completed using other methods. One advantage of trip-based models is that traffic data are readily available; for example, ITS applications are able to provide data on vehicle movements on highway networks. Trip-based models also consider empty vehicle trips (Holguín-Veras and Thorson 2000).

The trip-based model generates truck trips as a function of different land uses and trip data from trip logs or shipper surveys. The generated trips are distributed using spatial interaction models (such as a gravity model), which are calibrated using trip lengths obtained from trip logs (Jack Faucett Associates 1999).

Strengths

- Uses readily available data; and
- Easily calibrates truck movements to current volumes. Is easily incorporated into existing statewide and MPO modeling processes.

Weaknesses

- Does not consider the entire logistics chain in its estimation because of its simplistic design; and
- Does not provide an ideal method for distributing truck trips across a network because of limitations in the gravity model method.

Estimation Routines

Estimation routines apply localized, regional parameters to localized, regional zonal and network data to produce truck size, trips, and vehicle miles traveled (VMT) estimates for each vehicle category, and in some cases, goods movement by commodity and modes (Cambridge Systematics 2007). These techniques include

- Three-step model—Various techniques that estimate commercial vehicle trips from intercept surveys or trip-based, regional commercial vehicle surveys. These models, which typically include a trip generation, distribution, and assignment mode-chain structure, estimate commercial vehicle zonal trips, categorized by type, and link-based network volumes.
- Three-step plus port model—Various three-step model techniques that include a separate trip generation and distribution routine for a marine port.
- Tour-based microsimulation—Various techniques that estimate commercial vehicle tours from tour-based, regional, commercial vehicle surveys, considering transshipment and distribution center movements from the moment the vehicle leaves until it returns. These models provide estimates by type of establishment (e.g., manufacturing, construction) of the number of light, medium, and heavy commercial vehicles; the purpose of each trip on the tour; and each stop location.
- Sample enumeration—A technique that repeatedly samples regional large-scale survey data to develop multiple-class truck trip matrices as input to a multistep freight model (Donnelly et al. 2008).

Strengths

- The three-step model is computationally easy and consistent with the common practice in most four-step models. It can be based on local surveys, as well as national data sources (such as the *Quick Response Freight Manual* [QRFM]), and is easy to understand.
- The three-step plus port model has all of the strengths of the three-step model and includes unique characteristics of marine ports.
- Tour-based microsimulation provides more detailed information on truck distribution patterns than the three-step methods, is more behaviorally based than other methods, and can be integrated with economic input–output models.
- The sample enumeration technique uses locally collected survey data as the basis of truck movement patterns and is more behaviorally based than the three-step models.

Weaknesses

- The three-step model has little behavioral relationship to the actual decision-making process in freight movement, fails to consider the unique characteristics of some generators, lacks multimodal goods movement characteristics, and introduces some aggregation error.

- The three-step plus port model has little behavioral relationship to the actual decision-making process in freight movement, lacks multimodal goods movement characteristics, and is more dependent on certain local survey data than the three-step model.
- Tour-based microsimulation is computationally complex, is more dependent on some local survey data than the simple three-step model, and lacks multimodal goods movement characteristics.
- The sample enumeration technique is computationally complex, requires local survey data, lacks multimodal goods movement considerations, and does not address true logistical considerations.

Aggregate Measures

Aggregate measures apply national default growth factors or parameters to localized, regional data to produce fleet size, trip, and VMT estimates for each vehicle category (Cambridge Systematics et al. 2004). These techniques include

- Factored trip matrix—A technique that applies national growth factors to an existing, often dated, localized, regional truck trips matrix;
- Simple matrix estimation—Various techniques that apply a single seed, or best guess, truck trips matrix, calibrated using the most up-to-date truck counts, to develop a likely truck trip matrix, which is then factored using national growth trends;
- Elegant matrix estimation—Various techniques that apply multiple seed (weighted by quality and level of confidence) data, calibrated using the most up-to-date truck counts, to develop multiple-class truck trip matrices, which are then factored using national growth trends;
- Polenske–Roberts (PR) variant—A technique developed in the 1970s that uses basic input–output models to allocate Commodity Flow Survey (CFS) or Transearch® data into freight zonal-level trips; and
- PR variant plus matrix estimation—A technique that uses basic input–output models to allocate CFS or Transearch data into freight zonal-level trips and is calibrated using either simple or elegant matrix estimation (Donnelly et al. 2008).

Strengths

- The factored trip matrix relies on readily available data sources and avoids some of the aggregation errors in the three-step methods;
- The simple matrix estimation and elegant matrix estimation techniques rely on readily available data sources, avoid some of the aggregation errors in the three-step process, and incorporate local truck traffic patterns;
- The PR variant relies on readily available data, avoids the aggregation errors in the three-step process, and adds an economic component to the analyses; and
- The PR variant plus matrix estimation relies on readily available data, does not require the three-step methods (and thus avoids their aggregation errors), adds a national economic component to the analyses, and uses local survey data.

Weaknesses

- The factored trip matrix has no behavioral basis, no multimodal components, and is based on national factors that may not consider local development nuances;
- The simple matrix estimation has no behavioral basis, no multimodal components, is based on national factors, and cannot be readily used for forecasting in areas with rapid development;
- The elegant matrix estimation has no behavioral basis and cannot be readily used for forecasting in areas with rapid development;
- The PR variant is not based on locally collected data and is not readily forecasted; and
- The PR variant plus matrix estimation cannot be readily used for forecasting in areas with rapid development.

Quick Response Procedures

Quick response procedures typically apply national default parameters to localized, regional zonal and network data to produce truck fleet size, trip, and VMT estimates for each vehicle category (Cambridge Systematics et al. 1996). These techniques include

- QRFM model—QRFM does not recommend or supply a particular modeling technique; however, it provides a wealth of generalized urban freight patterns, compiled from several sources, to build a multistep freight model; and
- QRFM plus matrix estimation—A technique applying either single or multiple seed (weighted by quality and level of confidence) data, calibrated using the most up-to-date truck counts, to develop multiple-class truck trip matrices, which are then factored using national growth trends, and included in a multistep freight model developed using the generalized urban freight patterns outlined in QRFM (Donnelly et al. 2008).

Strengths

- The base QRFM method relies on readily available national data sources, is easy to implement, and requires no local data collection.
- The QRFM plus matrix estimation technique relies on readily available national data, is easy to implement, and uses some locally collected data.

Weaknesses

- The QRFM method has little behavioral basis and does not incorporate locally observed characteristics.
- The QRFM plus matrix estimation method has little behavioral basis and cannot be readily used for forecasting in areas with rapid development.

Summary and Implications

- Public and private decision makers involved in freight transportation must deal with an increasingly complex landscape involving rapid changes, both domestically and globally, related to population growth, economic forces, and technological advances.
- Significant changes in freight transportation documented in key research papers include the globalization of trade, underlying economic forces, private sector inventory and logistics practices, and centralized warehousing.
- Basic types of techniques used in freight planning, forecasting, and modeling include economic flow models, land use and economic input–output models, commodity-based models, trip-based models, estimation routines, aggregate measures, and quick response procedures.
- The strengths and weaknesses of these various techniques relate to the ease of understanding the method in question, the ability to use readily available data, the complexity of the modeling process, the relationship of the freight movement measurements to economic influences and land use, the flexibility to use different parameters for scenario-based testing, the accuracy of the modeling technique based on local data, the model's ability to incorporate behavioral considerations, and the consideration given to complex logistics processes in freight movement (e.g., multimodal transportation, local touring and delivery).
- Data typically used in freight planning and forecasting include local data sources (e.g., truck counts, land use data), the National Transportation Atlas Database (NTAD), CFS, Freight Analysis Framework (FAF), Transearch data, private sector data sets, and federal resources such as U.S. Census data, the Surface Transportation Board's Carload Waybill Sample, or the U.S. Army Corps of Engineers Waterborne Commerce Statistics Database.
- The strengths and weaknesses of these data involve their availability and frequency of updates, the cost of collecting data to fill gaps, their accuracy and suitability for planning and modeling on different geographic levels, potential errors in aggregating or disaggregating data for appropriate geographic scales, and the ability to establish relationships of attribute data with model networks. Moreover, it must be established that any of this information provides value in informing the transportation decision-making process.
- The traditional four-step technique for modeling freight, which is based on the basic modeling method for passenger travel, has served the industry for some time but has significant shortcomings related to freight modeling:
  - The use of multiple freight transport modes is a standard business practice, but it is not captured by the models;
  - The approach does not accommodate the varying needs related to data and forecasting tools for different geographic scales;
  - It does not reflect variations among transportation patterns for different types of commodities;
  - There is difficulty in obtaining certain proprietary data from private sources, and a lack of private data standardization among the various sources;
  - Peaking characteristics for freight activity differ substantially from passenger travel activity, which serves as the foundation for most travel demand forecasting tools;
  - These models do not include international trends and economic considerations, yet these trends heavily influence freight transportation activity in the United States;
  - The four-step technique does not capture the influence of time sensitivity in the mode choice process for various types of cargoes;
  - It is difficult to quantify local deliveries (touring) in metropolitan areas; and
  - The four-step technique falls short in identifying and quantifying the complex relationships between land uses and freight generation and attraction.

Data

Understanding how freight moves into, out of, and through a modeled area (i.e., nation, state, region, corridor) is an important first step to forecasting and planning for the movement of both goods and people. Providing easy-to-comprehend information on current and future freight movements helps inform decision makers about freight volumes and trends in relation to system capacity and impacts. Yet there is no single definitive source from which model developers forecast freight patterns to paint the picture of freight impacts on the transportation system. Forecasting and understanding the movement of goods within the United States requires assembling information from a variety of sources.

Several national, state, regional, and local data sets provide information on goods movement at any geographic level, as well as information on how that area fits into the larger local, state, national, or global perspective. Generally, depending on the size of the planning area, freight models developed and maintained by public agencies use the following data sources:

- Local data sources;
- NTAD;

- CFS;
- FAF;
- Transearch data;
- Other federal resources; and
- Private sector data sets.

Local Data Sources

Local plans and studies provide information about truck traffic counts and forecasts of truck and passenger car travel. These sources are often used by freight modelers to fill in data gaps and identify hot spots where truck traffic causes or is entangled in traffic breakdowns. Similarly, local land use plans frequently identify the location of current or future freight development (i.e., industrial sites, freight transfer centers), which is important to developers. Efficient access to and from these high-freight-traffic areas can be a major contributor to future economic development.

Local population and employment data provide a basis for performing simple regression analyses and likely growth scenarios for regional goods movement. With an understanding of the current production and consumption of goods per capita and goods per job, baseline forecasts of future goods production and consumption can be developed. Changes in productivity rates are often examined, particularly on the local production forecast elements, which could affect longer-term trends.

Local sources of data related to freight movement are oriented primarily toward the trucking industry, as trucks operating on public roadways are a key consideration in most local decisions involving traffic operations and infrastructure investment. Local data commonly used in the planning and forecasting process include vehicle classification counts, which provide reliable information about vehicle size and operating characteristics, but no insight into trip origins and destinations or commodities carried. For more detailed data needs, classification data that may be readily available from state or local DOTs are often supplemented by a more detailed data collection program to obtain the needed O-D and commodity data. Depending on the data needs and the geographic scale of the study in question, these data collection efforts could include roadside intercept surveys and surveys of local business establishments involved in the transportation of freight (shippers and carriers).

Strengths

- Local data are sometimes readily available through existing resources (local planning departments, state or local DOTs); and
- Local data tend to be very accurate at smaller geographic scales and are ideally suited for freight planning at this level.

Weaknesses

- Availability of data for a specific area or project can be uncertain; and
- Local data do not adequately reflect broad economic influences in local freight activity.

National Transportation Atlas Database

NTAD is a set of nationwide geographic databases of transportation facilities, transportation networks, and associated infrastructure. These data sets include spatial information for transportation modal networks and intermodal terminals, as well as the related attribute information for these features. Metadata documentation, as prescribed by the Federal Geographic Data Committee, is also provided for each database. The data support research, analysis, and decision making across various modes (highway, rail, and air). This database is most useful at the national level, but it has major applications at regional, state, and local scales (Research and Innovative Technology Administration 2012).

NTAD also includes information on the following related transportation infrastructure:

- Automated traffic counter locations;
- Highway Performance Monitoring System data;
- Highway and rail at-grade crossings;
- Intermodal terminal locations;
- National Bridge Inventory;
- Ports;
- WIM station locations;
- FAF; and
- Hazardous materials routes.

Strengths

- Is best suited for larger geographic scales; and
- Includes detailed descriptive data from a variety of different sources in a single database.

Weaknesses

- Is primarily descriptive in nature and not directly usable for network-based analyses;
- Establishing relationships of attribute data with model networks can be cumbersome; and
- Does not include any commodity flow information.

Commodity Flow Survey

CFS is a primary source of national and state-level data on domestic freight shipments by U.S. establishments in mining, manufacturing, wholesale, auxiliaries, and selected retail industries. It is used in the development of the FAF and Transearch databases. Data are provided on the types, origins and destinations, values, weights, modes of transport, distance shipped, and ton-miles of commodities shipped. CFS is a shipper-based survey that is conducted every 5 years as part of the Economic Census. It provides a modal picture of national (highway, rail, air, and pipeline) freight flows and is a publicly available source of commodity flow data. CFS was conducted in 1993, 1997, 2002, and in 2007. The final version of the 2007 CFS was released in December 2009 (Research and Innovative Technology Administration 2009).

CFS does not include the following information:

- Forestry, fishing, utilities, construction, transportation, and most retail and services industries;
- Farms and government-owned entities (except government-owned liquor stores); or
- Foreign-based businesses shipping goods to the United States (domestic portions of imported shipments are captured once at a U.S.-based establishment) (Research and Innovative Technology Administration 2009).

Most data are available, expanded, and summarized at the national, state, or county level as long as the data are not confidential. Unlike the FAF databases, CFS reports flow using the North American Industrial Classification System. This method of reporting is helpful as it adds a dimension to the understanding of freight flows in those states that report employment using that classification scheme. As with the FAF data, CFS information is reported on a regional level: metropolitan statistical areas (MSAs), combined statistical areas (CSAs), and states or balances of states outside MSAs and CSAs.

Strengths

- Comprehensive data include origins–destinations, value, tonnage, and transport modes;
- North American Industrial Classification System–based commodity flows allow for correlation with industry-based employment data; and
- Is best suited for larger geographic scales, but can be disaggregated for smaller regions.

Weaknesses

- Does not include all business sectors, and must be supplemented for international freight, which is particularly important given the impact of imported goods on the transportation network; and
- Is not well suited for local freight analyses; disaggregation process for subregional level can be cumbersome.

Freight Analysis Framework

FAF is a product of the FHWA Office of Freight Management and Operations. According to FHWA, "FAF is based primarily on data collected every five years as part of the Economic Census. Recognizing that goods movement shifts significantly during the years between each Economic Census, the FHWA produces a provisional estimate of goods movement by origin, destination, and mode for the most recent calendar year. These provisional data sets are extracted and processed from yearly, quarterly, and monthly publicly-available publications for the current year or past years and are less complete and detailed than data used for the base estimate" (Southworth et al. 2010). FAF integrates data from a variety of sources to estimate commodity flows (using Standard Classification of Transported Goods codes and categories) and related freight transportation activity among states, regions, and major international gateways.

The FAF commodity O-D database estimates tonnage and value of goods shipped by type of commodity and mode of transportation (highway, rail, air, water, and pipeline) among and within 123 areas (MSAs, CSAs, and states or balances of states outside MSAs and CSAs), as well as to and from seven international trading regions throughout the 123 areas plus 17 additional international gateways. The 2007 estimate is based primarily on CFS and other components of the Economic Census. Forecasts are included for 2010 to 2040 in 5-year increments.

Strengths

- Data has similar characteristics of CFS data, with added value of future forecasts; and
- Data translated from geographic basis to transportation network includes National Highway System and National Network roadways, along with limited coverage of intermodal connectors.

Weaknesses

- Is not well suited for local planning efforts;
- Commodity flows are based on O-D pairs only;
- Does not consider full supply chain activity; and
- Forecasting methodology is not clear.

Transearch Data

Transearch, a proprietary data set developed and owned by IHS Global Insight, describes goods movement, usually at a coarse level of geography, for various modes, commodities, and industries. Transearch is an annual, nationwide database of freight traffic flows between U.S. county or zip code markets, with an overlay of flow across infrastructure. The database draws from a variety of data sources covering commodity volume and modal flow, including a long-term, proprietary motor carrier traffic sample; proprietary railroad data; and numerous commercial and federal government surveys, samples, and census data. To compose the database, these multiple and diverse information sources are placed in a single, consistent format (IHS Global Insight 2010).

Most of the Transearch national data database is at the county level, except for major metropolitan areas, which are available in a zip code format. The database includes all domestic shipments and international traffic moved on U.S. infrastructure for rail, inland water, and air (for Canada only). Shipments by truck are captured for all U.S. domestic traffic of manufactured goods, and for inland international traffic including nonmanufactured goods, such as agricultural products, coal, ores, and nonmetallic minerals. Intermodal truck drayage is included for international marine, domestic air, and all railroad trailer-on-flatcar or container-on-flatcar moves. Drayage for inland waterways, pipelines, international air, and rail carload transfers is not included. Examples of other excluded domestic truck traffic are

- Nonmanufactured goods (e.g., from logging activities, waste);
- Small-package and mail shipments moved exclusively by truck;
- Military and other government trucks; and
- Household goods and local service trucks (e.g., utilities, repair) (IHS Global Insight 2010).

Transearch provides a variety of summary levels of data for the two-digit commodity code. This is the commonly accepted degree of resolution to understand the modal choice of certain commodities while acknowledging there may be some suppressed proprietary data. Should more detail be required for certain types of analyses, Transearch includes up to six-digit Standard Transportation Commodity Codes for certain commodities.

Strengths
- Is a more refined geographic scale than CFS and FAF data, and thus better suited for freight planning on a more localized level.

Weaknesses
- As with CFS and FAF, Transearch does not consider full supply chain activity;
- Delivery and touring trips and drayage activity are not covered; and
- Forecasting methodology is not clear.

Other Federal Resources

Various federal agencies have compiled databases of information related to freight activity and vehicles over the years. Population and employment information from the U.S. Department of Commerce and the U.S. Department of Labor are basic sources of information used in various freight planning processes.

Data from the nation's truck weigh stations can be obtained from FHWA's Vehicle Travel Information System. The Vehicle Inventory and Use Survey, which was compiled by the U.S. Census Bureau as part of its Economic Census every 5 years, included characteristics of the nation's commercial vehicle fleet (e.g., vehicle size and type, average daily miles traveled, commodities carried). The latest data available through the Vehicle Inventory and Use Survey are from 2002, and the U.S. Census Bureau lists this as a discontinued data source. This type of information is useful for validating models and estimating VMT over large geographic areas, but it lacks any of the O-D data that are provided by other data sources discussed here.

The primary federal source of rail data is the Carload Waybill Sample, which is compiled by the Surface Transportation Board. This database is a sample of rail waybill data provided by rail carriers, with detailed information about the shipper and receiver, O-D points, and other information about these loads.

The U.S. Army Corps of Engineers Waterborne Commerce Statistics Database is the most notable source of data for maritime freight data compiled by the federal government. Summary reports on these data, which are based on U.S. Census Bureau trade data and vessel data from U.S. Customs and Border Protection, are published annually.

Strengths
- These data sources usually provide very detailed information by mode or geographic area, or both;
- Accessing this public data is free or inexpensive; and
- Depending on the data source, updates may be frequent.

Weaknesses
- These data sources tend to be mode specific, and do not consider full logistics chain activity;
- Federal budget constraints may result in a cessation of the data-gathering and reporting process; and
- These sources generally do not include commodity flow, routing, or intermodal transfer information.

Private Sector Data Sets

Numerous private shippers' data sets may be used to analyze goods movement. Data are maintained within each enterprise, and data sets are small. Because the data are proprietary, private companies are generally perceived to be reticent to share data openly and publicly in common databases. Public sector agencies succumb quickly to this blanket perception that the private data will not be shared. Data sets proliferate among producers and receivers along complex supply chains in a plethora of industries, from the transaction level to the container level. Each enterprise stores its own data for use in internal applications. Subsets of these data are shared for specific purposes between trading partners and shippers to provide visibility in monitoring the goods and when intervening to resolve disruptions in the supply chain. The overall purpose is to meet delivery expectations while optimizing overall logistics and distribution costs.

Supply chain data can be shared among firms, including shipping companies, because domestic and international reporting formats have been standardized and refined over the past 30 years. These widely used formats are based on traditional value-added network transmissions via electronic data interchange standards defined by the American National Standards Institute (ANSI), ANSI X12, and the United Nations Directories for Electronic Data Interchange for Administration, Commerce and Transport. Many firms use other media, such as the Internet, using extensible markup language for transaction data that are based on the same data definitions as electronic data interchange. Typical data formats in wide use are

- Purchase order—Information for goods;
- Bill of lading—Detailed shipment bill;
- Advance ship notice—Prior notification of shipment details and contents; and
- Shipment status—Current status in terms of dates, times, locations, and routes.

Private carriers use either internally developed proprietary models or models embedded in many top-tier software packages for analysis.

Strengths

- These private or combined private and public data are often more detailed than the data behind other resources discussed in this report (e.g., CFS, FAF);
- Private data may offer more visibility to a full logistics process.

Weaknesses

- Data sources are often industry specific, which may not translate well to planning efforts across multiple modes and industries;
- The cost of obtaining data from proprietary sources can be high;
- A high level of cooperation with private interests across regions or multiple modes is necessary; and
- Private data are usually gathered and stored in a variety of different formats; data processing and analyses can be cumbersome when data require aggregation among different sources.

Summary and Implications

Forecasting and understanding the movement of goods, regardless of geographic scope, requires assembling information from a variety of data sources, all of which are incomplete or contain inaccuracies. However, despite the current data deficiencies, several state-of-the-practice modeling methods and techniques have been developed and successfully applied within a variety of planning processes. As a result

- Data issues related to the analysis of freight movements are now being discussed among the freight planning community. This much-needed dialogue can spur improvement.
- Progress is being made through the development of new data sources.
- Good national data exist; however, there are substantial data gaps for supporting regional and local analyses. Many agencies are now turning to developing better data sets for local movements and delivery tours.
- Freight forecasters are hindered by data deficiencies, and thus have an insufficient understanding of complex supply chains to successfully develop forecasting models that address the information needs of elected officials, transportation officials, and the public regarding the impact of goods movements.
- Dialogue and partnership between the public and private sectors regarding freight capacity are limited.
- Public sector transportation decision making is relatively uninformed with respect to freight transportation, though several MPOs throughout the United States have engaged the private sector through freight working groups. Uninformed decision making is due to the limits of the state-of-the-practice data, which make it difficult to accurately forecast the impacts of freight on future transportation systems and also limit the potential policies and improvements that might solve expected problems;
- Existing data resources are best suited to large geographic scales and do not translate well to local planning efforts.
- Current planning tools and data do not accurately reflect the nature of supply chains and increasingly complex logistics practices in freight-dependent industries.
- Documenting the various factors that influence freight transportation needs is challenging because establishing links between disparate data resources (e.g., land use, demographics, employment by industry) and the freight activity that relates to these measures (e.g., truck counts, vessel activity, rail activity) is extremely difficult.
- Transportation forecasting and modeling practices tend to focus on average trip generation rates, but freight activity is heterogeneous and does not lend itself to average rates of production and consumption.
- The growing role of third-party transportation providers makes freight less visible, which makes it more difficult to

document pricing and cost variables for various legs of multimodal freight transportation processes.
- There are very few freight modeling and data university research centers, freight planning consultants, and freight data providers, which limits both the development and use of tools and data and the incentive to innovate.

Best Practices

Of the current models and data being used, only a few stand out based on their technical merit. Some methods are efficient as a result of minimal data needs and their ready availability, but their outputs and analytic capabilities are not necessarily robust. These methods therefore have limited use for in-depth analysis of freight. The best practices in models and data that currently most fully address analysis needs are presented in this section.

The common underlying objective of model and data use is to analyze and document baseline conditions related to freight movement and estimate future activity based on metrics involving economic activity, demographic changes, employment by economic sector, supply and demand of raw materials and finished products by consumers and industries, commodity flows, and other factors. Different tools and data are used by practitioners for different geographic scales, depending on the issues and scale of needs. This section lays out those identified practices that most accurately address these metrics and offer potential innovations for future practices. The identified best practices

- Provide a baseline assessment of models and data;
- Find innovative approaches to better understand goods movement in a variety of contexts for a variety of users;
- Provide a springboard for future data and model development.

The underlying methodology for most tools used in freight planning and forecasting includes using resources to

1. Document existing demographic and employment conditions and characteristics of freight transportation (including tonnage, geographic origins and destinations, and mode of transport); and
2. Estimate future measures of freight transportation for these same parameters (tonnage, origins, destinations, modes of transport) based on changes in population and employment, productivity improvements by industry, and other economic drivers.

Depending on the geographic scale, the ultimate objective of freight planning and forecasting is to forecast freight activity and its effects on local or regional conditions related to economic activity, traffic congestion, air quality, and other impacts.

In addition to FAF commodity forecasts and other national freight forecasts, which have been shown to drastically under- or overestimate freight demand (Hancock 2008), researchers and practitioners have developed freight forecasting methods that use freight demand factors in various ways (Bhat et al. 2005; Sivakumar and Bhat 2002). Each method is best suited for describing different aspects of freight demand. Model developers must select appropriate methods based on how they define freight demand, their data sources, their assumptions regarding the factors affecting freight demand, and their modeling focus.

Defining Freight Demand and Factors

The best current practices characterize freight demand by several dimensions, including volume, geographic scale, time period, source, transportation mode, and commodity.

- Volume—The amount of freight demand being moved, typically described in terms of tons, ton-miles, or value.
- Geographic scale—The spatial extent of the origins and destinations of freight being moved, which can be framed within a local, regional, state, national, or international market context. Time period—The temporal dimension of freight demand, which can constitute seasonal, annual, or short-, medium-, or long-term time frames.
- Source—The basis of freight demand estimates, either as a specific area estimate (e.g., coal tonnage produced at a specific mine or the volumes moved through a specific port, rail intermodal terminal, airport, or border point of entry) or as an O-D flow. Both specific area estimates and O-D flows are commonly found in regional freight plans or corridor studies. These estimates describe the movement of freight within a specific area and between two specific locations;
- Transportation mode—The method of transport being used.
- Commodity—The freight (or goods) being shipped.

The U.S. DOT's Bureau of Transportation Statistics describes freight demand based on the following dimensions: multiple quantities (value, tons, and ton-miles), a national spatial scale, annual time periods, a general area source, and across all transportation modes and commodities.

Freight demand is intrinsically interrelated with regional, national, and international economic and demographic characteristics; operational factors and logistics; infrastructure; public policy and regulations; technology; and environmental factors. Changes in factors within these categories can not only cause changes in other factors, but also affect the quantities and method of transport of freight demand (Cambridge Systematics 1997). Among these categories, the infrastructure, public policy, and environmental factors have an indirect impact on freight demand; in contrast, the economic, demographic, and operational factors more directly affect freight demand. Theoretically, researchers should comprehensively consider all of these factors in freight demand models. But quantitative measures for factors are not always available, and this missing information must be accounted for by making assumptions or by narrowing the modeling focus (Eatough et al. 1998). Researchers must take these limitations into account when selecting a freight demand model.

Depending on the type of research or planning being completed, the factors have varying levels of sensitivity. For example, a study to determine the need for an intermodal facility is more sensitive to data related to mode than an analysis of warehousing and distribution facilities. The sensitivity of these factors to data has been taken into account within these best practices, which makes them more robust than methods that use existing data and perform analyses based on the limitations of those data.

Data Best Practices

The data used in the best freight planning and forecasting processes are predominantly drawn from public resources. Although national data sets are generally the most complete and accessible, they lack the detail required for local, regional, or specific freight analysis. Local data sources provide a more comprehensive scale for these analyses, but some of the data require expensive, ongoing updates.

Although these sources are the best in terms of current general practices, a critical challenge in the development of freight models remains insufficient and inferior-quality data. The principal data for predicting freight transportation demand are the commodity flows by truck, rail, and water, and through selected border ports of entry and marine ports available from FHWA in the 2007 CFS (Research and Innovative Technology Administration 2009). In addition, FHWA has recently released FAF Version 3, an improved version of FAF that estimates commodity flows (tonnage and value) within, to, and from states and select regions by mode based on 2007 data, as well as freight movements among major metropolitan areas, states, regions, and international gateways (Southworth et al. 2010). Based on new estimation methods developed for this version, the forecasts developed using older versions will be updated in the near future.

The most commonly used database for statewide analysis of freight movements is the commercial Transearch database developed by IHS Global Insight. Transearch estimates freight flows (i.e., commodity tonnage) by truck (i.e., for-hire truckload, for-hire less than truckload, and private truck), rail carload, rail–truck intermodal, water, and air at the county, business economic area, and state or provincial level (Prozzi et al. 2006; Bhat et al. 2005; Cambridge Systematics 2007). The Transearch database is a proprietary source of detailed freight data available for purchase that includes assumptions (undisclosed) to estimate and forecast movements (Prozzi et al. 2006).

Some research relies on smaller freight data sets compiled by facility operators and owners, data collected by public and private entities, and data collected as part of a customized survey. Sources for these data sets range from the Waterborne Commerce and Vessel Statistics database, to the U.S. Census Bureau's County Business Patterns and Economic Census databases, to mail-out–mail-back surveys of freight shippers. Unfortunately, many of the data sources and databases available for statewide or MPO-level freight planning have considerable limitations as they focus on certain modes or commodities and are available at different geographic levels. Consequently, combining or integrating the data sources into a comprehensive, coherent, and consistent database is a challenging task.

The Ontario Ministry of Transportation has conducted roadside vehicle surveys every 5 years since 1978 to develop truck travel and commodity flow information on intercity movements throughout the province. The Ministry is able to track Ontario-based trucks throughout North America as part of this program.

Modeling Best Practices

The development of models is generally constrained by the data available to populate them. If a specific model is required for an analysis, the pertinent data must either be available or collected. The models identified as best practices range from complex to simplistic and have been used successfully for their given purpose. There is no one tool that is ideally suited for every application, and the benefits and limitations for each have been identified.

Trend and Time Series Analyses

Trend analysis and time series analysis methods forecast freight demand through longitudinal extrapolation of historical trends. Depending on the data available, this category of freight demand modeling can consider varying levels of complexity and aggregation. The simplest trend analysis model involves the computation of a growth factor that represents the annual compound growth rate of freight shipments, which is computed from historical aggregate freight data and applied to project future freight shipments.

In order to account for temporal variations and temporal interdependencies, trend analysis is often implemented using more advanced statistical time series analysis techniques, including smoothing, autocorrelation, autoregressive moving average models, and the use of neural networks. The first technique involves smoothing out various short-term or random fluctuations in demand by determining patterns in the data and extrapolating into the future. These techniques remove random fluctuations through the use of parameters that dictate the extent to which more recent observations are weighted in isolating the trend (Cambridge Systematics 1997).

Autocorrelation predicts future demand through time series regression models with temporal correlation across error terms. The correlation in these models attempts to account for the fact that freight demand at a specific time is dependent on previous time periods and needs to be treated accordingly.

Autoregressive integrated moving average models are sophisticated time series modeling approaches that build forecasts from more inclusive and simultaneous analysis of complex past patterns in the time series than is achievable using simple smoothing models or models of autocorrelation. Autoregressive integrated moving average models process all of the information available in a time series data set with very limited information required from the researcher (Cambridge Systematics 1997).

Neural network methods represent the most advanced time series models for predicting freight demand. These models assume a probabilistic progression of demand through time (e.g., freight demand in 1990 is dependent on freight demand in 1980, which is further dependent on freight demand in 1970, and so forth) and related factors (Dougherty 1995).

Although these procedures can provide short- or long-term forecasts based on projection of the smoothed underlying patterns in the data, they are most appropriate for short-range forecasting. Trend and time series analysis is simple to use, not data intensive, and builds on historic trends to predict the future. These methods can also support modeling for freight shipments by mode, commodity, O-D pair, origin, destination, or a combination of these parameters.

Due to their simple nature, however, these methods have a number of limitations. First, freight projections become less accurate when researchers use data covering shorter periods of time. Second, they assume that "the underlying economic conditions on which the forecast is based remain the same throughout the duration of the time series data and continue forward through the forecast" (Cambridge Systematics 2008). Most importantly, such models often do not explicitly incorporate explanatory factors that affect freight transportation demand, such as changes in market factors, freight logistics, pricing, or policies.

Benefits

- Is simple to use;
- Requires historical information but is not data intensive; and
- Supports mode, commodity, and O-D analyses.

Limitations

- Accuracy is suspect if based on short-term historical data;
- Assumes past trends are indicative of future activity; and
- Lacks the dynamics of explanatory factors that affect freight demand.

Elasticity Methods

Elasticity methods are specifically used to estimate how freight commodities are split among transportation modes. These models assume that mode-choice decisions are based on the total logistics costs (TLC) associated with using various modes or modal combinations that are practical for a set of freight shipments. TLC includes the actual transport costs (or carrier charges) and other logistics costs (e.g., inventory costs, stock-out costs) incurred. The models assume that increases in TLC result in the diversion of some freight traffic to competing modes (Cambridge Systematics 1997).

Researchers use price elasticity, defined as shippers' sensitivity to TLC associated with a mode, to study how changes in TLC affect the quantity of freight demand shipped by each mode. Elasticity is calculated in two ways: change in demand for a mode with respect to its own price, known as a direct elasticity; and change in demand for a certain mode with respect to a change in price of a competing mode, referred to as a cross elasticity (Wilson 1980; Miklius et al. 1976). Either way, researchers can calculate point elasticity, arc elasticity, or shrinkage factors from field observations on price and quantity before and after a price change or from knowledge of the functional relationship between quantity and price.

Because this method separates freight demand by mode, elasticity measures must be used in conjunction with other models of total freight demand. Modal diversion may be estimated using disaggregate data for a sample, or by using more aggregate data when the total volume of movements is summarized by key variables (such as commodity). The diversion estimates can then be derived from estimated changes in TLC, or when other logistics costs are unaffected by cost changes (Cambridge Systematics 1997).

Elasticity measures derived from recent data sources can be useful, particularly for sketch planning applications. Elasticity may be computed using observed data directly (often leading to aggregate elasticity) or by estimating models on data (leading to aggregate or disaggregate elasticity). In either case, elasticity can be used to determine changes in freight traffic by mode, commodity, and corridor in response to a change in one explanatory factor. Elasticity can be short-run or long-run in nature, depending on the time period over which changes in demand are observed. Differences between short- and long-run elasticity can be substantial, as considerable adjustments in behavior can be made in a long-term time frame.

Still, elasticity models face a number of challenges. Planners must be careful when dealing with results from elasticity studies in the 1970s, before deregulation, which may not be appropriate in today's context of a deregulated and highly competitive business environment. Collecting data to update elasticity studies to current practices can be equally challenging, as many researchers find it difficult to collect proprietary cost information due to alliances and contracts. This problem is further complicated by the fact that many elasticity studies do not explicitly incorporate intermodal combinations. Perhaps the most serious limitation is the inability to simultaneously account for multiple factors in predicting changes in freight traffic. As a result, it can be challenging to apply elasticity methods for comprehensive freight transportation planning (Hancock 2008).

Benefits

- Observed or estimated data may be used;
- Can be applied for short- or long-term analyses; and
- Can be useful for sketch planning applications.

Limitations

- Not applicable for using data prior to deregulation in the 1970s;
- Difficult to collect data for inputs; and
- Difficult to correlate multiple factors that affect demand.

Logistic Network Models

Logistic network models forecast how freight demand is divided between modes (or carriers) and travel corridors between a specific origin and destination. Like elasticity methods, logistic network models can be used in conjunction with other models of total freight demand. These models are recognized because they consider the freight transportation system as a whole, defined by interactions among producers, consumers, shippers, carriers, and the government. In particular, logistic network models "assign commodity flows to a mode (or combination of modes) and specific route within a network that minimizes total transport costs, taking into account the location of activities within the network" (Cambridge Systematics et al. 2008).

Depending on the factors in which they are most interested, researchers have two main options for modeling logistic networks. The first approach, known as freight network equilibrium modeling, focuses on shipper–carrier interactions (Tavasszy 2008). In these models, the generation of trips from each region is assumed to be known; shipper transportation needs are determined and are then routed so that the carrier's costs are minimized (Friesz et al. 1983).

The second approach, known as spatial price equilibrium, focuses on producer, consumer, and shipper interactions. These models estimate trip generation by including commodity supply and demand functions. Transportation costs are fixed values or functions of the flows on the network. Producer and consumer behaviors are incorporated through a supply and demand function for each zone. The shippers are assumed to behave according to the following two equilibrium principles:

(a) If there is a flow of commodity *i* from region A to region B, then the price of commodity *i* in A plus the transportation costs from A to B will equal the price of the commodity in B;
(b) If the price of commodity *i* in A plus the transportation costs from A to B is greater than the price of commodity *i* in B, then there will be no flow from A to B (Friesz et al. 1983).

Neither approach is considered technically superior, as both face limitations due to their underlying assumptions (Cambridge Systematics et al. 2008). For example, the freight network equilibrium models' treatment of shipper and carrier decision-making processes presupposes that carriers will provide commodity routings that give levels of service perfectly consistent with those levels of service perceived and anticipated by shippers. This is possible only if the shippers have perfect foresight, which is difficult due to unpredictable congestion and independent carrier routing decisions. In contrast, carriers must know shipper demands before route establishment. Therefore, shipper and carrier decisions must be modeled simultaneously (Friesz et al. 1983).

Logistic network models have been shown to be best suited to larger geographies, such as intercity freight flows. They are more complex to implement than other modeling methods and often have more intensive data requirements. The implementation of network models of logistics should be used as a viable long-term strategy for statewide freight demand forecasting.

Benefits

- Is good for larger geographic areas; and
- Considers the defined interactions among producers, consumers, shippers, carriers, and the government.

Limitations

- Requires an assumption of shared perfect knowledge of freight movements between the shipper and carrier; and
- Is complex to implement.

Aggregate Demand Models

Aggregate demand models estimate freight traffic using aggregate data that include limited information on the multitude of factors affecting freight transportation demand. They attempt to model the aggregate volume of commodity flow rather than the number of individual trips. These methods support modeling for freight shipments by mode, commodity, O-D pair, origin, destination, or a combination of these parameters.

The simplest aggregate demand models use a total flow approach, which uses regression-based statistical methods to calculate an overall aggregate measure of freight travel demand in an economy. The main factor considered in this model is the predicted output of economy (commonly prepared in conjunction with time series or cross-sectional data) (Bayliss 1988). Total flow measures of demand are typically measured in tons or ton-miles for a specific mode over a given period of time.

Another approach to aggregate freight demand models is to consider relative flows, attempting to determine the proportion of total traffic carried by each discrete mode (Bayliss 1988). An advantage of this type of model is that, in some contexts, it may be more appropriate to use a single equation that estimates a single aspect of freight traffic demand. This method uses regression techniques to model the relative flow of one mode when compared against another.

The aggregate demand model has several limitations, primarily due to its highly aggregate nature. Total flow approaches are much more satisfactory than the fully aggregated model when applied in a disaggregate industry or commodity context by mode, because the analyst would deal with a possibly more homogeneous data set. However, no attempt is really made to construct a demand model. It is also noteworthy that national output figures are usually on an industry basis, but ton or ton-mile figures are usually on a commodity basis. Reconciling these two data sources often creates problems.

Still, aggregate models are extremely useful for freight travel demand modeling. First, aggregate data are commonly available for national as well as local scales. Second, the model can easily be applied by commodity, thus providing an estimate of freight demand by commodity or industry classification. It also incorporates relative modal attributes (time and cost) in determining freight traffic demand. This joint demand model is appealing for statewide freight traffic demand modeling. Most aggregate joint demand models contain two separate sets of variables with interaction effects embodied in the coefficients rather than explicitly specified in the model. As a result, aggregate freight demand models can be applied in most planning scenarios (Hancock 2008).

Benefits

- Availability of required data; and
- Easily applied to commodity, time, and costs to determine freight demand.

Limitations

- Does not consider route choice; and
- Does not estimate overall freight demand.

Disaggregate Demand Models

Disaggregate demand models take the methods of the aggregate models one step further, which offers several theoretical and empirical advantages. Specifically, these models attempt to estimate the number of individual trips on modes and links of the freight transportation network. Unlike aggregate models, they can distinguish freight demand across different routes and trips. In addition, disaggregate demand models are more accurate at identifying freight shipments by mode, commodity, O-D pair, origin, and destination. Researchers have a variety of disaggregate models to choose from that parallel the four-step urban transportation modeling process (Cambridge Systematics et al. 2008).

The market survey approach involves the administration of detailed market surveys to shippers. Shippers are asked to rank various factors with respect to their importance in the modal decision-making process. These factors include such items as certainty of delivery time, charge, speed, safety, regularity, service to customer, packing requirements, length of haul, location of firm, method of payment, and intermodal capability. In addition, shippers may be asked to rate different modes on ordinal ranking scales with respect to these factors. The survey results are used to construct a modal preference matrix to indicate the mode chosen for a shipment of certain characteristics. This matrix is then used to determine freight shipments by mode for various O-D pairs. As this approach does not involve the use of a model per se, it is not considered useful for freight transportation planning efforts. However, the information from such surveys may be useful for constructing disaggregate demand models.

Alternatively, the behavioral mode split model predicts freight demand by focusing on the mode choice decisions made by the manager of the receiving or shipping firm. The advantage of this approach is that choice is observed at the most disaggregate level possible, namely, with respect to individual shipments dispatched by individual firms. In contrast to the market survey approach, these models are estimated using revealed choices without depending on the shipper explaining how he or she chooses a mode. Behavioral mode split models are based on the assumption that the shipper is concerned with maximizing utility (i.e., satisfaction) with respect to the various explanatory variables that affect the mode choice decision-making process. These decisions incorporate mode characteristics, consignment characteristics, firm characteristics, and shipper characteristics. The empirical model used to estimate the demand for freight transportation within this framework is known as a random expected utility model. Because the framework assumes that the random components of the total utility function of the alternative modes are independently and identically distributed with a Gumbel distribution, the behavioral choice model takes the form of the well-known multinomial logit model. Due to the shifting nature of freight logistics, this model is best suited for analyzing small windows of time. Additional research is needed to develop improved ways of correlating multiple decisions and predicting freight demands over longer time periods.

A third inventory-based approach attempts to integrate the mode choice and production decisions made by a shipper. Variables related to production, such as shipment size, mode choice, and frequency of shipments, are treated as internal decisions. The rationale of the inventory approach is that freight in transit can be considered to be, in effect, an inventory of goods on wheels, similar to goods in process in the factory. The model predicts the expected total annual variable cost of hauling the commodity (Winston 1983).

The basic difficulty with implementing inventory theoretic models is the acquisition of data. Several approximations have to be made in order to estimate the TLC and its role in modal choice behavior. These approximations often lead to the inventory theoretic model being very similar to the behavioral mode choice model. However, there is merit to simultaneously modeling the choice of mode, shipment size, and shipment frequency.

By far the most advanced disaggregate models of freight demand are agent-based microsimulations. These microsimulations track individual vehicles and commodities over an entire network for a given period of time. Each individual agent is assigned a set of decisions and behavior using carrier and shipper characteristics, network design, and other factors as exogenous variables. The microsimulation allows interactions between agents and adjusts carrier and shipper behavior accordingly. Agent-based microsimulations reflect the actual process with which carriers and shippers contend (Tavasszy 2008). Researchers are also able to incorporate a variety of factors into the models to evaluate how changes in supply or operations will affect freight movements (Jinhua et al. 2003). In the end, simulations provide a comprehensive summary of how freight commodities are distributed and where vehicles are routed (Cambridge Systematics 2008). Although this method is the most accurate means researchers have for forecasting freight demand, it also requires the most in-depth data collection, financial investment, and technical expertise. Nevertheless, many areas, such as Calgary, Alberta, have successfully implemented tour-based microsimulation of freight demand (Stefan et al. 2005).

Disaggregate freight demand models have several advantages over aggregate freight demand models. Disaggregate models rely on microeconomic theories and richer empirical specifications that attempt to reflect real decision making. By incorporating actual modal attributes for freight movements and actual characteristics of commodities, disaggregate models allow for a better understanding of intermodal competition (Winston 1983). Current applications of disaggregate freight models are detailed in the *Quick Response Freight Manual* (Cambridge Systematics et al. 1996). Unfortunately, disaggregate freight demand models continue to be used sparingly for freight transportation applications (de Jong et al. 2004) due to the expense and challenges associated with collecting comprehensive survey data from shippers and carriers (Cambridge Systematics 2008).

Benefits

- Estimates freight demand by mode over a network; and
- Is more accurate than aggregate demand models.

Limitations

- Cost-intensive; and
- Difficult to collect the necessary data inputs.

Input–Output Models

Input–output models are the simplest and, consequently, least descriptive methods for forecasting freight demand. They are used primarily in sketch planning applications, regional planning studies at an aggregate level, and when data are extremely scarce.

Input–output analysis involves using economic input and output indicators to determine the levels of economic activity that may drive freight transportation demand. Inputs (e.g., capital, labor, land) are entered into an input–output analysis matrix to determine the various economic outputs. These may include the quantity of goods and services produced by type, geographic location, and temporal frame; the demand for goods and services by type, geographic location, and temporal frame; and other such measures of economic output. The outputs are converted into estimates of freight transportation demand that would satisfy the demand for goods and services.

In today's context, when data are generally available (at least at an aggregate level), these methods are not used very often for comprehensive statewide or local freight transportation modeling and planning. Instead, input–output models are used when data are scarce and time is very short. For comprehensive statewide and metropolitan freight transportation planning, the modeling methods discussed earlier would be more appropriate as they can quantitatively estimate freight transportation demand as a function of various explanatory factors. However, such modeling approaches may benefit from peer interaction and qualitative reviews by different agents involved in freight transportation. In such a situation, input–output methods may be used to complement quantitative modeling approaches.

Benefits

- Simple and quick to implement.

Limitations

- Is not comprehensive.

Summary and Implications

- Freight demand is characterized by a variety of factors, including quantity, geographic scale, time period, source, transportation mode, and commodity;
- Freight demand models are emerging as tools to inform transportation policies; however, insufficient and inferior-quality data remain a critical challenge in the development of these tools;
- Freight demand is intrinsically interrelated with regional, national, and international economic and demographic characteristics, operational factors and logistics, infrastructure, public policy and regulations, technology; and environmental factors, all of which have varying data sets that are incomplete or contain inaccuracies, or both;
- Freight demand model developers use a variety of methods to account for this missing information, such as making assumptions or narrowing the modeling focus when selecting a freight model; and
- Current best practices in freight demand model development include trend analysis and time series analysis methods, elasticity methods, logistic network models, aggregate and disaggregate demand models, and input–output models.

Forecasting and understanding the movement of goods, regardless of geographic scope, requires assembling information from a variety of data sources, all of which are incomplete or contain inaccuracies, or both. Despite the current data deficiencies, several best practice modeling methods and techniques have been developed and successfully applied within a variety of planning processes. Nevertheless, the lack of useful freight forecasting data has several serious implications:

- Freight forecasters are hindered by data deficiencies and thus cannot completely analyze complex freight supply chains. This limits the development of forecasting models that answer the questions asked by today's elected officials, transportation professionals, and public regarding the impact of goods movement.
- There is limited dialogue and partnerships between the public and private sectors about freight capacity due to the lack of common understanding of the conditions and range of solutions.
- Because state-of-the-practice models are limited and cannot accurately forecast the impacts of freight on future transportation systems—and the potential policies and improvements that might solve expected problems—decision makers are not adequately informed.

The body of recent and ongoing research in freight data and modeling tools is extensive, including research into data development, modeling methods, and freight operations. Important practices that relate to the desired innovative elements of the Strategic Plan include

- Freight modeling that reflects the transportation system, land use, and economic factors—Examples of such freight modeling include the Oregon Statewide Integrated Model (SWIM2) and a series of transportation–economic models that culminated in the development of the MOBILEC model for Flanders in Belgium. Papers on both of these models were presented at the 2010 Innovations in Freight Demand Modeling and Data Symposium conducted for this SHRP 2 C20 research effort.
- Modeling that reflects logistics patterns—Excluding logistics is one of the shortcomings of otherwise advanced forecasting techniques. The combined PINGO and logistics models developed in Norway represents an innovative attempt to combine the transportation and economic elements of traditional freight modeling with a logistics-based module that reflects real-world decision making in freight transport. These models were also presented at the 2010 Innovations in Freight Demand Modeling and Data Symposium. Beyond this important development, there is an enormous body of research involving private sector transportation practices that can support future research in this area. This research often gets little exposure in traditional public venues because it is primarily oriented toward supporting enhancements in private sector logistics practices, is often specific to certain industries, and is rarely used to support and inform current public sector freight forecasting techniques. The examples are too numerous to list, but several have been referenced in this document for illustrative purposes (Zsidisin et al. 2007; Cruijssen et al. 2007; Cooper et al. 1997; Bolumole 2001; Lieb and Bentz 2005; Belman and White 2005; Mello et al. 2008; Wiegmans 2010).
- Integration of local touring and trip chaining—This is an important element of local freight transportation, comprised primarily of local truck distribution and deliveries. Local touring activity has been documented as a key research need in *NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making* (Cambridge Systematics and GeoStats 2010). This type of local truck activity is not captured in national data sets and is not modeled accurately in regional freight models. Research conducted at the University of Illinois at Chicago (Ruan et al. 2010) is particularly innovative in that it incorporates various commodity types and various combinations of direct and peddling touring with single-base and multiple-base delivery systems. Additional research at the State University of New York at Buffalo and Rensselaer Polytechnic Institute developed an entropy

maximization technique (Wang and Holguín-Veras 2010) to address a key limitation of traditional four-step modeling as it pertains to local deliveries. Another example of an innovative current practice related to local touring and chaining is the truck element of the model developed for the City of Calgary in Alberta, Canada (Stefan et al. 2005). This tool is incorporated in the Calgary EMME/2 transportation demand forecasting model, making Calgary the first major city to incorporate a tour-based microsimulation element in a regionwide transportation model.

Decision-Making Needs and Gaps

To establish a strategic direction for innovative freight research, an extensive review and outreach process was undertaken. The focus of the outreach was state DOTs, MPOs, county and municipal planners, toll road authorities, and port infrastructure owners and operators. The purpose of this effort was to identify the data and tool needs of various decision makers in the public and private sectors and to lay the foundation for a programmatic approach to meeting these needs. Needs common to both the public and private sectors were of particular interest to researchers. The outreach elements of this effort included

- State DOT workshops in Washington and Ohio;
- A regional freight stakeholders workshop for the Northeast held in Newark, New Jersey;
- Stakeholder engagement at various conferences, including the American Planning Association's National Planning Conference, the Innovations in Travel Modeling Conference, the TRB Toward Better Freight Transportation Data Conference, and the meeting of the TRB Visualization in Transportation Committee at the TRB Semi-Annual Meeting;
- A special stakeholders workshop in Washington, D.C., which included representatives of public agencies, consultants, and transportation industry representatives to validate previous outreach results; and
- The 2010 Innovations in Freight Demand Modeling and Data Symposium in Washington, D.C., which was conducted as part of this research effort.

Decision-Making Needs

Although the research and outreach efforts identified a variety of different needs for the wide array of participants, there were common threads and recurring themes.

Freight forecasting and analysis should be enhanced through a recognized and valid inventory of standardized data sources with common definitions. One of the common items of discussion among stakeholders is the need for standardization of data sources across different geographic levels and transport modes. There is little consistency among data sources for truck, rail, marine, and air transport, and they are not all ideally suited for comparable geographic scales. This makes multimodal freight planning extremely difficult.

A number of stakeholders expressed great interest in developing a statistical sampling of truck shipment data, similar to the Carload Waybill Sample for railroads. This would enable planners to get a microscopic view of trucking activity that would be comparable to the level of detail available for the railroad industry.

Not surprisingly, a range of standardized analytic tools and applications is needed to address diverse decision-making needs. There is a generally recognized need for some standardization of planning tools and methods for different geographic scales, including large regions, states, metropolitan areas, and corridors.

Behavior-based facets of freight decision making must be incorporated into modeling, or at least better understood as important context. One of the major deficiencies in current freight planning practice is that the tools and data are based on the movement of freight as measured in unit loads (i.e., trucks, railcar loads, tonnage) transported between origin and destination points. Freight planning and forecasting must undergo a dramatic transformation to include provisions for all of the complex factors that are involved in decision making by freight shippers and carriers. This relates to a general need to expand the knowledge base of public sector planners and decision makers to include a more thorough understanding of private sector decision-making processes.

Better information is needed to understand the nature, volume, and trends of intermodal transfers. This item relates to the need for developing real-world logistics-based planning tools. One particular element of freight planning that is not always covered in current tools and data sources, but is of great interest to some decision makers, is the movement and repositioning of empty trucks, vessels, and rail equipment.

Industry-level freight data are needed at the subregional level, and there is also a need to better understand local deliveries in urban areas. The current practice in freight planning is best suited for large geographic scales that do not translate well to local planning efforts. In addition, even the best tools and data do not accurately model the local touring aspect of freight deliveries.

Freight models should incorporate local land use policies and controls to increase the accuracy of freight forecasting at the local level. Since freight transportation is a derived economic activity that is ultimately driven by consumption and production at a local level, local land use decisions have an enormous impact on freight transportation demand. The current planning tools based on population and industry employment trends should be enhanced by incorporating a wide variety of land uses, especially those that are major generators of freight traffic (e.g., manufacturing, warehousing, retail sales, transportation terminals).

There is a need to better understand the correlation between freight activity and various economic influences such as fuel price, currency valuation, and macroeconomic trends. One of the major challenges facing many public agencies is their inability to accurately predict important changes in freight transportation activity that result from external influences and underlying economic forces. In addition, the influence of passenger traffic on shipper and carrier decisions related to routing, mode choice, time-of-day freight shipments, and other freight activity in a region needs to be understood more clearly. Conversely, decisions in industries involved in freight transportation (e.g., manufacturing, trucking, warehousing), such as site selection, production schedules, and mode choice, produce demographic and economic impacts that need to be quantified.

Enhanced tools are needed to help review and evaluate freight forecasts. Any evaluation process has to account for a myriad of factors that drive freight demand. One of the inherent weaknesses of freight modeling today is that the field is so new that long-term planning horizons have not yet been reached for any of the models developed in the last 10 to 15 years.

An overarching need for the freight planning practice is to develop and cultivate a process to routinely generate new data sources and problem-solving methods. This challenge points to an underlying need for innovation in freight planning and modeling and a recognition that major advances in the state of the practice are likely to be tied to the industry's ability to harness creativity and technological advances.

Attention should be given to using ITS resources and related technologies, such as GPS and IntelliDrive, to generate data to support freight planning and modeling. This item was usually discussed in the context of the planning community's understanding of the need to promote advances in technology that have become commonplace in other industries. The need for enhanced visualization tools for public outreach related to the freight planning process was also mentioned frequently.

There is a need to develop a full multimodal, network-based freight demand model that incorporates all modes of transport (vehicle, railcar, vessel) to a similar level of detail for various geographic scales. To be truly effective, this ambitious effort would have to address some of the other needs identified in this section: namely, the need to more fully understand the underlying economic drivers in freight transportation and the need to incorporate real-world supply chain and logistics practices in the planning process. The development of such a model is the ultimate goal of the freight planning and modeling community.

Of great interest are benefit–cost analysis tools that go beyond traditional financial measures by including other direct and indirect benefits and costs (public and private). Tools would include metrics to assess environmental and economic development policy initiatives on a comparable basis with standard financial measures.

More effective methodologies are also needed to apply freight forecasts to funding and finance analyses, such as revenue projections. These types of tools are of great interest to toll road authorities and owners and operators of freight infrastructure such as port terminals, whose future needs and financial stability are tied to the ability of the owners and operators to develop accurate forecasts of demand by mode and commodity.

Highway authorities have a strong interest in the development of tools that would let them use freight forecasts to support their infrastructure design processes. This need relates particularly to the relationship between truck volumes and weights and highway infrastructure (e.g., bridge and pavement design). Agencies with oversight responsibilities for inland waterway systems that serve as important freight links have similar needs.

Stakeholders consistently emphasized the importance of a concentrated effort to develop the requisite knowledge and skills to support freight analysis. The factors that drive freight transportation demand are complex and require an understanding of a wide range of topics, such as economics, political science, demographics, transportation planning, engineering, finance, information technology, and organizational skills. This need for knowledge and skills also relates to the need to understand the goals and objectives of shippers and carriers in the private sector and planners in the public sector. Bridging the gaps between the needs of the public and private sectors would help facilitate more effective planning and forecasting.

Decision-Making Gaps

Table 3.1 shows the decision-making needs, the gaps between the needs and the current modeling and data practices, and the data and modeling requirements to meet those needs. Articulating the capabilities of the current state-of-the-art models and data sets and comparing them with the needs of decision makers sets the stage for identifying the modeling and data needs to fill the gaps. These needs are the foundation for the actions incorporated in the Strategic Plan.

Research Program

The SHRP 2 C20 Freight Demand Modeling and Data Improvement Strategic Plan advances a broad new direction for improving freight planning, promoting continuous innovation for breakthrough solutions to freight analytic and data needs, and fostering a collaborative approach for private, public, and academic stakeholders.

Table 3.1. Freight Decision-Making Needs and Gaps

Decision-Making Needs	Gaps Between Needs and Current Practices	Data or Modeling Requirements to Close Gaps
Standardized data sources with common definitions	• Various data sources collected through different programs result in extensive inconsistencies.	• Homogeneous data for ease of incorporation into freight models and for consistency of freight models in different regions. • Reduction in data manipulation to improve accuracy.
Statistical sampling of truck shipments	• Detailed knowledge of truck movements in local areas. • Understanding of current truck activity by different industry segments (long-haul, local, drayage).	• An ongoing standard data-collection program to gather local truck movements. • Compilation of truck data to a level comparable to rail industry data (i.e., Carload Waybill Sample).
Standardized analytic tools and applications	• Wide range of various tools that require unique data sets.	• Consistency in modeling approaches and data needs for similar geographic scales.
Inclusion of behavior-based elements into freight models	• Current practices use truck movements and commodity flows, but should be based on the behaviors, economic principles, and business practices that dictate the movement of freight. • Current modeling tools do not accurately reflect real-world supply chains and logistics practices.	• Determination of the influencing behavioral factors that affect freight movement and ongoing data collection to inform models. • Behavior-based freight modeling tools to take advantage of newly collected data sets for various geographic analyses. • Incorporation of intermodal transfers, consolidation and distribution practices, and other shipper and carrier practices in modeling tools.
Data development to understand the nature, volume, and trends of intermodal transfers	• Public sector access to intermodal transfer data of containers, bulk material, and roll-on–roll-off cargo is lacking for most transfer facilities other than those of large ports and rail yards.	• Data sets developed through collaboration with the private sector to inform the planning practice knowledge base and models on intermodal transfers. • Protocols to collect data on a regular basis.
Industry-level freight data development at a sub-regional level and within urban areas	• Freight data are generally not industry-specific, which translates into forecasts that are not sensitive to the unique industry trends that are critical to regions that rely heavily on specific industries.	• Industry-level forecasts that are sensitive to the unique factors of different industries. • Tools and data at a disaggregated level (local) that can be aggregated for larger geographic analyses. • Tools and models to take advantage of the new data sets.
Incorporation of local land use policies and controls for better local forecasting accuracy	• Current freight data and models lack local detail related to the generation of freight activity, which hampers local efforts to effectively plan for the last mile.	• Enhanced understanding of land use decisions and their implications on freight activity. • Resources for local organizations to incorporate land use considerations into freight planning data and models.
Development of a correlation between freight activity and various economic influences and macroeconomic trends	• Freight models are typically based on population-, employment-, and industry-level productivity forecasts, with no consideration for the impacts of other economic factors.	• Enhanced models that incorporate a wide array of economic factors in forecasting freight demand.
Better accuracy of freight forecasts	• Freight models rarely (if ever) are reviewed to see how accurately they are forecasting, calling into question their reliability and validity.	• A systematic approach for freight model and data owners to review and evaluate forecasts (every 3 to 5 years) and adjust models and data methods accordingly.
Development of a process to routinely generate new data sources and problem-solving methods	• The improvement of freight planning nationally depends on continuing innovation and steady progress in the development of models, analytic tools, and knowledge acquisition.	• A value-adding and sustainable process to generate new and innovative ideas. • Acknowledgment of failed practices that can contribute to the knowledge base of practitioners.
Use of ITS resources to generate data for freight modeling	• Technologies that can be used to collect freight data have not been used to their potential. • Data can provide a wealth of information related to current conditions and diversions as a result of traffic incidents.	• An understanding of the information needed by the modeling community and the standard to which it can be used. • An accessible data bank for freight modeling developed with the cooperation of GPS device providers, ITS infrastructure owners, and other data providers.

(continued on next page)

Table 3.1. Freight Decision-Making Needs and Gaps (continued)

Decision-Making Needs	Gaps Between Needs and Current Practices	Data or Modeling Requirements to Close Gaps
Development of a universal multimodal, network-based model for various geographic scales	• The fragmentation of modeling techniques and data means that practitioners typically must develop or improvise data and models for their own applications. • Agencies with fewer resources are not able to adequately analyze freight movements. • Some freight transport modes are analyzed more than others because they have more data available for analysis.	• An open-source data bank and universal freight modeling tool is the ultimate goal. • A level playing field among different modes of freight transportation in terms of quantity and accuracy of data and complexity of modeling tools.
Development of benefit–cost analysis tools that go beyond traditional financial measures	• Analysis of the benefits of project-based scenarios lacks the precision required for those decisions, including direct and indirect impacts, costs, and benefits.	• Tools that incorporate a comprehensive analysis of the factors associated with infrastructure development, expansion, and enhancement specifically related to freight.
Development of funding assessments resulting from freight forecasts	• Transportation funding scenarios and what-if analyses are limited in their ability to forecast revenues associated with freight movement.	• Estimated costs and potential funding sources that can be justified based on credible freight forecasts.
Creation of tools to support the infrastructure design process	• Infrastructure design, unless specific to freight, rarely focuses efforts on how best to accommodate freight movements.	• Incorporation of freight forecasts into infrastructure design related to vehicle size and weight and future freight activity (i.e., tonnage) by mode.
Development of knowledge and skills among the freight planning community as a foundation for improved analysis	• The freight planning community is relatively small and knowledge transfer is challenging. • Talented innovators who can lead new approaches to freight transportation planning are pursuing careers in other industries.	• A comprehensive knowledge base for planning professionals that includes the wide range of subject areas related to freight transportation. • Greater recognition or formal standing of freight planning as a profession with an associated body of knowledge.

This research program is built on a foundation of seven strategic objectives that have been identified as the basis for future innovation in freight travel demand forecasting and data. The desired direction for enhanced freight planning, forecasting, and data analysis expressed by the many stakeholders who participated in this project are reflected in these objectives, which are aimed at stimulating innovation through the avenues laid out in the accompanying strategic plan.

The seven strategic objectives are

1. Improve and expand the knowledge base for planners and decision makers.
2. Develop and refine forecasting and modeling practices that accurately reflect supply chain management.
3. Develop and refine forecasting and modeling practices based on sound economic and demographic principles.
4. Develop standard freight data (e.g., CFS, FAF, and possible future variations of these tools) to smaller geographic scales.
5. Establish methods for maximizing the beneficial use of new freight analytic tools by state DOTs and MPOs in their planning and programming activities.
6. Improve the availability and visibility of data among agencies and between the public and private sectors.
7. Develop new and enhanced visualization tools and techniques for freight planning and forecasting.

Building on the foundation of the seven strategic objectives listed above, the SHRP 2 C20 research effort culminated in the development of 13 research areas, described in this report as *sample research initiatives.* Collectively, these sample research initiatives constitute a programmatic approach for systematically improving freight modeling and data availability and forecasting tools. Each of these initiatives is tied to one or more of the seven strategic objectives, with the ultimate goal of promoting and cultivating innovation through Strategic Objectives 2 and 3, supported by the innovations in data development in Strategic Objective 4 and visualization in Strategic Objective 7.

Each of the 13 research initiatives also relates to one or more of the three main research dimensions identified at the 2010 Innovations in Freight Demand Modeling and Data Symposium:

- *Knowledge* relates to a general understanding of freight transportation issues and the extensive array of elements involved in planning and forecasting freight demand;
- *Models* are the tools used to carry out planning and forecasting activities at various geographic levels; and
- *Data* are the underlying information resources for modeling and planning efforts, and often represent an important limitation of modeling.

The ultimate long-term goal for the research documented is to build on Strategic Objectives 2 and 3 to promote the development of a full network-based freight forecasting model that incorporates all modes of freight transport and accurately reflects the various factors related to the supply of freight infrastructure and services (Strategic Objective 2) and the underlying demand for these services (Strategic Objective 3). This model will effect a dramatic change in current freight planning and forecasting. It is a highly ambitious endeavor because of the complexity of freight transportation and the numerous elements that are necessary to achieve this long-term goal.

The other five strategic objectives are tied to this goal through the development of the applicable knowledge base needed to further it (Strategic Objective 1), the development and dissemination of data necessary to support it (Strategic Objectives 4 and 6), and the development of enhanced methods for disseminating information from these analytic tools for public stakeholders (Strategic Objective 5) and decision makers (Strategic Objective 7).

Although development of a full multimodal network-based freight forecasting model is the ultimate long-term goal, it is important to note that freight transportation has not traditionally lent itself to innovative planning and forecasting methods. This is because freight transport has historically been a relatively uncomplicated, low-tech process. In addition, past experience in freight transportation does not necessarily correlate well with future freight activity due to short-term changes in the forces of supply and demand. As a result, developing accurate forecasts for freight transportation will require a radical paradigm shift in the way the practice is currently conducted.

These research initiatives are based on the SHRP 2 C20 research conducted for this effort, but they should be viewed in their proper context as steps in support of the seven strategic objectives. The specific research initiatives are initial recommendations for potential research to help move this process forward. These recommendations will likely change as a result of funding availability, industry needs, and developments that spring from some of the other elements of the Strategic Plan, such as the Global Freight Research Consortium (GFRC); future data and modeling symposia recommended in this study; other data and modeling innovations featured in TRB conferences; and NCHRP and NCFRP research.

Identification of Freight Modeling and Data Innovations

Innovations in freight modeling and data have primarily been borrowed from technologies developed for other purposes and then applied to facilitate a particular process related to freight movement. For example, GPS, after being developed by the Department of Defense and made available to the general public, provided drivers with point-to-point route navigation tools. Only recently have captured truck route–related data been used to provide valuable information to planners to better understand truck movements. Another example involves the data collected by weigh-in-motion (WIM) technology, used for the enforcement of safety and trucking regulations, and the subsequent use of that data to track truck movements along major highways throughout the United States.

For the purposes of this research, *innovations* in the freight modeling and data community are defined as significant (or potentially significant) movements toward the betterment of freight models, tools, data, or knowledge in freight planning practices. Innovations were identified through the review of past practices, research reports, studies, and entries for the symposium held as part of this research.

Innovations are ongoing and dynamic. Many innovations in the freight industry are not published because their applications for freight movements have not yet been realized—similar to the way GPS and WIM data took some time to be applied to freight modeling and data collection practices for use in freight planning. Other innovations that seem promising at first may actually be lacking in detail or applicability.

The innovations identified as part of the research effort are by no means exhaustive. Ongoing and future initiatives may hold great promise for freight planners. The Strategic Plan is the starting point for setting the course to foster new innovations, allowing the industry to pursue promising areas of research and develop methods for improved decision making by learning from innovations that are not quite ready for planning applications or are found to be subpar for such applications. Early identification of potential initiatives and allowing for setbacks assists in the growth of the practice and should not be discounted outright.

Assessment of Current Freight Transportation Technologies and Innovative Programs

Several promising technologies in use and under development may affect freight forecasting tools. This section includes high-level assessments of these technologies and programs, including how each technology is used, by whom, the opportunity costs associated with not fully integrating these technologies into the modeling process, and what prevents developers from using them. To successfully implement these techniques, several challenges must first be overcome. As seen in Table 3.2, these institutional and technical issues limit how technologies are used in, and developed for, freight modeling.

Table 3.2 acknowledges the current challenges in freight model development, but as Table 3.3 shows, it is equally clear that many potential opportunities exist to improve how the process of freight planning can be addressed to meet both public and private sector needs.

Technological advancements offer some of the greatest opportunities to improve the reliability and accuracy of goods

Table 3.2. Institutional and Technical Issues Affecting Freight Modeling Advancements

Institutional Issues	
Lack of a freight analysis national vision	Because state-run freight models are affected by out-of-state policies and activities, it is important to establish a national vision for interstate freight analysis for efficiency and improvement purposes. National guidelines regarding model structure, data requirements and collection, and calibration and validation would help MPOs, regardless of their size. A national freight analysis system would identify states that are primarily through states for freight movement and fully use their freight movement.
Insufficient data and data collection	Data limitations are the primary obstacle to developing and upgrading freight demand models.
Inability to analyze market-driven changes	Freight demand models do not always include changes in market demands or economic trends. For example, the Texas DOT analyzes mode shifts from a policy perspective, but does not analyze market-driven mode shifts, such as trackage rights.
Inability to analyze policy-driven changes	Decision makers do not always have quick access to required information (e.g., fuel costs, climate change–related information, energy usage) when considering policies. Quick response analytic tools are important for policy-driven changes, but they are not always available.
Lack of multimodal modeling	Multimodal flows and the interactions between truck, rail, water, and air modes are important for efficient modeling, but they are not always available.
Technical Issues	
Lack of data	Detailed models require detailed data, which are not always available.
Truck distribution errors	Truck route forecasting is limited because it incorrectly distributes trucks across all roadways evenly and thus does not accurately account for common trucking routes.
Limited modeling scopes	Models only provide a small portion of a larger transportation picture. Because freight demand models have not been fully integrated with economic models, they do not sufficiently relate freight transportation improvements to economic developments.
Inconsistencies in modeling	No clear standards exist regarding data input and validation, methodologies, model validation, calibration, or updating and recalibration. This lack of standard procedures contributes to the black box effect of freight demand modeling.
Missing relevant information	Certain relevant information, such as time-of-day and seasonal demand, are not incorporated into freight demand models.
Lack of multimodal diversion estimates	Many freight models are limited to truck movements, even though other freight modes are sometimes used.

Table 3.3. Opportunities for Model Improvement

Behavioral	Better consideration of private sector decision-making criteria.
Multimodal network	Public sector applications of private sector network models.
Network design	Improved applications of private sector terminal and facility location models for public sector purposes.
Supply chain and logistics	Methods of forecasting cargo chaining may be of particular interest to private sector and economic agencies while freight vehicle chaining may be of more interest to public transportation agencies.
Improved routing and scheduling	A consideration of internal freight trips, possibly related to supply chain topics.
Hybrid commodity models or applications[a]	Improved real-time freight data.

[a] Beagan 2009.

movement planning. Some technologies are familiar to almost anyone with a modern cell phone, and others are emergent from the freight industry itself. Taken together, existing and emergent technologies offer possibilities to improve processes and close knowledge gaps.

Current Freight Technologies

Global positioning systems (GPS) and intelligent transportation systems (ITS) can collect freight data via transponders that trace individual trip activities, but they do not collect key trip characteristics, such as commodities hauled, shipment size, or trip end activity. However, these technologies serve as a basis of how such data collection might be accomplished when combined with other information systems.

Global Positioning Systems

GPS technology is based on a geosynchronous global satellite system that provides location and time information anywhere on Earth. Location estimates are achieved through triangulation of a time differential as measured by the time it takes for a signal to leave a satellite and reach a ground-based receiver and the time stamp indicating when the signal was sent. By measuring the difference in time stamps between the various received satellite signals, GPS receivers can estimate location, trajectory, and speed. A minimum of four (or more) line-of-sight satellite signals are necessary to estimate location, but the more satellite signals received, the more accurate the estimate of location and speed will be. Although the GPS satellite system only provides one-way information to receivers, onboard GPS devices can translate time and location to information that can be transmitted to ground-based data management systems. This technique allows highly accurate real-time location data to be transmitted and collected by shipping companies or even a GPS-enabled cellular phone.

The data transmitted or collected by ground-based GPS devices have entered both the public and private sector in day-to-day operations. Because privacy concerns related to GPS-based data have become less pronounced over time, GPS combined with other technologies may offer a rich source of information to support future data and model development efforts.

- Safefreight Technology uses SecurityGuard™ GPS tracking devices that can either be mounted to a vehicle or embedded in cargo (Safefreight Technology 2010). The system uses real-time tracking to manage fleet systems. UPS uses a GPS tracking system to track the progress of shipments with a user-friendly web application that plots the customer's shipment progress (Belt 2008).
- Integrating GPS and freight technology has resulted in greater efficiency, as well as increased customer services and satisfaction. This technology could be developed to track more cargo options, which could result in better carrier performance, which in turn would decrease lost revenue and make the shipment process more efficient and smoother.

Intelligent Transportation Systems

ITS is a name given to "the application of advanced information, electronic, communications, and other technologies" to maximize the efficiency of the transportation system and address surface transportation needs (Donnell et al. 1998). ITS technologies include those as basic as signal preemption and as complicated as dynamic weather and integrated deicing systems. Some of the ITS technologies below offer particular promise for the advancement of freight movement data collection or model development efforts in the coming years.

Commercial Vehicle Operations

A commercial vehicle operation is an automated preclearance system that checks a commercial vehicle's weight, safety, and credential status and monitors individual commercial vehicle activities. This system would typically be used by the managers of a trucking company. Vehicle information is transmitted in real-time to a centralized computer system under the control of a team of dispatchers and stored as a concise electronic record called a *snapshot* (Cutchin 2005). Information is conveyed through a satellite navigation system, a small computer, and a digital radio in every truck. This system allows for the central office to know where the trucks are at all times. Additional functions include commercial vehicle clearance (on-board electronic tag identification that provides vital credentials, such as vehicle weight, safety status, and cargo); automated roadside safety inspection (automatically generated vehicle credentials that are stored in the vehicle's electronic tags and can be read electronically); on-board safety monitoring (detects vehicle problems such as load imbalance, shifts in the load, load temperature changes, an open door, low tire pressure); hazardous materials incident response (timely electronic cargo information in the event of an accident); automated administrative processing (data processing such as tax information and automated fuel reporting); and basic commercial fleet management (vehicle, driver, carrier, and cargo information). Individual loads are tracked using a bar-coded container system, and pallets to track loads combined into a larger container. If a truck is lost or delayed, the system can divert the truck to a more efficient route. Automatic vehicle identification readers are installed at exit gates; these gate systems detect the vehicle's electronic tag while the software references the container and related information and posts it to a secure web-based database.

FedEx, which operates one of the best proprietary systems, tracks its shipments through the method described above and achieves better than 99.999% on-time delivery. Load-tracking systems use queues, linear programming, and minimum spanning tree logic to predict and improve arrival times.

Efforts to implement these new technologies may fail because they may not be used properly or not to their full potential. Benefits of using this technology include

- Safety enhancements, such as reduced congestion at weigh stations (reduced accident risk) and freeing law enforcement to concentrate their efforts on high-risk and uninspected carriers and operators;
- Simplicity, such as automated screening (improved enforcement efficiency), automated administrative filing, and quicker information gathering; and
- Savings, through reduced costly paperwork, eliminating unnecessary weight and safety inspections, eliminating manual filing, more efficient government license processing and revenue and tax collection, and less cost to implement the commercial vehicle operation system than to maintain and construct new weigh stations (Pratyush 2003).

AUTOMATED CONTAINER TRANSPORT

Automated container transport (ACT) refers to an automated system of controlled vehicles on dedicated lanes between ports and terminals. The framework of this system would be a (most likely underground) network of conveyer belts that would transport goods. Similar to how underground networks transport sewage, gas, oil, and water, ACT would carry goods in an underground freight network. This system would be an expansion of the already-existent road, rail, air, and water modes of transport. A simpler ACT-like system was used in Paris and Berlin until the end of the twentieth century, when it was damaged by floods. Benefits of the ACT system include a reduction of labor and operating costs (Decker 2008).

The European Combined Terminal in Rotterdam, Netherlands, was the first fully automated container terminal in the world. All containers in the terminal are handled by automated stacking crane and automated guided vehicle systems. These automated vehicles can carry 20-, 40-, 45-, and 50-foot containers that weigh up to 40 tons. The system uses free-ranging-on-grid (FROG) technology to navigate the terminal (Spasovic 2004).

RADIO FREQUENCY IDENTIFICATION

Radio frequency identification (RFID) uses a passive, active, or semipassive transponder device with memory for data storage, a small battery, and an antenna for receiving and transmitting a radio signal used to establish real-time location. RFIDs are used in supply chain management and manufacturing, as well as in processing on-time deliveries. RFID systems consist of interrogators (which read information) and tags (which are the readable labels). These tags can be applied to or incorporated into a product, animal, or person for the purpose of identification and tracking. RFID technology can be used for toll collection, machine-readable travel documents, and airport baggage tracking logistics, as well as to track retail goods, people, and animals.

For example, microSD cards are being used by DeviceFidelity in Dallas, Texas, to store bank account information and to electronically pay mobile phone bills (D'Hont 2004). A personal identification number is used to secure sensitive information stored on the RFID system (Swedburg 2009). The Housing and Development Board of Singapore implemented a parking ticket system using RFID that replaced the paper season parking ticket (Tay 2007). The first E-Passport was used in Malaysia in 1998 to log information about a citizen's travel history. Many toll roads, both nationally and internationally, use RFID technology to improve efficiency. An E-ZPass system—which is currently being used in Massachusetts, Delaware, New Hampshire (Reino 2010); Maryland (Maryland Transportation Authority 2008); New Jersey (Tri-State Transportation Campaign 2002); and a few other states—uses RFID to create an easier alternative to the typical, manual toll road framework. In South Korea, T-money cards can be used to pay for public transit and, in some stores, used as cash. In Hong Kong, mass transit is paid for almost exclusively through the use of RFID-enabled Octopus Cards (Mas and Rotman 2008). RFID is also used to track animals on large ranches and in rough terrain and to identify crucial animal information. If a packing plant condemns a carcass for safety purposes, RFID information can identify the animal's herd of origin. RFID technology was used after the outbreak of mad cow disease.

Potential problems and concerns about RFID include data flooding (which requires a means of filtering raw data), the need for global standardization, security concerns (because of world-readable private, corporate, and military information), exploitation, passport hacking (the encryption on U.K. chips was broken in under 48 hours), shielding (to block unwanted reading of data), and hardware susceptibility (vibration and high temperatures may loosen an RFID connection). Privacy concerns are a variable because of the perceived threat of RFID implantation in humans and potential government control (BBC News 2004). Because of these concerns, an anti-RFID campaign was launched in Germany (Hansen and Meissner 2007).

MACHINE VISION

Machine vision refers to automated systems of digitization, manipulation, and analysis of images used for traffic monitoring, navigation, and transport safety, as well as for detecting lane markings, vehicles, pedestrians, road signs, traffic conditions, traffic incidents, and driver drowsiness. These systems could potentially offer a source of generalized freight data.

Emergent Technologies and Processes

Perhaps one of the most exciting areas of freight data and methods development will come from emerging technologies that at present have limited real-world application but are sufficiently mature to merit testing and evaluation. These technologies, built to improve safety or delivery efficiency, can provide new sources of data to improve the goods movement planning processes used by both public and private sectors.

AUTOMATED GUIDED VEHICLES

An automated guided vehicle uses an on-board automated system of vehicle cruise control, lane departure warnings, collision avoidance, and obstacles detection. A FROG vehicle uses sensors to navigate and orient itself on a grid (or map), such as posted calibration points along its route. An operator uses a call button, similar to an elevator call button, to activate the FROG. When the vehicle arrives, the operator enters the vehicle and selects a destination via an onboard touch-screen computer, and the FROG vehicle automatically drives toward the destination, leaving the operator free to perform other tasks. Statistics (pickups, deliveries, movements, events) are all recorded over a wireless network and stored on a management system. Automated guided vehicle systems typically have only one or two vehicles, only a few pickup and drop-off locations, and simple road systems (John 2009). When operating, an automated guided vehicle uses rear laser bumpers, side safety bumpers, and optical sensors to detect obstacles; that is, the safety bumpers are active in all directions of vehicle travel (Deaton 2008).

Pickup Centers

Pickup centers are convenient local collection and distribution depots, or boxes, where consumers can pick up goods they have ordered. Scheduling, online booking, detailed shipping manifests and reports, shipment tracking, and confirmation and delivery notices are all provided at the pickup center. Freight agents locate qualified carriers with proper insurance and licensing, negotiate preferred rates, and manage all the processes from initial pickup through final delivery to ensure a timely and cost-effective shipment. Platinum Worldwide Logistics (a division of Pak Mail Centers of America, Inc.) is an example of a pickup center that provides integrated, global freight forwarding solutions for businesses and consumers via ground, air, and water, as well as shipping logistics (Pak Mail WorldWide 2010).

Freight Forwarders, Brokers, and Third-Party Logistics Providers

These relatively new companies use new communications technologies to directly link worldwide business-to-business and business-to-consumer transactions through an outsourced one-stop shop. Third-party logistics providers typically specialize in integrated operation, warehousing, and transportation services that can be customized based on the needs of the customer and the demands of the market (Murray 2012). Internet access to management information is becoming more popular; it provides intranet and extranet access, administration, support, and management. Third-party logistics providers also provide legal assistance, such as liability concern analysis and contract and risk assessment (Marsh 2007).

Innovative Freight Programs

Several innovative approaches to programs and studies have been initiated around the world to harvest some of the fruits of new technologies. U.S. DOT has several initiatives that have introduced freight data and freight management and goods movement optimization to several urban areas around the United States. These programs have evolved from a variety of needs ranging from safety, U.S. Customs and North American Free Trade Agreement requirements, pavement design, and web-based coordination. These initiatives are described below.

Smart Roadside Initiative

The Office of Freight Management and Operations partnered with the Federal Motor Carrier Safety Administration (FMCSA) to introduce advanced roadside technologies to conduct inspections and measurements that traditionally have been delivered at weigh station sites. The Smart Roadside Initiative is a system deployed at strategic points along commercial vehicle routes to improve the safety, mobility, and efficiency of truck movement and operations on the roadway (IntelliDrive Program 2010). Smart Roadside Initiative technology includes wireless roadside inspections, electronic truck size and weight enforcement, electronic driver credentialing, customs and borders preclearance, and advanced traveler information systems to establish communication protocols (Trucking Industry Mobility & Technology Coalition 2008). Although a standardized system would be used, the initiative would not be exclusively used by a government. Four applications would be deployed: (1) E-screening a vehicle while it is in motion to detect safety issues; (2) improved truck size and weight enforcement; (3) direct information transmitted from the vehicle to the roadside carrier system to a government system; and (4) commercial vehicle parking information, including advanced route planning decisions that would survey hour-of-service constraints, location and supply of parking, travel conditions, and loading and unloading. The Smart Roadside Initiative, as a concept, would create efficient data handling between private and public sector motor carrier systems while maintaining current operational systems (IntelliDrive Program 2010).

Cross-Town Improvement Project

The Cross-Town Improvement Project is a high-level concept program that incorporates an intermodal move database for coordinating crosstown traffic to reduce empty moves between terminals. The program also tracks intermodal assets and distributes information to carriers wirelessly. The intermodal move exchange facilitates the exchange of load data and availability of information between railroads, terminal operators, and trucking companies. Chassis utilization tracking provides a means for chassis owners and users to accurately account for asset use. Real-time traffic monitoring provides a means to obtain the up-to-the minute information about roadway conditions, travel speeds, and predicted travel times that is captured by traditional roadway sensors and traffic probes. Dynamic route guidance uses input from real-time traffic monitoring and a geographic information system source along with simulation tools to provide real-time visual routing around congested areas. Wireless drayage updating provides a means to wirelessly and inexpensively exchange information with drivers regarding trip assignments, traffic congestion information, trip status, and location information through a truck-mounted driver interface device (Cross-Town Improvement Project 2010).

e-Permitting and Virtual Weigh Stations

The Office of Freight Management and Operations recently completed two program initiatives that addressed electronic permitting and virtual weigh stations (VWS). VWS can improve the operational efficiency and effectiveness of states' roadside enforcement programs by targeting commercial carriers that have a history of poor safety performance or commercial vehicles that are known to be overweight. The program would provide additional information on tracking, weather, and traffic conditions for system managers. Currently, however, VWS technology can only be applied with the current state of technology, which is primarily license plate information, vehicle identification numbers, and U.S. DOT numbers. Research is creating a more efficient and more reliable system of identification through camera recognition; however, some states are concerned that such optically based VWS identification will be unable to achieve a perfect identification system with current technologies. Because human interaction is still required to screen, enforce, and issue citations for compliance issues, VWS technology could be slowed by manual operations, thereby reducing its efficiency. These potential problems may be remedied by the development of architecture for e-permitting and virtual weight, determining which vehicle identification technology is best suited to identify all commercial vehicles, conclusively documenting the benefits of VWS, and investigating the deployment of direct enforcement concepts in the United States (Federal Highway Administration 2009a).

Universal Truck Identifier Project

The Office of Freight Management and Operations initiated a program to identify the advanced technologies capable of uniquely identifying commercial vehicles subject to U.S. Code Titles 23 and 49 inspections and measurements. WIM devices are designed to capture and record truck axle weights and gross vehicle weights as they drive over a sensor. Unlike older static weigh stations, the vehicle can be in motion while information is being gathered, which makes WIM devices more efficient (Federal Highway Administration 2009b). Benefits of WIM include quicker processing rates, safety improvements through decreased vehicle accumulation, continuous data processing, increased coverage with lower costs, minimized scale avoidance (i.e., monitoring trucks without alerting truck drivers, thereby providing more reliable data), and dynamic loading data (Norikane 2008). WIM shortcomings include a reduction in accuracy, reduced information (information that is usually collected at static weight stations, such as fuel type, state of registry, year model, loaded or unloaded status, origin, and destination cannot be collected), and susceptibility to damage from electromagnetic transients (Washington State DOT 2010b).

Electronic Freight Management

Electronic freight maintenance (EFM) is a U.S. DOT–sponsored program that applies web technologies to improve data and message transmissions between supply chain partners, enabling process coordination and information sharing for supply chain freight partners through public–private collaboration. A common electronic freight framework would improve the efficiency and productivity of the transportation system. The initiative would first test the concept at the truck–air freight interface, and then move on to other modal interfaces, such as truck–truck, truck–rail, rail–sea, and truck–sea. EFM provides shippers (the supply chain owners) with visibility to meet very tight performance standards and improve operational efficiencies by offering uniform access to existing customized MySQL database formats, computing platform independence, and adaptable services. The value and operational efficiencies grow as more supply chain partners link into EFM. Because international trade accounts for a quarter of the U.S. gross domestic product, the trend toward globalized trade places new burdens on those organizations involved in freight movement. EFM provides improved data quality, administrative cost reduction, more efficient operations, better supply chain agility, extended supply chain visibility, improved supply chain security and resiliency, and the ability to coordinate business processes across organizations (Intelligent Transportation Systems Joint Program Office 2009).

Columbus EFM Project

The Columbus EFM project was a successful 2007 deployment test that implemented web services and other components to support an existing international import truck–air–truck supply chain. The Columbus EFM project encompassed a broad, worldwide air cargo supply chain and was successfully deployed from overseas suppliers in China to distribution centers in Columbus, Ohio. The deployment test focused on the pilot test of a portion of a single supply chain. The evaluation of the deployment is especially important because it tests potential government impacts and wider industry impacts while quantifying the benefits. The goal of the EFM program was to provide a platform to exchange information among trading partners on a many-to-many basis over the web (Intelligent Transportation Systems 2008).

Innovative Freight Studies

Several ongoing freight studies have explored how data from modern technologies can be integrated to advance freight planning. These efforts bridge various technologies to solve specific problems, identify trends, and gauge the willingness of private shippers to embrace technology in their day-to-day business.

European Truck Technology Scan Implementation Project

Ten transportation professionals participated in a scan of six European nations (Slovenia, Switzerland, Germany, the Netherlands, Belgium, and France) sponsored by the Office of Freight Management and Operations, the American Association of State Highway and Transportation Officials (AASHTO), and NCHRP. The scan focused on the use of advanced technologies employed to support truck size and weight enforcement. The technologies observed included "a high speed WIM system, video/photograph capture, [and] handheld/portable equipment" for real-time selection of noncompliant vehicles (Federal Highway Administration 2009c).

Unique enforcement technologies such as heavy goods vehicle control sites in Switzerland (including a three-dimensional vehicle profile scanner, a full gross vehicle weight static scale system, an automated citation issuance system, and full safety inspection facilities) and bridge weigh-in-motion systems in Slovenia and France were tested (Federal Highway Administration 2009c).

Washington State Freight Performance and Mobility Improvement Study

The Washington State Transportation Research Center tested commercial vehicle information systems and networks (CVISN) electronic truck transponders using software to link the transponder reads from sites anywhere in the state to collect specific truck movement data in order to benchmark when and where the monitored trucks experienced congestion. The goal of the CVISN program is to improve safety and security, simplify operations, improve efficiency and freight mobility, and move toward nationwide deployment. To achieve these goals, the U.S. DOT is targeting high-risk operators, integrating various systems and improving the credentialing and screening process (Federal Motor Carrier Safety Administration 2010). CVISN uses WIM scales and transponder readers to electronically screen trucks from about a half-mile away as they approach a weigh station. The weigh stations use carrier and vehicle snapshots (electronic records) to support screening decisions. These snapshots contain information such as the carrier's current safety rating based on the state's computer files, a historic review of the carrier's safety records, an overview of the last safety inspection for the vehicle being screened, and the expiration date of any Commercial Vehicle Safety Alliance decal on the vehicle being screened.

In 2009, Washington State DOT reported that "transponder-equipped trucks were pre-cleared and received more than 1,048,000 green lights at Washington weigh stations" with an average weigh station stop of 5 minutes. The DOT estimates that this yielded industry savings of approximately 87,000 hours of travel time and $6.5 million dollars (Washington State DOT 2010a). Oregon uses a similar Green Light weigh station preclearance program, which is arguably the nation's best screening program. The program has precleared truckers 10.5 million times since January 1999, which has resulted in an estimated $9.8 million in savings per million preclearances (Oregon DOT 2008).

National Roadside Technology Survey

FMCSA conducted a perception survey that documented nationwide motor carriers' input regarding the use of roadside technologies to electronically identify commercial vehicles and the sharing of commercial driver data. The project included perspectives on GPS and transponder benefits, cost implications, and information sharing. The study focused on what motor carriers would like to see in the future. FMCSA states the Roadside Technology Corridor's goal as having "a series of specially-equipped testing facilities at weigh stations to demonstrate, test, evaluate, and showcase innovative safety technologies under real-world conditions in order to improve commercial truck and bus safety. Data gathered from experiments and field tests along the corridor will be used to support FMCSA enforcement and compliance programs, state safety programs, policy research, and future rulemaking activities" (Federal Motor Carrier Safety Administration 2011).

Summary and Implications

Model developers forecast the impacts of freight patterns to support the development and implementation of policies and infrastructure improvements to enhance safety, efficiency, and the overall effectiveness of goods movement on national, state, regional, and local transportation systems. Forecasting and understanding the movement of goods, regardless of geographic scope, requires assembling information from a variety of data sources, all of which are either incomplete or contain inaccuracies. Recent studies have shown that technology is playing an increasing role in data collection, policy development, and private shipper response to market stimuli. Current and emergent technologies will make the ground more fertile for such endeavors and, with the right framework, will provide opportunities for data

Table 3.4. Sample Research Initiatives

Sample Research Initiatives[a]	Research Dimensions			Strategic Objectives						
	Knowledge	Models	Data	1. Improve and expand knowledge base.	2. Develop modeling methods to reflect actual supply chain management practices.	3. Develop modeling methods based on sound economic and demographic principles.	4. Develop standard freight data to smaller geographic scales.	5. Maximize use of freight tools by public sector for planning and programming.	6. Improve availability and visibility of data between public and private sectors.	7. Develop new and enhanced visualization tools and techniques.
A: Determine the freight and logistics knowledge and skill requirements for transportation decision makers and professional and technical personnel. Develop the associated learning systems to address knowledge and skill deficits.	●			■						
B: Establish techniques and standard practices to review and evaluate freight forecasts.		●		■	□	□				
C: Establish modeling approaches for behavior-based freight movement.	●	●			■					
D: Develop methods that predict mode shift and highway capacity implications of various what-if scenarios.	●	●			■	■				
E: Develop a range of freight forecasting methods and tools that address decision-making needs and that can be applied at all levels (national, regional, state, metropolitan planning organization, municipal).		●	●		■	■	□			
F: Develop robust tools for freight cost–benefit analysis that go beyond financial considerations to the full range of benefits, costs, and externalities.	●	●				□		■		
G: Establish analytic approaches that describe how elements of the freight transportation system operate and perform and how they affect the larger overall transportation system.	●	●				■		□		
H: Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics. Document economic and demographic changes related to freight choices.	●					■				
I: Develop freight data resources for application at subregional levels.			●		□	□	■			
J: Establish, pool, and standardize a portfolio of core freight data sources and data sets that supports planning, programming, and project prioritization.			●				■	■	□	
K: Develop procedures for applying freight forecasting to the design of transportation infrastructure, particularly pavement and bridges.		●						■		
L: Advance research to effectively integrate logistics practices (private sector) with transportation policy, planning, and programming (public sector).	●				□			■	■	
M: Develop visualization tools for freight planning and modeling through a two-pronged approach of discovery and addressing known decision-making needs.	●	●	●							■

Note: Directly Addresses Objective ■; Indirectly Addresses Objective □.

[a] The sample research initiatives outlined as part of the SHRP 2 C20 research project demonstrate how the strategic objectives could be advanced. Each initiative also applies to one or more of the three research dimensions (indicated by ●).

mining and evaluations that can effectively serve the needs of both public and private decision making.

Some of the major findings from this section of the research follow:

- The majority of freight technologies and innovative programs use GPS or ITS technologies, or both;
- A multitude of current freight technologies, programs, and innovative studies are not fully used by freight model developers due to institutional challenges that limit the use of the data;
- Institutional challenges that might explain why these technologies are underused include a lack of national direction and modeling standards, the proprietary nature of the data sets, and the cost and time required to collect (or purchase) the data and develop the models. In addition, the economic downturn has reduced the urgency (and resources) with which elected officials and transportation planners had previously supported the development of accurate, complex freight models; and
- The need for effective and efficient transportation systems to move freight will most likely become an issue once the economy rebounds.

SHRP 2 C20 Sample Research Initiatives

Thirteen research areas were identified for future pursuit that flow from the strategic objectives described above. The primary goal of the proposed research initiatives is to promote, cultivate, and support innovative research related to the modeling of freight activity based on real-world supply chain and logistics practices and tied to an enhanced understanding of the demographic and economic influences of freight activity. These efforts would be supported by new data development methods for small geographic scales, as well as improved visualization techniques for freight planning. This research is aimed at advancing an industrywide vision for developing a comprehensive network-based freight forecasting model that incorporates all freight transportation modes and can be applied at different geographic scales.

An overview of the sample research initiatives and their relationships to the strategic objectives is shown in Table 3.4. Detailed information for each of the sample research initiatives, along with potential research projects and implementation time lines, is provided in Chapter 4.

CHAPTER 4

Conclusions and Suggested Research

Policy makers, state DOTs, MPOs, and varied stakeholders acknowledge that freight transportation is an issue of growing importance. Freight modeling practice, which informs freight planning and programming to support goods movement, is evolving. However, communication among practitioners, coordination and integration of models and data, the overall direction of the practice, and methods for addressing decision-making needs all require improvement. A structured approach to addressing the current shortcomings of freight modeling and data is critical to the evolution of the practice toward better freight planning.

The SHRP 2 C20 research initiative has been developed to provide the strategic framework for making further inroads in freight forecasting, planning, and data, and to accelerate innovative breakthroughs with the aim of integrating freight considerations into the planning process with confidence. The Strategic Plan establishes a framework for joining the strategic objectives, the sample research initiatives, and the strategic directions for future research.

Strategic Plan Introduction

The SHRP 2 C20 Freight Demand Modeling and Data Improvement Strategic Plan (in this chapter and also provided as a stand-alone web document) advances a broad new direction for improving freight planning, promoting continuous innovation for breakthrough solutions to freight analytic and data needs, and fostering a collaborative approach for private, public, and academic stakeholders.

The long-term goal for the research documented is to build on the strategic objectives to ultimately develop a full network-based freight forecasting model that incorporates all modes of freight transport and accurately reflects the various factors related to the supply of freight infrastructure and services and the underlying demand for these services. This will be a dramatic change in current freight planning and forecasting. It is a highly ambitious endeavor because of the complexity of freight transportation and the many elements that are necessary to achieve this long-term goal.

In addition, goals will be achieved through the development of the applicable knowledge base needed, the development and dissemination of necessary support data, and the development of enhanced methods for disseminating information from these analytic tools for public stakeholders and decision makers.

Although development of a full multimodal network-based freight forecasting model is the ultimate long-term goal, it is important to note that freight transportation has not traditionally lent itself to innovative planning and forecasting practices. This is because freight transport has historically been a relatively uncomplicated, low-tech process. In addition, past experience in freight transportation does not necessarily correlate well with future freight activity due to short-term changes in the forces of supply and demand. As a result, accurately planning for freight transportation will require a radical paradigm shift in the way the practice is currently conducted.

Sample Research Initiatives

The SHRP 2 C20 research effort culminated in the development of 13 sample research initiatives. Collectively, these research initiatives constitute a programmatic approach for systematically improving freight modeling and data availability and forecasting tools. Each of the research initiatives relates to at least one of the three main research dimensions: knowledge, models, and data.

The sample research initiatives described in detail below are based on the SHRP C20 research, but they should be viewed in their proper context as steps in support of the seven strategic objectives. The specific research projects are initial recommendations for potential research to spur progress; many of these recommendations are likely to change based on funding sources, industry needs, and developments such as the GFRC and the future data and modeling symposia recommended in the Future Directions section of this chapter.

Given that the required research related to planning and decision-making support will evolve over time, an important function for those involved in implementing the Strategic Plan is to periodically assess changing research needs based on decision-making requirements relative to the changing dynamics of goods movement.

Sample Research Initiative A

Determine the freight and logistics knowledge and skill requirements needed for transportation decision makers and professional and technical personnel.
Develop the associated learning systems to address knowledge and skill deficits.

Description

The complex factors that drive freight transportation demand require an understanding of economics, land use, public policy, demographics, finance, and information technology. The education and development of professionals involved in freight planning and forecasting will be an effective strategy for improving freight planning, analysis, and decision making. Successful planning and forecasting in freight transportation can be enhanced through the dissemination of knowledge among professionals whose current training is likely to be oriented toward passenger travel or general transportation issues.

The intermodal revolution of freight transportation in the past several decades, for example, was primarily aimed at enhancing efficiency for private sector interests. The dramatic transformation of freight transportation during the same period, however, was not reflected in advances in planning practices by state DOTs or MPOs. These advances in freight transportation practices were largely driven by advances in information technology and information management. Consequently, this research is aimed at sparking a revolution in freight planning and forecasting through a broad-based initiative to enhance knowledge of public and private sector interests.

The lack of uniformity in knowledge levels about freight issues in the transportation planning community is compounded by a significant disconnect between the goals and objectives of shippers and carriers in the private sector and planners in the public sector. This research identifies skill sets and techniques to help bridge these gaps and facilitate more effective planning and problem solving. An ideal skill set includes an integrated curriculum with subject areas such as computer science, planning, economics, political science, and organizational skills. Communication skills are also critical for professional development in this area.

This initiative will be implemented in three major research phases:

1. Conduct an extensive knowledge and skills requirements analysis for all levels of transportation professionals and decision makers.
2. Over time, develop, pilot, and evaluate comprehensive knowledge transfer subject matter and media. This phase will include a wide range of approaches, even including brief employment swaps.
3. Develop the supporting organizational and structural approaches, such as national and regional freight innovation academies, to effectively deliver an ongoing knowledge and skills delivery system.

Benefits and Expected Outcomes

- Enhanced performance of individuals and organizations through a greater knowledge of freight and logistics;
- Greater understanding of the need for public planning and analysis to incorporate freight and logistics; and
- Greater collaboration between public and private sectors, to provide a much-needed understanding of the discrete segments of the freight transport community, including shippers, carriers, customers, and other elements of the supply chain.

Implementation

Sample Research Initiative A implementation ideas and considerations are summarized in Table 4.1.

Other Considerations

Sample Research Initiative A does not directly relate to any of the other initiatives and does not inform them directly as a research effort, but the knowledge base developed and cultivated during the course of this effort will ultimately support all other ongoing research efforts related to freight planning, forecasting, and model and data development. Thus, this initiative should be considered for early action.

Although recent and ongoing research efforts, such as those presented at the 2010 Innovations in Freight Demand Modeling and Data Symposium, tend to be highly technical and oriented toward specific transport modes or logistics processes, the underlying concepts of transportation economics and other factors that influence freight transportation demand should be incorporated in this initiative.

The Freight Academy program organized by the I-95 Corridor Coalition could inform this initiative, along with an

Table 4.1. Sample Research Initiative A Implementation

Products or Projects	Phases and Time Lines	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Analysis of knowledge and skills requirement.	9 months	$150,000	na
Develop, pilot, and evaluate a comprehensive knowledge transfer subject matter and media.	Continuous, with implementation following knowledge and skills analysis as basis for moving forward.	$1,000,000 annually	na
Develop the supporting organizational and structural approaches for a major knowledge transfer initiative.	12 months	$200,000	To begin after analysis of knowledge and skills requirement is completed.

Note: na = not applicable.

interesting global supply chain game developed by researchers at Delft University and the Robert H. Smith School of Business at the University of Maryland, and tested through course offerings at the business school since 2005 (Corsi et al. 2006). Possible champions of this effort could include universities, AASHTO, and perhaps some collaborative initiatives involving academia and private industry. Decision makers in government would benefit from an executive-level training program that provides a general overview of issues related to freight planning and forecasting.

Sample Research Initiative B

Establish techniques and standard practices to review and evaluate freight forecasts.

Description

Freight modeling, like passenger travel demand modeling, has forecasting capabilities that are used to estimate the movement of freight on highways, railroads, and other elements of the freight transportation system. The effectiveness of these modeling tools is rarely analyzed, mainly because review and evaluation processes completed years after forecasts are done are perceived to be of dubious value in light of how rapidly circumstances may change during the planning period.

This research aims at developing practices to review previous freight forecasts over short- and intermediate-term horizons, with a review of factors used in forecasts and a backcasting comparison of actual freight values, mode shares, and other characteristics of freight transportation. In light of the ongoing developments in freight forecasting and the fact that the most robust forecasting tools used by public agencies have been developed within the past two decades, the review and evaluation of long-term projections is not considered a near-term research priority.

This research effort will be oriented toward the freight forecasting methods documented in *NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand* (Cambridge Systematics 1997) and in National Highway Institute Course 139002: Uses of Multimodal Freight Forecasting in Transportation Planning (Federal Highway Administration 2010). This research involves a historical survey of 15 to 20 public agencies that (1) have used one or more of the various tools described in these publications and (2) have documented or published results from their freight forecasting processes that can be assessed at the present time. The review and evaluation research is based on a mix of short-term (up to 3 years from original forecast) and intermediate-term (3 to 10 years from original forecast) results. The survey will document projected versus actual conditions for these 15 to 20 models as measured by facility (highway, rail, and terminal) operating characteristics (volumes), mode choice, routing, and commodity flows. The use of these measures will depend on their applicability to individual models.

Benefits and Expected Outcomes

- Improve freight forecasting through a structured learning process related to actual versus projected conditions;
- Develop model calibration tools to improve models over time;
- Provide guidance on additional data and other factors to be incorporated into the planning and forecasting process; and
- Provide insight into how various factors used in previous freight forecasts can change over time and influence each other in ways not previously considered.

Implementation

Sample Research Initiative B implementation ideas and considerations are summarized in Table 4.2.

Table 4.2. Sample Research Initiative B Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Historic survey of 15 to 20 freight forecasting tools and processes used by multistate regions, states, MPOs, and local and county agencies, including comparison of forecasts for short- and intermediate-term planning horizons with actual conditions.	12 months	$150,000–$200,000	Should include two or more international models.

Other Considerations

Because this research effort does not relate to the future highway capacity considerations of the SHRP 2 program as directly as others, this initiative should not be considered a top priority for early implementation. It may provide more value some years down the road when recently developed models with freight forecasts can be tested.

Sample Research Initiative B relates to the following initiatives:

- Modeling approaches and tools included in Sample Research Initiatives C and E may offer some interesting possibilities for backcasting with previous models using different types of data;
- The results of this research effort can support and inform the what-if scenarios described in Sample Research Initiative D; and
- The review of economic, demographic, and other factors described in Sample Research Initiative H can provide insight into additional factors to consider in documenting deviations between forecasts and actual results.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The modeling effort for the Mississippi Valley Region conducted by the Center for Freight Infrastructure Research and Education at the University of Wisconsin–Madison incorporates some narrowly defined commodity groups that might be somewhat easier to use for validation efforts than the aggregated commodities typically used in freight forecasts;
- The evaluation metrics of the second Oregon Statewide Integrated Model (SWIM2) may offer some insight for this initiative;
- The interclass correlation process described in Analysis and Multi-Level Modeling of Truck Freight Demand (Wang et al. 2010) may be informative for this research effort;
- The touring element of freight transportation is typically the most difficult to validate. The research documented in Modeling Commercial Vehicle Daily Tour Chaining (Ruan et al. 2010) should be reviewed in detail for applicability to this initiative; and
- Vilain and Muhammad (2010) have recently presented research on validating econometric models in Freight Demand Modeling Using Econometric Models.

Sample Research Initiative C

Establish modeling approaches for behavior-based freight movement.

Description

Analytic tools are needed to model or forecast freight flows and modal volumes in ways that generally reflect the decision making of shippers, carriers, and receivers of goods. These tools will assist state DOTs and MPOs in better planning and prioritizing system investments and assessing and measuring system performance. Private sector freight stakeholders must work with public sector stakeholders to establish model parameters, processing methods, and product elements. The end goal of this initiative is to establish tools that better model the freight movement patterns of various segments of the industry. Behaviors are not monolithic; that is, long-haul operations behave differently from hub-and-spoke operations, which behave differently from local dray operations. Each has different behaviors and operating characteristics, such as time of day, preferred routes, parking needs, and congestion contribution levels.

The research will cover the equipment choices, motivations, and economic choices germane to individual segments and stakeholders of the freight transport community. Specifically, each research task will provide an in-depth and complete look at a single segment of the industry. Examples include detailed explorations of deliveries to various-sized grocery stores, restaurant delivery of food and beverages, fuel delivery, and parcel package delivery.

The tasks in this project will serve as building blocks in the development of a more comprehensive overall freight transport model. Much like subroutines embedded in a highly complex program, this research will provide a modeling approach that includes decision tree creation methodology.

Benefits and Expected Outcomes

- Provide a much-needed understanding of the discrete segments of the freight transport community, including shippers, carriers, customers, and other elements of the supply chain;
- Help public sector agencies gain a better understanding of the impacts policy decisions have on individual freight transport segments;
- Develop a well-rounded and representative understanding of freight movement that does not generalize nor assume that freight movement activity is similar across different industry sectors;
- Provide insight on service availability, pricing, and reliability as performance measures for different industry sectors; and
- Develop an improved understanding of the intermodal freight movement.

Implementation

Sample Research Initiative C implementation ideas and considerations are summarized in Table 4.3.

Other Considerations

Sample Research Initiative C relates to the following initiatives:

- This research can support the research efforts described in Sample Research Initiative G for different geographic scales, since both initiatives involve research into the characteristics of individual businesses and industries;
- Some of this research can be used to document industry-specific limitations in mode choice related to reliability, service availability, and other factors to inform the what-if scenarios described in Sample Research Initiative D; and
- This initiative can serve as the basis for the logistics practices described in Sample Research Initiative L.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The microsimulation work on freight transport in the Mississippi Valley Region can provide insight into logistics practices for certain commodities that are critical to that region.
- The research described in Modeling Commercial Vehicle Daily Tour Chaining (Ruan et al. 2010) is a good example of behavior-based modeling for local truck deliveries. Recent research from Japan, Modeling Truck Route Choice Behavior by Traffic Electronic Application Data (Hyodo 2010), is specific to local container truck movements.

Table 4.3. Sample Research Initiative C Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
In-depth research of package delivery characteristics, including door-to-door delivery from long-haul to end receiver (e.g., multistory urban office complex).	12 months	$90,000	na
In-depth research of food and beverage delivery for restaurant industry (including door-to-door delivery for different population densities).	18 months	$180,000	na
In-depth research of grocery store distribution characteristics (including key products or product groups).	9–18 months	$60,000–$180,000	Time line and cost are dependent on number of product lines or product types included in research.
In-depth research of sensitive medical-related deliveries (including medication, equipment, organs, and other time-sensitive items).	12 months	$90,000	na
Other significant freight segments as proposed by researchers.	9–18 months	$60,000–$250,000	Time line and cost are dependent on industries and commodity types.
Regional shipper and carrier surveys to develop regional profiles described in Sample Research Initiative E.	Up to 24 months	$400,000 to $1.5 million, depending on number of business establishments surveyed.	Should be done based on geographic levels (regional, state, major MSA, minor MSA) described in Sample Research Initiative E.

Note: MSA = metropolitan statistical area; na = not applicable.

- The MOBILEC model documented in Innovative Freight Transportation Framework for Flanders (Maes and Ramaekers 2010) strongly relates to this initiative.
- The combined PINGO model and logistics model documented in A Model System for Forecasting National and International Freight Transport in Norway (Hovi and Hansen 2010) is an innovative approach to logistics-based freight forecasting.
- For truck deliveries, this research can be informed by Fusing Public and Private Truck Data to Support Regional Freight Planning and Modeling (Liao 2010) and the analysis tool to process GPS data developed by Sharman and Roorda (2010) of the University of Toronto.
- The tour-based entropy model documented in A Tour-Based Urban Freight Demand Model Using Entropy Maximization (Wang and Holguín-Veras 2010) and the business establishment–based modeling process documented in A Firm-Based Freight Demand Modeling Framework Capturing Intra-Firm Interaction and Joint Logistic Decision Making (Guo and Gong 2010) are innovative research efforts that strongly tie to this initiative.
- This research initiative can also be informed by the hybrid microsimulation model of urban freight transportation developed by Donnelly et al. (2010) in A Hybrid Microsimulation Model of Urban Freight Travel Demand.

Sample Research Initiative D

Develop methods that predict mode shift and highway capacity implications of various what-if scenarios.

Description

Freight is substantially more varied than passenger transport in the complexity of its transportation processes and its global multimodal and intermodal nature. Some trucking companies are now transportation brokers, making customer service, cost, and the freight's delivery schedule the focus—not the mode. State DOTs and MPOs need to better understand how freight shifts across modes and how highway capacity is affected by such shifts. What-if scenarios are valuable for planning and testing alternative investment scenarios. Considerations in such scenarios include fuel costs, congestion pricing, toll increases, new or closed rail spurs, and improved waterway infrastructure.

This area of research identifies the key decision points and factors that dictate mode shifts, route selections, equipment selection (e.g., size and type of truck, container or noncontainer), trip frequency, and so forth. These decision points and factors vary greatly in any given situation. In addition to the example considerations identified above, variables include policy changes, customer demand, weather, infrastructure capacity, transportation company mergers, and strategic partnership development. Completed research will provide a decision tree model to illustrate what-if scenarios.

The research effort described in this initiative will build on the underlying economic and demographic foundations of traditional econometric models used in freight forecasting, with enhancements related to considering intermodal transfers, the growing role of third-party and fourth-party logistics providers (3PLs and 4PLs, respectively) in the freight transportation industry, and ongoing refinements in supply chain management.

Benefits and Expected Outcomes

- Provide public agencies and private entities with a tool that can help determine unforeseen effects caused by a variety of factors facing the freight community on a regular basis;
- Allow public agencies an opportunity to consider the impacts associated with infrastructure investments (or lack of investments) and also to create realistic contingency plans;
- Help public sector agencies gain a better understanding of the impacts that policy and infrastructure investment decisions may have on individual elements of the freight transportation system or geographic regions;
- As with Sample Research Initiative C, help provide insight on service availability, pricing, and reliability as performance measures for different industry sectors; and
- An improved understanding of freight movement and the role of intermodal transfers and service providers (including less-than-truckload carriers and 3PL and 4PL firms) in freight transportation.

Implementation

Sample Research Initiative D implementation ideas and considerations are summarized in Table 4.4.

Other Considerations

Sample Research Initiative D relates to the following initiatives:

- The research proposed in Sample Research Initiative C would be useful in understanding the needs of different industry sectors and the impact of service availability, reliability, pricing, and other factors on their mode decisions;
- The extensive data collection effort in this initiative would help support the logistics and policy linkage effort in Sample Research Initiative L and potentially inform the localized decision-making needs documented in Sample Research Initiative E;

Table 4.4. Sample Research Initiative D Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Conduct research identifying the key factors involved in mode choice decisions by shippers, carriers, and 3PLs by commodity type.	9 months	$150,000	Should be based on current practices in supply chain management and freight forecasting.
National survey of shippers, carriers, and 3PLs.	18 months	$250,000 to $1.5 million, depending on sample size	na
Develop tools to identify infrastructure impacts based on prior tasks within this initiative (as described above).	18 months	$250,000	Must wait for completion of previous items in this initiative.

Note: na = not applicable.

- Data collected in this effort could help in illustrating freight–passenger transportation relationships as described in Sample Research Initiative G;
- Ongoing research in standardizing freight data, as described in Sample Research Initiative J and in *NCFRP Report 9: Guidance for Developing a Freight Transportation Data Architecture* (Quiroga et al. 2011), should be considered when assembling and analyzing data for this effort; and
- The shipper and carrier research described in this initiative could inform the research proposed in Sample Research Initiative H.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- This initiative can be informed and supported by ongoing research related to econometric models for freight analysis, including Freight Demand Modeling Using Econometric Models (Vilain and Muhammad 2010);
- Some of the logistics and industry-related research used to support the MOBILEC model as described in Innovative Freight Transportation Framework for Flanders (Maes and Ramaekers 2010) may relate to this initiative;
- Truck data obtained and documented in Fusing Public and Private Truck Data to Support Regional Freight Planning and Modeling (Liao 2010) may be useful for this effort; and
- Urban delivery characteristics as developed in A Hybrid Microsimulation Model of Urban Freight Travel Demand (Donnelly et al. 2010) may provide some insight to support the what-if scenarios in this initiative.

Sample Research Initiative E

Develop a range of freight forecasting methods and tools that address decision-making needs and that can be applied at national, regional, state, MPO, and municipal levels.

Description

Many of the techniques currently used in forecasting freight movement are oriented toward specific geographic scales reflecting varied planning needs. Some of these methods require tools and data that are specific to one geographic scale and may not translate well from one geographic scale to another. Data sources that are most applicable to more coarse geographies (e.g., FAF, Transearch) do not translate to local levels, and local freight planning techniques are usually vehicle-based, are inextricably linked to land uses, and do not take into account the broad economic factors that drive freight movement. In addition, wide differences exist between the warehousing and distribution practices for different commodity types (e.g., the delivery process for a local food distributor versus a multistate distribution process for major retailers).

This research will bridge the gap created by the varied geographic scales used in freight planning by establishing a set of tools that can be applied to different geographies depending on need. These tools can be developed and defined by research into

- Freight and truck generation rates for different types of land uses and commodity types by trip type (local, long haul, drayage) and direction (inbound–outbound);
- Different practices for warehousing and distribution for various commodity types, geographic areas, and population densities; and
- Approaches to combine this information with data that are readily available on a broader geographic scale through existing industry sources in order to create planning and forecasting processes for up to four geographic scales.

Sample Research Initiative E is similar to Sample Research Initiative C and will build on that research effort. Sample Research Initiative C relates specifically to freight data, while Sample Research Initiative E involves enhancing analytic processes that build on previous and ongoing research in this area. Previous work related to this research effort includes *NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making* (Cambridge Systematics and GeoStats 2010); *NCHRP Synthesis of Highway Practice 384: Forecasting Metropolitan Commercial and Freight Travel* (Kuzmyak 2008); *NCHRP Report 606: Forecasting Statewide Freight Toolkit* (Cambridge Systematics et al. 2008); *NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand* (Cambridge Systematics 1997); and others. The multitiered planning and forecasting processes documented in National Highway Institute Course 139002: Uses of Multimodal Freight Forecasting in Transportation Planning (Federal Highway Administration 2010) can also provide direction for this effort.

The approach for this initiative involves research at four geographic levels:

1. Regional (e.g., mid-Atlantic region);
2. State (e.g., Pennsylvania);
3. Major metropolitan area (e.g., Philadelphia); and
4. Minor metropolitan area (e.g., Harrisburg).

In general, the research involves documentation of current freight planning practices for the types of areas listed above and research on freight activity (by all modes) within each geographic level, including special generators such as rail terminals and port facilities. The nesting of data for different geographic scales and the relationships between different data types for different scales would ideally be studied through a region–state–MSA hierarchy in a single state in a single region, as indicated with the Pennsylvania examples cited above. Internal links between generators and intermediate destinations (e.g., intermodal terminals and regional distribution centers) will be documented, along with links between these intermediate destinations and final freight delivery locations (e.g., retail establishments). Freight activity will be documented by mode, commodity, origin and destination (internal–internal, internal–external, external–internal, and through movements), and other pertinent characteristics for each geographic level. This effort will be carried out in close collaboration with the Sample Research Initiative C effort, as the final recommended research element of Sample Research Initiative C specifically ties to the four geographic levels described here.

An innovative element of this effort is the use of data resources that may not be used in traditional freight forecasting practices, such as state labor departments, economic development authorities, and similar public agencies. The development of data fusion tools, collective industry knowledge, and advanced technology (e.g., GPS data, RFID technology for inventory control) to support these efforts is a potential outcome of this research. Further efforts to link these data to existing data resources used in traditional planning practices (e.g., FAF Version 3, Transearch) are also envisioned as an outcome of this initiative.

Benefits and Expected Outcomes

- Document current freight planning and forecasting practices for different geographic levels, along with ongoing research related to potential enhancements of these practices;
- Provide a detailed view of freight planning and forecasting considerations for different geographic levels;
- Link enhanced data resources from Sample Research Initiative B to new or enhanced forecasting methods for different geographic levels;
- Develop new tools for linking disparate data resources not traditionally used for freight planning and forecasting;
- Establish a correlation between or supplement to local data (including nontraditional data) and commodity flow data available for broad geographic scales, including national data sources such as FAF and Transearch; and
- Develop methods for nesting local freight planning data and tools into those that are used for larger scales (i.e., development of local tools that function as subsets of national tools and data resources).

Implementation

Sample Research Initiative E implementation ideas and considerations are summarized in Table 4.5.

Other Considerations

Sample Research Initiative E relates to the following initiatives:

- The data collection and research effort for Sample Research Initiative C should be done in conjunction with the research for this initiative;
- This initiative, in conjunction with Sample Research Initiative C, can inform and support the research in Sample Research Initiative I;
- The data collection for this initiative will strongly inform the policy, planning, and programming efforts of Sample Research Initiative L;
- To the extent that this initiative results in improved and enhanced methods of freight forecasting, it can help inform the review and evaluation methods described in Sample Research Initiative B;
- In support of Sample Research Initiative H, this research can provide insight into other factors that influence freight transportation demand; and
- The pooling and standardization process described for Sample Research Initiative J should be considered for all data collected for this initiative.

Table 4.5. Sample Research Initiative E Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Research on current practices, tools, and data: Regional level (three regions).	9 months	$60,000	These projects can run concurrently; should be done in conjunction with Sample Research Initiative C to the extent possible.
Research on current practices, tools, and data: State level (10 states).	12 months	$125,000	
Research on current practices, tools, and data: Major MSA (10 MSAs).	12 months	$125,000	
Research on current practices, tools, and data: Minor MSA (15 MSAs).	12 months	$150,000	
Development of new tools for all four geographic areas, including the use of nontraditional data sources; should include links to current and newly developed national data sources.	24 months	$400,000	The previous four items must be completed before this part of the project begins.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The online freight data repository developed in California can provide some guidance on disparate data sources and fusion of data for this initiative.
- The Oregon SWIM2 model can be an ideal resource for a state-level data tool in this research effort.
- The modeling effort for the Mississippi Valley Region performed by the Center for Freight Infrastructure Research and Education at the University of Wisconsin–Madison offers insight on modeling freight in large geographic regions. Similarly, the PINGO and logistics models used in Norway's national and international freight transport forecasting process will be a useful resource for this initiative.
- The research effort *Generation of a U.S. Commodity Flows Matrix Using Log-Linear Modeling and Iterative Proportional Fitting* (Peterson and Southworth 2010) can inform the process for filling data gaps and nesting freight forecasting tools for different regional scales.
- *Transportation Research Board Special Report 304: How We Travel: A Sustainable National Program for Travel Data* (Committee on Strategies for Improved Passenger and Freight Travel Data 2011) recommends the organization of a national travel data program built on a core of essential passenger and freight travel data sponsored at the federal level and well integrated with travel data collected by states, MPOs, transit and other local agencies, and the private sector.
- Various research efforts presented at the Data Collection and Visualization Techniques session of the 2010 Innovations in Freight Demand Modeling and Data Symposium can provide insight into tour chaining and other freight activity on smaller geographic scales.

Sample Research Initiative F

Develop robust tools for freight cost–benefit analysis that go beyond financial considerations to the full range of benefits, costs, and externalities.

Description

Freight movement and logistics are significant components of the nation's economy and gross domestic product. Transportation agencies are looking for ways to better link transportation planning decisions with economic development and other factors, both costs and benefits. This research is aimed at helping to better understand and estimate the full range of monetary and nonmonetary freight costs and benefits in support of more informed decision making and analyses of policies, programs, projects, and investments.

The research objectives include the development of measures that can standardize the disparate costs and benefits for use in an overall cost–benefit analysis. This effort includes metrics such as congestion, air quality, employment, social equity, property value impacts, community livability, diversification of economic activity, system redundancy, and safety and security.

Several research efforts provide guidance on nonmonetary metrics related to freight transport. These include Shipper Willingness to Pay to Increase Environmental Performance in Freight Transportation (Fries et al. 2010) and Building Resilience into Freight Transportation Systems (Ta et al. 2010).

Benefits and Expected Outcomes

- Identify nontraditional components necessary for a comprehensive, holistic cost–benefit analysis;
- Document and include external benefits and costs in infrastructure investment decisions; and
- Garner support from a range of stakeholders, including those not directly involved in transportation, in the planning and decision-making processes for major transportation investments.

Implementation

Sample Research Initiative F implementation ideas and considerations are summarized in Table 4.6.

Other Considerations

Because this research effort does not relate to the highway capacity considerations of the SHRP 2 program as directly as others, this initiative should not be considered a top priority for early implementation. However, it can be pursued as a stand-alone research project because it does not directly affect other recommended initiatives.

Sample Research Initiative F relates to the following initiatives:

- Some of the data collected in Sample Research Initiatives C and I related to logistical practices may provide insight into additional factors outside the traditional cost–benefit measures that affect decisions in the freight transportation field.
- The interaction of freight and passenger transportation as documented in Sample Research Initiative G will likely yield some useful information about costs and benefits that go beyond traditional monetary factors and relate instead to issues of regional mobility for all types of users.
- When applicable, the portfolio of core freight data sources described in Initiative J should incorporate additional metrics developed in this initiative.
- The research documented in Sample Research Initiative H will likely include potential new performance measures and data resources beyond what has been traditionally used in freight planning and forecasting. When applicable, these metrics should inform this initiative.
- Sample Research Initiative K involves the use of freight data and tools for operational and design considerations related to bridge and pavement design. To the extent that this initiative includes nonmonetary factors such as safety and redundancy, those items should be incorporated in this research effort if applicable.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The performance measures used in the MOBILEC model documented in Innovative Freight Transportation Framework for Flanders (Maes and Ramaekers 2010) may offer some insight into this research effort;
- The research effort *Transportation Research Board Special Report 304: How We Travel: A Sustainable National Program for Travel Data* (Committee on Strategies for Improved Passenger and Freight Travel Data 2011) recommends the organization of a national travel data program built on a core of essential passenger and freight travel data sponsored at the federal level and well integrated with travel data collected by states, MPOs, transit and other local agencies, and the private sector; and
- Data used in various commodity-based and industry-based econometric models can serve as a basis for some nonmonetary metrics related to freight transportation (e.g., employment and production by industry type).

Table 4.6. Sample Research Initiative F Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Identify nonmonetary performance measures used in transportation planning efforts, particularly with regard to freight activity.	9 months	$75,000	Should include a global perspective for added benefit.
Develop nonmonetary performance measures and identify opportunities for inclusion in planning and project prioritization processes in five MPOs or state DOTs. Research will include documentation of standardized measures across all processes for these nonmonetary costs and benefits, if applicable.	12 months	$125,000	Will require converting multiple types of data into measurable quantities.

Sample Research Initiative G

Establish analytic approaches that describe how elements of the freight transportation system operate and perform and how they affect the larger overall transportation system.

Description

One of the challenges in freight transportation planning is identifying how local and regional freight operations are affected by passenger travel and land uses that potentially conflict with freight activity, and vice versa. Issues to be examined include the effects of trucking activity on congestion on the highway system during commuter peak periods, passenger and freight rail conflicts on shared rail alignments, and the effect of local ordinances limiting freight activity near certain types of land uses (e.g., residential, institutional).

The purpose of this research is to develop, pilot, and validate new analytic techniques to effectively integrate freight movement behavior with passenger movements. The intent of this research is to demonstrate the interaction and impacts of freight on the overall transportation system. The research needs to be sensitive to variations in long-haul shipping and local deliveries, as each relates to land use patterns, population density, and underlying (non-freight-related) congestion on the transportation system. This sample research initiative attempts to identify the relationship between freight activity and infrastructure and land use constraints related to competing transportation needs and land uses that do not complement intensive freight activity. These efforts will be accomplished through research into

- Decisions related to transport mode and route choice due to congestion on a freight transportation network;
- Relationships between population density and freight activity on local and regional levels;
- Changes in delivery schedules by time of day based on constraints during periods of peak passenger travel; and
- Variations in freight activity by time of day under local regulatory constraints (e.g., zoning ordinances restricting freight activity during overnight periods).

The research as it relates to the second and fourth items above will build on some of the temporal freight data documented extensively in Chapter 3 of *NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making* (Cambridge Systematics and GeoStats 2010).

The approach for this initiative involves research in three metropolitan regions of North America, with existing travel demand modeling tools in place that have been subject to peer review and have been used extensively for general transportation planning. The three regions include (1) a metropolitan area with freight movement activity associated with freight generators such as manufacturing and warehousing centers and port and rail terminals (e.g., Columbus, Ohio); (2) a metropolitan area where most of the freight activity is associated with local consumer demand (e.g., New York City); and (3) a metropolitan area that serves as a major freight hub even as it supports a sizeable local consumer market (e.g., Chicago or Los Angeles). The cities used as the basis for the research documented in *NCFRP Report 8* will be examined to determine their applicability to this effort; using these metropolitan areas will provide this research effort with an extensive array of GPS data.

Although the research documented in Chapter 3 of *NCFRP Report 8* was done using FHWA's Highway Performance Monitoring System and Vehicle Traveler Information System data, the present research is aimed at taking this type of base data and documenting the relationship between local trucking activity and local roadway congestion. A second element of this research involves a survey of business establishments in each of the three metropolitan areas to document how local congestion on the freight transportation system (primarily highway, but rail congestion will also be addressed) affects the business and operating decisions of shippers and carriers with respect to mode choice, operating hours, delivery processes, and routing. This research is qualitative by nature, but these business practices need to be quantified to the extent possible (e.g., "we start our driver shifts at 5:00 a.m. to avoid highway congestion" or "we use 30% more drivers today than we did 10 years ago due to increased congestion and fewer turns at the port terminals").

Work related to congestion pricing as it pertains to trucking may be applicable for this research, as well, such as Tolling Heavy Goods Vehicles: Overview of European Practice and Lessons from German Experience (Broaddus and Gertz 2008).

Benefits and Expected Outcomes

- Improved understanding of how freight movement affects the overall transportation system at a corridor, regional, or possibly larger geographic scale;
- Improved analytic tools enhance the ability to develop long-range transportation plans that meaningfully consider goods movement, especially in the evaluation of long-term needs and investment alternatives;
- Establish better coordination between transportation and land use planning;
- Provide improved means to evaluate alternative system capacity investment scenarios;
- Provide improved means to evaluate transportation operations, including ITS applications;

- Provide a means to enhance public–private mutual understanding and collaboration for freight planning and analysis;
- Support the development of meaningful transportation system performance measures.
- Develop common metrics for freight planning and modeling for similar geographic scales (when applicable);
- Develop an improved understanding of the intermodal freight movement; and
- Enhance understanding of reliability as a performance measure for freight movement.

Implementation

Sample Research Initiative G implementation ideas and considerations are summarized in Table 4.7.

Other Considerations

Sample Research Initiative G relates to the following initiatives:

- The data collection and research effort for Sample Research Initiative C should be done in conjunction with the research for this initiative, since they both involve research into the characteristics of individual businesses and industries;
- Some of this research can be used to inform the what-if scenarios described in Initiative D;
- Many of the tools and data resources included in Sample Research Initiative E would be applicable here; in fact, this initiative involves a refinement of freight data and tools to a geographic level that is needed for this effort; and
- This initiative is somewhat similar to Sample Research Initiative H, which is a macro-level analysis of factors affecting freight movement. This initiative involves a close look at how freight operations are affected by constraints on a local scale.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The data, processes, and outputs of the Oregon SWIM2 model can serve as a basis for developing similar metrics on different geographic scales.
- The synthetic generator development process used in the microsimulation work on baseline freight transport conditions in the Mississippi Valley Region offers interesting insight into filling data gaps. In addition, this project can be refined or expanded to different geographic scales and enhanced by the research proposed in this initiative.
- Some of the data used in Analysis and Multi-Level Modeling of Truck Freight Demand (Wang et al. 2010) can provide insight into the correlation between truck volumes and economic and demographic factors for some geographic scales.
- The direct and peddling research described in Modeling Commercial Vehicle Daily Tour Chaining (Ruan et al. 2010) may help fill data gaps for local truck trips at smaller geographic scales.
- The research paper Freight Demand Modeling Using Econometric Models (Vilain and Muhammad 2010) indicates that factors such as inventory levels, industrial production, and local employment have a strong correlation to freight movement as it relates to truck shipments.

Sample Research Initiative H

Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics.
Document economic and demographic changes related to freight choices.

Description

Freight movement is part of a complex supply chain involving the movement of raw materials and products from a source to

Table 4.7. Sample Research Initiative G Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Documentation of freight activity, land uses, and highway data for three types of metropolitan area.	18 months	$300,000	na
Qualitative research of business establishments in these same three metropolitan areas (assume 50 business establishments per area).	18 months	$150,000	na
Statistical analysis of correlation factors between freight activity, congestion, coping strategies, and other measures implemented by various industries.	9 months	$100,000	na

Note: na = not applicable.

a point of consumption or to an intermediate point for manufacturing or distribution. The characteristics of this supply chain are heavily influenced by economic factors such as access to labor, markets, transportation infrastructure (various modes), and capital.

This research topic involves the development of correlating factors between market conditions for consumption and production and their impact on freight movement for different commodities. In addition, the economic benefits of freight activity and the relationship between freight movement and land use needs and decisions will be explored. This research is built on current principles and practices in econometric modeling, with additional research into factors beyond population and labor (i.e., age and income-based modeling and other demographic factors). This research also includes a variation of econometric modeling to assess economic and demographic changes that may result from decisions by shippers and carriers related to site selection, operations, and other considerations.

This effort can be informed by recent and ongoing research related to local trip generation, land use, and zoning, such as *NCHRP Synthesis 298: Truck Trip Generation Data* (Cambridge Systematics and Jack Faucett Associates 2001) and *NCFRP Project 25: Freight Trip Generation and Land Use* (Holguín-Veras 2011). However, the aim of this research is to go beyond traditional factors related to freight movement in terms of land use, industry types, and other issues. One key outcome of this effort will be the documentation of the economic benefits of freight activity related to various industries rather than the impacts of freight activity on infrastructure. The industrial real estate development and brokerage communities will likely serve as good sources of information for this research.

Benefits and Expected Outcomes

- Establish correlating coefficients and analytic tools that can be applied to regional and state transportation plan development;
- Enhance existing econometric models to reflect additional factors that drive freight transportation demand;
- Provide supporting data to enhance cost–benefit analysis tools for infrastructure investment decision making; and
- Support more robust analyses of alternative investment scenarios by including economic development and land use considerations.

Implementation

Sample Research Initiative H implementation ideas and considerations are summarized in Table 4.8.

Other Considerations

Sample Research Initiative H relates to the following initiatives:

- The Sample Research Initiative L research effort involving industrial real estate should be done in conjunction with this initiative;
- Some of the data refinement in the Sample Research Initiative I research effort may relate to this initiative for subregional levels;
- The results of this effort can inform Sample Research Initiative E; and
- The passenger travel characteristics of Sample Research Initiative G may provide some demographic data to support this initiative.

Table 4.8. Sample Research Initiative H Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
In-depth research of industrial real estate sector and factors related to site selection and facility development, including access to labor, transportation infrastructure, and tax incentives. This research should include manufacturing, distribution, and transportation subsectors for 12 to 15 different industries.	12 months	$125,000	Should be done in conjunction with similar industry research described in Sample Research Initiative L.
Research of 25 to 30 industrial sites that have been developed within the past 5 years, documenting economic benefits (e.g., wages and primary and secondary economic activity, tax revenues) for local and regional areas. Demographic changes (e.g., age cohorts and migration patterns) related to these industrial developments should also be documented.	18 months	$150,000	The research described in the previous item should be completed before this research begins.

In addition to NCFRP Project 25, ongoing innovations in the freight planning and forecasting practice that can inform and support this initiative include the following:

- The Oregon SWIM2 model contains a wealth of information related to labor, land development characteristics, industry sectors, household income and size categories, labor and service occupations, and land use types that all relate strongly to this initiative;
- The factors detailed in the Analysis and Multi-Level Modeling of Truck Freight Demand (Wang et al. 2010) are income, population, and numbers of business establishments, all of which can provide insight into this initiative;
- The MOBILEC model described in Innovative Freight Transportation Framework for Flanders (Maes and Ramaekers 2010) offers an abundance of information for factors that drive freight demand; and
- The PINGO and logistics models in A Model System for Forecasting National and International Freight Transport in Norway (Hovi and Hansen 2010) should be reviewed for this initiative.

Sample Research Initiative I

Develop freight data resources for application at subregional levels.

Description

A major breakthrough for freight data analysis and modeling will be the ability to conduct meaningful analyses at small geographic levels that are not currently supported by national-level or large metropolitan area data sets. This research includes the refinement of these current data sources or development of new data sources on smaller geographic scales (e.g., by county, municipality, or zip code). In addition, this research incorporates existing and emerging freight-related data to include permitting data, WIM data, license plate reader data, toll agency data, Highway Performance Monitoring System traffic count data, and others. All of these resources are to be measurable at the local and corridor-specific levels.

This research identifies the data currently collected by state and local jurisdictions and recommends standard formats for consolidating these currently unlinked data sources so that collectively they can provide reliable assessments of freight movement at a more refined granular geographic level.

This research will build on applicable efforts recently documented in *NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making* (Cambridge Systematics and GeoStats 2010), specifically as they pertain to local decision-making needs. In addition, the tour-based commercial vehicle model used in Calgary, Alberta, documented by Kuzmyak (2008) in *NCHRP Synthesis of Highway Practice 384: Forecasting Metropolitan Commercial and Freight Travel,* is a useful reference for the types of local data that support freight forecasting efforts on a small geographic scale.

Benefits and Expected Outcomes

- Identify disparate sources of data that exist but are not used for modeling freight movements;
- Develop recommendations for refinement and augmentation of existing public data resources (e.g., FAF, CFS, U.S. Census Bureau) and private data sets (e.g., Transearch) to address gaps in data and enhance or supplement these data sources to support analytic tools on smaller geographic scales;
- In conjunction with the efforts described for Sample Research Initiative J, provide guidance to all states and local jurisdictions on acceptable data formats that will facilitate data incorporation into local freight models and allow for transferability of data across institutional and jurisdictional boundaries;
- Establish methods for local agencies to fill gaps in data and create placeholders for freight data that they may not collect currently but plan to incorporate in future freight forecasting methods; and
- Improve understanding of local freight activity that is not captured accurately in national and regional data sets (including local distribution, touring, and intermodal transfers).

Implementation

Sample Research Initiative I implementation ideas and considerations are summarized in Table 4.9.

Other Considerations

Sample Research Initiative I relates to the following initiatives:

- The proposed research in Sample Research Initiative C will be critical in identifying real-world logistics practices that are not accurately reflected in data sets, as well as planning tools that are geared toward large geographic scales;
- The extensive data collection effort in Sample Research Initiative D would be an ideal source of information to document the influence of local deliveries and logistics practices on freight flows;
- The data collected in this effort can inform the integration of logistics practices and policy and programming decision making as described in Sample Research Initiative L;
- This initiative can help inform the review and evaluation research documented in Sample Research Initiative B;

Table 4.9. Sample Research Initiative I Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Review of current practice, including national survey of state DOTs, local and regional governments, and other agencies to identify data sets currently used in freight planning and forecasting; a key element of this effort is to document methods currently used to disaggregate national and regional data and methods used to fill gaps through local data collection efforts.	12 months	$250,000	Assumes 15 states, 45 MPOs and local and county governments, and 10 other agencies, including toll authorities and port authorities.
Develop recommendations for data collection at county, municipality, and zip code levels to support enhanced forecasting and modeling capabilities. Identify potential improvements in disaggregation methods (if applicable) for current national and regional data resources.	9 months	$150,000	Must wait for completion of previous item in this initiative. Should be done in conjunction with other initiatives as described below.
Develop improved methods in combining commodity flow data on large geographic scales with local data related to distribution, touring, and intermodal transfers.	18 months	$300,000	Related closely to Sample Research Initiative C.

- This research area relates strongly to Sample Research Initiative E. This effort involves the collection, aggregation, and disaggregation of data, while Sample Research Initiative E is a similar effort related to methods and tools; and
- The results of this research should support and inform the research effort in Sample Research Initiative J.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- The Oregon SWIM2 model can be an instructive example of an application of local data resources to planning and forecasting efforts.
- The microsimulation work on freight transport in the Mississippi Valley Region has some valuable insight into the process of refining data to local levels and filling data gaps.
- The data gap closure process documented in a recent research effort by the Oak Ridge National Laboratory, *Generation of a U.S. Commodity Flows Matrix Using Log-Linear Modeling and Iterative Proportional Fitting* (Peterson and Southworth 2010), should inform this initiative.
- *Transportation Research Board Special Report 304: How We Travel: A Sustainable National Program for Travel Data* (Committee on Strategies for Improved Passenger and Freight Travel Data 2011) recommends the organization of a national travel data program built on a core of essential passenger and freight travel data sponsored at the federal level and well integrated with travel data collected by states, MPOs, transit and other local agencies, and the private sector.
- The small geographic scale of the research effort described in Modeling Commercial Vehicle Daily Tour Chaining (Ruan et al. 2010) would be applicable to this research.
- Several recent research efforts that could provide insight into metrics, indicators, and methods for developing local data include A Bayesian Hierarchical Network for Truck Demand Modeling (Boile et al. 2010) and Freight Demand Modeling Using Econometric Models (Vilain and Muhammad 2010).
- Various research efforts presented at the Data Collection and Visualization Techniques session of the 2010 Innovations in Freight Demand Modeling and Data Symposium can inform this research.

Sample Research Initiative J

Establish, pool, and standardize a portfolio of core freight data sources and data sets that supports planning, programming, and project prioritization.

Description

This research initiative recognizes that varied sources of freight data are used by planners and state DOTs. It also recognizes that the use of freight data for analytic, planning, and decision-making purposes is far more of a hodgepodge than a uniform approach. The research for this initiative is built on the following assumptions:

- Flexibility in data sources and analytic methods remains important to individual jurisdictional needs and requirements;
- The general myth that private sector freight data are unattainable can be substantially debunked through the development of some common or core data sets;
- The benefits of this research will be substantially greater than its cost because fewer MPOs and state DOTs will duplicate efforts; and
- The development of web-based data resources will be an ideal mechanism for sharing and disseminating data.

This research is timely because government agencies are operating under unprecedented fiscal austerity that will likely become even greater. Data collection is typically viewed as expensive and discretionary. This research in effect becomes an intelligent way of pooling resources nationally rather than continuing a fragmented approach to data collection. The organization of this research must include a wide cross-section of private and public sector users and data suppliers in the process.

A solid foundation for this effort has already been established through the recently published *NCFRP Report 9: Guidance for Developing a Freight Transportation Data Architecture* (Quiroga et al. 2011). The recommendations and specifications of that report will serve as the basis of this research effort, specifically with regard to its three-tiered (single-application, intermediate, and holistic) approach for developing a national freight data architecture. This effort will also include research into existing electronic data interchange protocols and processes used in freight transportation (e.g., ANSI 856 Ship Notice/Manifest).

Benefits and Expected Outcomes

- Improved and more reliable analytic results;
- Greater efficiency and cost-effectiveness of planning and analysis;
- Opportunity to overcome some of the perceived barriers related to data availability;
- Improved understanding of processes in individual industries and their impact on freight demand at different geographic levels;
- Improved understanding of the relationships between businesses and industries;
- More comprehensive understanding of issues related to full supply chains (as opposed to discrete freight movements); and
- Elimination of costly freight data redundancies.

Implementation

Sample Research Initiative J implementation ideas and considerations are summarized in Table 4.10.

Other Considerations

This research effort should be considered for immediate implementation for several reasons: the extent of the need, the long timeline for some of its elements, and the extensive availability of data from a myriad of sources that can be used to inform the process. The recommendations documented in *NCFRP Report 9* (Quiroga et al. 2011) should be a springboard for early action items.

Table 4.10. Sample Research Initiative J Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Development of data architecture standards for five applications following the single-application approach documented in *NCFRP Report 9.*	18 months	\$150,000–\$400,000	na
Development of data architecture standards for 10 to 15 applications following the intermediate approaches (documented in *NCFRP Report 9*) that can be implemented to address existing needs.	24–60 months	\$1.5 million to \$3 million, depending on complexity of process	Should incorporate research in single-application approach.
Ongoing development of data architecture standards for a holistic approach (documented in *NCFRP Report 9*) aimed at oversight of application development for the purpose of ensuring compatibility even while single-application and intermediate approaches may require flexibility.	Ongoing	\$1.5 million to \$2 million annually	na

Note: na = not applicable.

This initiative does not directly relate to other initiatives in terms of its detailed recommendations, but all of the other recommended research areas should be executed with the awareness that this data standardization process is also under way and will likely have an evolving influence over all research areas involving freight data and tools.

Ongoing innovations in freight planning and forecasting practice that can inform and support Sample Research Initiative J include the following:

- The Online Freight Data Repository for Freight Modeling and Analysis developed by the University of California at Irvine can inform this research; and
- Various research efforts presented at the 2010 Innovations in Freight Demand Modeling and Data Symposium that involve data fusion and the use of private sector data to support planning and vehicle routing analyses will advance this initiative.

Sample Research Initiative K

Develop procedures for applying freight forecasting to the design of transportation infrastructure, particularly pavement and bridges.

Description

Freight movements have unique characteristics and infrastructure needs. Often these needs are not fully considered in infrastructure design, particularly with regard to pavement and bridge design. Procedures and processes to integrate true freight forecasting into this design will ensure that current and near-term projects will not become future freight constraints. Research includes collecting best practices for considering freight needs in the design, construction, operations, and maintenance of roadway infrastructure.

The research efforts in this initiative involve documenting the role of truck weight and volumes in pavement and bridge design among public agencies in the United States and abroad, along with the role that forecasting tools play in the design process. Design vehicles, current and projected volumes, and oversized load considerations will be examined. The focus of this effort is to bring freight planning tools and data into the design process for pavement and bridges.

The recommended approach for this research includes an initial survey of highway departments and toll authorities, with detailed documentation of how these agencies incorporate truck activity into the design and maintenance of their infrastructure. The primary design parameters to be included in this effort include truck volumes and vehicle weight, length, height, and axle configuration.

This research will build on ongoing developments in GPS tracking and asset management for truck fleets, along with existing WIM, permit, and routing data. Collaboration with private industry for vehicle configuration and weight data (when possible) is crucial to the success of this effort.

Benefits and Expected Outcomes

- Document the role of truck size and weight characteristics in the planning, design, and maintenance of highway infrastructure across an array of different agencies;
- Identify design parameters for which changes in future truck activity, measured in terms of increased truck volumes, or changes in truck sizes, or changes in load characteristics (i.e., full trucks versus empty trucks), can influence life cycles and design standards; and
- Identify ways to incorporate freight planning tools and data into the planning, design, and maintenance of highway infrastructure.

Implementation

Sample Research Initiative K implementation ideas and considerations are summarized in Table 4.11.

Other Considerations

Because this research effort does not directly relate to future highway capacity considerations of the SHRP 2 program and is oriented toward design considerations more than planning and forecasting, this initiative should not be considered a top priority for early implementation.

Sample Research Initiative K relates to the following initiatives:

- Some of the research related to Sample Research Initiatives E and I, particularly the refinement of data and tools to local and corridor levels, should support and inform this research;
- The standardized pool of freight data developed in Sample Research Initiative J should serve as the basis of the programmatic elements of this research track;
- To the extent that this research effort involves nonmonetary design considerations such as safety and redundancy, the results should inform Sample Research Initiative F; and
- Life-cycle costs related to functional obsolescence, as described in Sample Research Initiative L, should inform this research if applicable.

Because this research area requires some degree of coordination with other initiatives described in this SHRP 2 C20 research program, the final three research projects described

Table 4.11. Sample Research Initiative K Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Survey of highway and toll authorities across the United States to document current practices in bridge and pavement design and maintenance standards (assume a maximum of 60 agencies surveyed in all).	9 months	$125,000	These projects can run concurrently.
Survey of best practices among transportation departments internationally (assume data collected from 15 to 25 international agencies).	9 months	$100,000	
Documentation of freight planning tools and data that can be used in the design and maintenance process for bridges and pavement and development of programmatic tools for incorporating other tools and data into the design and maintenance processes (including those described for future development in this SHRP 2 C20 research program).	12 months	$200,000	Must be done after previous two projects in this initiative are complete.

here should be done after the other initiatives mentioned above are well under way.

Ongoing innovations in freight planning and forecasting practice that can inform and support this initiative include the following:

- Research efforts related to truck demand and route choice modeling; and
- The use of electronic data collection to calibrate truck models; and
- Other efforts using truck data for planning and forecasting truck activity by region and roadway segment.

Sample Research Initiative L

Advance research to effectively integrate logistics practices (private sector) with transportation policy, planning, and programming (public sector).

Description

There is a substantial disconnect between private and public sector decision making related to the movement of goods and the infrastructure that supports those activities. This research builds on the behavior-based freight research documented in Sample Research Initiative C and attempts to integrate the real-world supply chain management practices of the private sector with the policy and planning decision making of the public sector. Although it is unrealistic to expect that the timelines and planning horizons of the public and private sectors will be fully harmonized in an effective manner (public sector planning horizons are typically years or decades in length, but the decision-making needs of private industry can change almost on an hourly basis), a thorough understanding of the decision-making needs of both private and public sectors enhances the interests of both. Once these needs are identified, regional, state, and MPO planning capabilities (and resources) to meet those needs must then be assessed.

This research is an initiative to determine areas of mutual benefit for improving data and planning tools across public and private sectors and to develop ideas for planning processes to incorporate actual supply chain management processes and logistics decisions to the extent possible. The research includes answers to why, how, when, where, what, who, and how much in order to bridge the gap between how shippers and carriers operate on a short-term basis and what the public sector needs to make decisions, taking into account that decision making often requires years of planning. Recommendations for streamlining public sector decision-making processes are beyond the scope of this effort, but the research will yield interesting ideas about approaches to public sector planning and programming efforts that include phased implementation, interim short-term improvements in place of costly long-term investments, and conditional approvals.

NCHRP Report 594: Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes (Cambridge Systematics et al. 2007) will serve as a foundation and an instructional guide for this sample research initiative.

The areas included in this research and some of the pertinent questions related to these areas are as follows:

- Real estate—What are the standard time lines for private sector investments in real estate that are related to freight activity, including port and rail terminals, distribution centers, and truck terminals and hubs? What are some of the variations among different types of ownership and operating arrangements, including site selection, modifications of existing facilities versus construction of new facilities, and build-to-suit versus "spec" buildings?

- Facility operations—What are some of the ongoing changes in facility operations that extend the useful life of existing facilities or result in dramatic changes in off-site impacts? What are some of the factors that drive functional obsolescence of facilities far in advance of physical depreciation of these assets, and what are the life-cycle implications of these factors? Examples of these factors include port and rail terminal hours of operation, the gradual transformation of warehouses (focused on product storage) to distribution centers (focused on load consolidation and distribution, with accompanying reductions in on-site product inventory), and other improvements in the efficiency of facility operations.
- Vehicles and vessels—This research area includes freight rolling stock, such as trucks and rail cars, in addition to freight vessels (including barges). How have the dimensions of these various elements of the freight system changed over time, and what are the implications of these changes with regard to roadway design, bridge height and weight limits, channel depth, and other infrastructure considerations? How frequently do these elements of the system change relative to the life cycles of the accompanying infrastructure? What are the life cycles of these vehicles and vessels, and how quickly do different types of carriers change their fleet management decisions to reflect changing business conditions?
- Infrastructure—What are the time lines for various types of infrastructure improvements, including roadway and rail rehabilitation, new construction of these types of facilities, channel deepening, and other major infrastructure development? What potential changes should be made in the permitting and approval processes for these elements to provide short-term or conditional capacity enhancements to reflect the needs of private industry as documented in the above items?

Benefits and Expected Outcomes

- An understanding of the investment cycles for different elements of the freight transportation industry, including shippers, carriers, and public agencies, encompassing decision-making cycles for land use, facilities, and infrastructure;
- A detailed view of operational, rolling stock, and supply chain decisions that may change on a short-term basis to reflect private sector needs;
- Documentation of potential inefficiencies in the freight transportation system related to the disparate decision-making cycles of the public and private sectors; and
- Development of potential approaches through which public agencies can implement short-term or interim measures to reflect the changing, dynamic needs of the private sector.

Implementation

Sample Research Initiative L implementation ideas and considerations are summarized in Table 4.12.

Table 4.12. Sample Research Initiative L Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
In-depth research of the industrial real estate sector and the key decision cycles for site selection and facility development.	12 months	$90,000	Include manufacturing and warehousing subsectors.
In-depth research of industrial facility management issues and key issues related to facility operations and functional obsolescence.	12 months	$90,000	Include manufacturing and warehousing subsectors.
In-depth research of the freight transportation sector, including history of vehicle and vessel size characteristics, asset replacement cycles, and impacts of these issues on freight transportation infrastructure.	9 months	$60,000	Include truck, rail, and marine transportation (ship and barge) subsectors.
In-depth research of transportation infrastructure planning and implementation horizons, along with development of potential short-term measures to address dynamic changes in private sector needs.	12 months	$125,000	Include manufacturing and warehousing subsectors.

Other Considerations

Sample Research Initiative L relates to the following initiatives:

- The research efforts in this initiative can be conducted in conjunction with the behavior-based freight movement research described in Sample Research Initiative C;
- The mode shift analyses described in Sample Research Initiative D may inform this research effort to a small degree; and
- The relationship between public sector and private sector decision making in this initiative can support and inform the analytic approaches of Sample Research Initiative G.

Ongoing innovations in freight planning and forecasting practice that can inform and support this research include the following:

- Some of the recent and ongoing research in tour chaining and local logistics practices can be of some use in documenting decision-making cycles for different industry groups; an example of this research is Modeling Commercial Vehicle Daily Tour Chaining (Ruan et al. 2010);
- The Innovative Freight Transportation Framework for Flanders (Maes and Ramaekers 2010) may serve as a good starting point for some of the logistics practices in this initiative;
- Additional insight into logistics practices to inform this research may be found in A Model System for Forecasting National and International Freight Transport in Norway (Hovi and Hansen 2010);
- The modeling process documented in A Firm-Based Freight Demand Modeling Framework Capturing Intra-Firm Interaction and Joint Logistic Decision Making (Guo and Gong 2010), which is based on business establishment activity, may provide good information about decision-making cycles across different industries in the private sector; and
- The interaction of importers, exporters, and other transshipment activity, as described in A Hybrid Microsimulation Model of Urban Freight Travel Demand (Donnelly et al. 2010), may also be informative for this research initiative.

Sample Research Initiative M

Develop visualization tools for freight planning and modeling through a two-pronged approach of discovery and addressing known decision-making needs.

Description

Visualization tools provide a powerful means of communicating complex concepts and data. This research is aimed at providing analysts with tools for managing data (discovery) in an organized and intuitive way to make freight information more accessible, understandable, and usable. In addition, this effort seeks to apply visualization techniques to provide a sensible platform for developing more robust forecasting models, while communicating concepts and analyses to decision makers. A general need for the freight planning and forecasting industry is the enhancement of computer science skills related to graphic presentation.

The nature of the freight transportation process across different geographic scales lends itself well to a geographic information system platform for visualization. An innovative element of this research involves developing standard visualization techniques and tying them to improved web access to data for different geographic levels. Private companies such as Esri that already develop products for a multitude of clients will be good partners and research champions, along with other private sector firms that develop tools to meet their own internal needs.

This initiative includes the use of gaming technologies and methods as part of learning systems to address knowledge and skill deficits in freight planning and modeling. Existing tools and methods currently being applied in all levels of education (e.g., Epistemic Games at the University of Wisconsin–Madison and the Virtual Construction Simulator at Penn State University) are examples of ongoing developments that may be applicable to this field.

Benefits and Expected Outcomes

- Fostering of a strong interest among data visualization and user interface experts currently applying their skills in other industries to bring their talents to bear on freight demand modeling and data to assist this industry with seeing, understanding, and communicating;
- Application of visualization tools and techniques systematically across other appropriate research initiatives in this effort to enhance their effectiveness and promote unconventional thinking;
- Use of visualization as a common language to promote a greater understanding and more productive dialogue among modelers, planners, researchers, the private sector, and other stakeholders; and
- Incorporation of visualization techniques to evaluate innovative freight demand models.

Implementation

Sample Research Initiative M implementation ideas and considerations are summarized in Table 4.13.

Other Considerations

Sample Research Initiative M directly influences and supports all of the other research documented in this plan to

Table 4.13. Sample Research Initiative M Implementation

Products or Projects	Time Required	Estimated Costs and Resource Opportunities	Other Implementation Perspectives
Survey of visualization techniques in other industry sectors and elsewhere in the transportation planning and operations field.	12 months	$125,000	Gaming technologies and methods may be of great interest here.
Develop a guide of applicable visualization techniques for freight forecasting and modeling that go beyond traditional pie charts and two-dimensional graphs.	18 months	$400,000	na
Provide visualization support to other ongoing research efforts, including the initiatives documented in this plan.	Continuous	$200,000 annually	na

Note: na = not applicable.

some degree, as enhanced visualization techniques would be valuable assets for all of them. This initiative should be considered for early action and conducted in parallel with the others to the extent possible, with a process in place to regularly inform the other research teams of progress, developments, and innovations in visualization. The relationship between Sample Research Initiative M and Sample Research Initiative A is particularly important, since training in the use of visualization tools (as well as the development of such tools) should be considered among the training and education needs in Sample Research Initiative A.

Some ongoing innovations in the freight planning and forecasting practice that can inform and support this initiative include the following:

- A number of visualization elements of the Oregon SWIM2 model could inform this research and
- The various commercial vehicle touring research efforts presented at the 2010 Innovations in Freight Demand Modeling and Data Symposium could inform this research and could be enhanced through visualization tools that help describe route choices, congestion impacts, bottlenecks, time-of-day variations, and other factors.

Future Directions

This section highlights future directions for building momentum beyond the completion of this SHRP 2 C20 report. This road map provides a broad direction and an organizing process for sustaining innovation in freight planning and modeling. The approach is designed to address the wide range of opportunities and needs that have been identified to date and expressed broadly by the seven strategic objectives.

The future directions build on a strong foundation of the SHRP 2 C20 project accomplishments, including

- Fostering interest among the freight community based on extensive outreach and engagement of public and private freight stakeholders;
- Documenting freight decision-making needs, particularly those of state DOTs and MPOs;
- Piloting a successful Innovations in Freight Demand Modeling and Data Symposium with national and international participation to spur breakthrough thinking and innovative ideas; and
- Developing an initial set of sample research initiatives validated by freight stakeholders.

Organizing Concept: Global Freight Research Consortium

SHRP 2 C20's project leadership stressed that the future directions should not include an inflexible bureaucratic organization or cumbersome administration. Rather than establishing a program as part of a government organization, the organizing concept lays out a flexible mechanism—an agile, collaborative framework—for achieving the strategic objectives.

To meet this expectation, a Global Freight Research Consortium (GFRC) is recommended. This consortium would promote research through funding agencies and others having a stake in improved freight system performance and decision making supported by enhanced analytic approaches. Participation would be voluntary, attracting those sectors that have a stake in the achievement of the strategic objectives.

This peer-based consortium would enable, fund, and promote research, supported through national and international public organizations, together with private organizations whose efforts serve the freight transportation sector.

The member organizations will include public domestic agencies, modal and other associations, universities, and the transportation research entities of other countries. It is also envisioned that the private sector will participate in the GFRC. Firms such as Con-way, Wal-Mart, EXCEL Logistics, FedEx, and UPS also have a stake in the research innovation that the consortium will promote. Table 4.14 summarizes the organizational mix that will potentially represent the core of the consortium.

Table 4.14. Illustrative Organizations for GFRC Participation

Agency	Role and Focus Area
TRB cooperative research programs (e.g., NCFRP, NCHRP)	Funding applied research on freight modeling and data; integrating existing separate research tracks with freight
TRB, Second Strategic Highway Research Program (until March 2015)	Sponsoring innovation symposia; funding development of training and outreach materials suggested by the future directions
U.S. DOT modal administrations (e.g., Federal Highway Administration [FHWA], Federal Railroad Administration)	Supporting pilots of advanced freight demand models
U.S. DOT intermodal organizations (e.g., FHWA, Research and Innovative Technology Administration, Bureau of Transportation Statistics)	Improving and expanding freight data resources
Academic institutions and university transportation centers	Funding and conducting basic research on freight models and data collection and fusion; pooled fund consortia
Associations such as the American Trucking Association	Networking work and priorities of GFRC to industry and modal operators and carriers
State DOTs and MPOs	Piloting and application of research
Private sector	Improving and expanding freight data resources; identifying advances in freight transportation technology and business practices for future research

This partnership will support independent research and reward innovative and compelling investigations and experiments by sponsoring an annual research competition spanning various research tracks and providing a seed-grant award. Establishing and maintaining the GFRC will require careful planning.

- Investigate the appropriate governance model (e.g., foundation, institute, charity) for the GFRC and completing its charter;
- Perform outreach to possible member organizations to promote participation;
- Obtain public and private start-up funding as appropriate;
- Secure the services of a qualified consultant to assist in the early organizing and start-up activities of the GFRC, which could include developing a draft GFRC work program, organizing additional research idea competitions, holding annual competitions for grants, and facilitating the first few GFRC meetings; and
- Regularly restructure and renew the governance model to ensure an entrepreneurial approach and genuine innovation.

The SHRP 2 C20 Technical Expert Task Group participated in a facilitated discussion to help frame the future directions. That consensus-building exercise helped establish basic definitions and parameters for the GFRC, including what the consortium should and should not be, as seen in Table 4.15. These important attributes are documented for reference as this initiative goes forward.

Global Freight Research Consortium: A Win–Win Proposition

The GFRC provides an effective means for public–private–academic collaboration on freight modeling and planning with abundant benefits for all participants. Further, these benefits can be accomplished without creating another formal organization bureaucracy. The consortium's power is one of influence: it brings together those with a shared stake in greater innovation and successful implementation of new forecasting and analytic tools. The wins may differ by organization or sector, but they include the following:

- Improved infrastructure investment from a freight transportation perspective;
- Achieving a global perspective that reflects freight's global dimensions;
- Improved performance of the transportation system over time as a result of better investment decisions;
- An opportunity to validate research from the standpoint of its utility to the freight industry;
- An opportunity to gain a better mutual understanding of the analytic needs of the public and private sectors and how they intersect;
- An opportunity to validate any research or tools from a practitioner standpoint;
- Greater understanding of freight movement requirements and performance criteria and how any new analytic tools must reflect such key factors; and
- An opportunity to shape the knowledge and skill requirements for employees in public and private organizations and to influence the instructional focus for universities.

Table 4.15. Defining the Global Freight Research Consortium

What the GFRC is	What the GFRC is not
• More innovation • Nonlinear progress • Mechanism similar to National Academies • All relevant research funders at the table • Mechanism to broadly diffuse the research agenda • Way to seek resources • Vehicle to attract participants and one or more champions • Methods to stimulate innovative ideas and research and assessment of who is capable of pursuing less conventional methods • An approach for infusing freight modeling efforts with knowledge, innovation, and capacity building • Bridge to greater public and private understanding of system development needs • Framework to broadcast information and ideas • Living, dynamic, experimental, and evolutionary • Window on other fields that might be able to provide input • Explicit—not implied—international outlook and focus • Momentum builder, viral • Bridge between private sector and public sector freight planning	• A research program • A single university transportation center–run research program • Centralized • A formal organization with a governing body • A governance program • Concentration on one or a few projects that narrow the scope • A predefined end product • A Procrustean bed (an arbitrary standard to which exact conformity is forced) for ideas or processes • Hosted by an academic organization (although academic institutions will participate in the GFRC)

Innovations in Freight Demand Modeling and Data Symposium: A Foundation for Moving Forward

The successful Innovations in Freight Demand Modeling and Data Symposium held in September 2010 provided a solid foundation for future efforts. The symposium's success rested on several factors:

- The symposium provided a low-cost approach to generating a variety of research concepts;
- The competitive nature of the symposium generated numerous excellent ideas and promising research concepts;
- The symposium brought together academic, private sector, and public sector perspectives; and
- The symposium fostered a greater shared understanding of the issues and requirements for improved freight modeling and planning.

Future symposia may have a different focus or emphasis area, but the principles of collaboration, competition, and communication represent significant building blocks for successful symposia.

The Innovations in Freight Demand Modeling and Data Symposium was held in Herndon, Virginia, with about 50 in attendance. The symposium featured 18 presentations selected to address the challenge of developing the next generation of freight demand models (symposium materials are available at www.trb.org/Main/Blurbs/167629.aspx). A monetary award was presented to Tetsuro Hyodo, Tokyo University of Marine Science and Technology, for the top presentation.

The symposium model was characterized by a combination of modeling data and ideas presented by U.S. and international practitioners and academics, followed by open and direct dialogue and debate. Major needs identified during the symposium include the following:

- A priority need to include international research addressing the macro view of global freight and its impact on multimodal freight traffic;
- A need to share unfettered domestic and international research; and
- A need to weave data, modeling, and knowledge (and terminology) within the public infrastructure modeling and policy view, as well as private sector logistics and distribution forecasting efforts.

In short, the successful Innovations in Freight Demand Modeling and Data Symposium provided a strong foundation for moving forward in the following ways:

- Generated ideas;
- Attracted international attention and participation;
- Resulted in the identification of several promising areas of research; and
- Provided a forum for public and private sector stakeholders, as well as university researchers.

Global Freight Research Consortium Initiatives and Focus Areas for Achieving Strategic Objectives

This section briefly describes six major activities or initiatives that the GFRC would address as part of its overall approach to achieving the strategic objectives. The list is by no means exhaustive, recognizing that the ultimate activities of the consortium will be determined based on the combined interests and priorities of the participants.

Each of the six major initiatives is briefly defined below and is followed by a bullet list of actions to advance that initiative.

Define Priority Research Issues

The GFRC will periodically issue a list of research priority areas based on submissions to GFRC-sponsored calls for ideas, similar to the process followed for the 2010 Innovations in Freight Demand Modeling and Data Symposium. Defining research focus areas that reflect the decision-making needs of state DOTs and MPOs in relation to freight planning, policy making, and project development will be of particular importance. Ideally, these research focus areas will reflect a dynamic communication and consensus building between the private and public sectors, both on the GFRC and between state DOTs and MPOs with the freight industry, and with international practitioners, as well.

Actions

- Establish the initial set of problems or research issues demanding attention;
- Publish and widely distribute a call for ideas; and
- Communicate the submission format approach standards and the incentives or awards being made available.

Provide Recognition and Incentives to Spur Breakthroughs

The 2010 Innovations in Freight Demand Modeling and Data Symposium confirmed that recognition and a nominal financial award are powerful inducements for generating ideas. The GFRC is encouraged to recognize the value in continuing to offer awards and recognition, particularly for meritorious research ideas with potentially breakthrough solutions. Non-financial recognition is also important. Efforts will be made to promote this process to the greatest extent possible as a way of doing business for the GFRC.

Actions

- Establish initial sources for the first call for innovative ideas;
- Consider establishing GFRC following a foundation model to provide a basis for contributions for funding awards, prizes, and related activities; and
- Over time, as funding for awards increases, establish multiple categories and multiple award winners.

Conduct Regular Innovation Forums

An annual forum, similar to the 2010 Innovations in Freight Demand Modeling and Data Symposium, will be conducted for presenting innovative research and selecting the most promising ideas in freight modeling and data for further development. Each forum will publish a report that will frame the near- and long-term freight modeling and data research agenda.

Actions

- Determine the content, themes, or focus areas for periodic innovation forums;
- Review and incorporate the results of the forums in relation to other GFRC activities; and
- Provide guidance for maximizing the dissemination of forum results and promoting forum participation among colleagues and peers.

Promote Technology Transfer from Other Disciplines

The SHRP 2 C20 Technical Expert Task Group has expressed the need to consider solutions to modeling needs from other fields that can be transferable or adaptable to freight transportation. Transferable solutions will be promoted regularly and serve as a focus for a broader outreach to various utilities and other sectors, and will also be a consideration in screening ideas.

Actions

- Organize a forum that would bring together presenters from other sectors to consider how their modeling and planning techniques might be adaptable to freight forecasting; and
- Organize a competition devoted to adopting and adapting analytic techniques from other sectors.

Promote an International Focus

Research innovation for freight demand and analysis must necessarily reflect the global nature of freight movement. Implementation must draw on global research and promote participation from all relevant freight sectors and academic institutions worldwide.

Actions

- Secure public, private, and academic participants from other nations through the contacts and networks of those who have already been involved in SHRP 2 C20;
- Conduct an early GFRC meeting in a strategically selected country; and
- Regularly showcase freight planning and modeling approaches employed in other nations.

Recognize the Application of Completed Research

Another important component of recognition and information dissemination for the consortium will be to periodically draw attention to the impacts and benefits of applied freight modeling and data research. This activity will be particularly important from the standpoint of promoting broader implementation of successful freight analytic approaches.

Actions

- Advance a general tracking activity to capture the benefits and experiences of freight professionals using new research approaches; and
- Publish this information periodically to reflect the long-term benefit of GFRC efforts.

Achieving Tangible Progress

The formation of a GFRC represents a significant institutional breakthrough with a strong potential for success. It is important to move to a start-up or implementation phase sometime within the first 6 to 12 months of the publication of this report to build on the momentum achieved to date through the Innovations in Freight Demand Modeling and Data Symposium and other stakeholder forums.

Early activities should include bringing together the prospective members of the GFRC for a facilitated organizational meeting or strategy workshop. The initial focus would include presenting the business case for the GFRC and seeking participant buy-in and input on how to strengthen the consortium approach and implementation. A draft work program for the first year or two of activities should also be presented for review of those initially involved. Of particular importance is that all of the current research funding agencies be at the table with the other prospective partners, as consideration should be given to how freight modeling and data research will be prioritized, which promising areas of research from SHRP 2 C20 should be advanced, and what other areas of research should be identified. This early work plan development and GFRC formation should be consultant-supported as there is no one agency or organization positioned to carry out the process on its own.

Conclusion

This second decade of the twenty-first century will place even greater emphasis on global trade, technology, innovation, and competitiveness. These megaissues will strongly influence transportation strategy and decisions about system investments. These strategies and decisions, in turn, will require capacity building for state DOTs and MPOs and greater collaboration with the freight industry at every level, including collaboration on the types of freight planning research described in this report.

The long-term ability to effectively and efficiently move goods will depend on the performance of public and private infrastructure, which is a key strategic asset to enterprises that ship and receive freight of all types in a fiercely competitive business environment.

Ironically, in this information age when the linkage between goods movement and information technology continues to expand, state DOTs and MPOs lack the kind of data and analytic tools needed to effectively plan for freight transportation. The result is that public decision makers lack the information they need to effectively support freight-related transportation decision making. This research has established a road map to move freight tools and data innovation forward through

- Implementing sample research initiatives that support the seven key strategic objectives; and
- Expanding the dialogue on freight analysis and data innovation through the GFRC, an ongoing international forum of key stakeholders comprising a public–private–academic collaboration to encourage innovative research to support decision-making needs.

By the end of this decade, a vision for improved freight modeling and data will be characterized as follows:

- A robust freight forecasting toolkit has been developed and is the standard for public sector freight transportation planning;
- Forecasting tools and data link dynamically with other key variables, such as development and land use, and their application to local scale, corridors, or regions is also dynamic;
- The challenges associated with the data necessary to support new planning tools have been addressed through a broad-based effort bringing together the varied resources of the public and private sectors;
- The knowledge and skills of state DOT and MPO staff have been methodically enhanced to complement the development of better tools and data; and
- Decision makers recognize that transportation investments are to a greater degree being informed by an understanding of the implications, benefits, and trade-offs relative to freight.

References

Bayliss, B. 1988. *The Measurement of Supply and Demand in Freight Transport.* Avebury, Gower Publishing Company Limited, Aldershot, United Kingdom.

BBC News. 2004. *Barcelona Clubbers Get Chipped.* London. http://news.bbc.co.uk/2/hi/technology/3697940.stm. Accessed Nov. 9, 2012.

Beagan, D. 2009. *NCFRP Project 06: Freight-Demand Modeling to Support Public-Sector Decision-Making.* Cambridge Systematics, Inc., Cambridge, Mass.

Belman, D., and C. White (eds.). 2005. *Trucking in the Age of Information.* Ashgate Publishing Co., Burlington, Vt.

Belt, S. 2008. *Three Most Common Uses for GPS.* Associated Content, Denver, Colo.

Bhat, C. R., J. Prozzi, and S. Sen. 2005. *Decision Support Framework for the Evaluation of Modal Competitiveness.* Summary Report 0-4013-S. Texas Department of Transportation, Austin.

Boile, M., M. Golias, and S. Ivey. 2010. A Bayesian Hierarchical Network for Truck Demand Modeling. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Bolumole, Y. A. 2001. The Supply Chain Role of Third-Party Logistics Providers. *International Journal of Logistics Management,* Vol. 12, No. 2, pp. 87–102.

Broaddus, A., and C. Gertz. 2008. Tolling Heavy Goods Vehicles: Overview of European Practice and Lessons from German Experience. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2066,* Transportation Research Board of the National Academies, Washington, D.C., pp. 106–113.

Cambridge Systematics, Inc. 1997. *NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand.* TRB, National Research Council, Washington, D.C.

Cambridge Systematics, Inc. 2007. *Quick Response Freight Manual II.* FHWA, U.S. Department of Transportation.

Cambridge Systematics, Inc. 2008. *NCFRP Project 06 Draft Interim Report: Freight-Demand Modeling to Support Public-Sector Decision Making.* FHWA, U.S. Department of Transportation.

Cambridge Systematics, Inc., A. Chatterjee, and H. Cohen. 2004. *Accounting for Commercial Vehicles in Urban Transportation Models.* FHWA, U.S. Department of Transportation.

Cambridge Systematics, Inc., Comsis Corp., and University of Wisconsin-Milwaukee. 1996. *Quick Response Freight Manual.* Office of Planning and Environment, FHWA, U.S. Department of Transportation.

Cambridge Systematics, Inc., and GeoStats, LLP. 2010. *NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making.* Transportation Research Board of the National Academies, Washington, D.C.

Cambridge Systematics, Inc., Global Insight, H. Cohen, A. Horowitz, and R. Pendyala. 2008. *NCHRP Report 606: Forecasting Statewide Freight Toolkit.* Transportation Research Board of the National Academies, Washington, D.C.

Cambridge Systematics, Inc., and Jack Faucett Associates. 2001. *NCHRP Synthesis of Highway Practice 298: Truck Trip Generation Data.* TRB, National Research Council, Washington, D.C.

Cambridge Systematics, Inc., Prime Focus, LLC, and K. Heanue. 2007. *NCHRP Report 594: Guidebook for Integrating Freight into Transportation Planning and Project Selection Processes.* Transportation Research Board of the National Academies, Washington, D.C.

Committee on Strategies for Improved Passenger and Freight Travel Data. 2011. *Transportation Research Board Special Report 304: How We Travel: A Sustainable National Program for Travel Data.* National Research Council of the National Academies, Washington, D.C.

Cooper, M., L. Ellram, J. Gardner, and A. Hanks. 1997. Meshing Multiple Alliances. *Journal of Business Logistics,* Vol. 18, No. 1, pp. 67–89.

Corsi, T., S. Boyson, A. Verbraeck, S.-T. van Houten, C. Han, and J. MacDonald. 2006. The Real-Time Global Supply Chain Game: New Educational Tool for Developing Supply Chain Management Professionals. *Transportation Journal,* Vol. 45, No. 3, pp. 61–73.

Cross-Town Improvement Project. 2010. Project Management. San Antonio, Tex.

Cruijssen, F., W. Dullaert, and H. Fleuren. 2007. Horizontal Cooperation in Transport and Logistics: A Literature Review. *Transportation Journal,* Vol. 46, No. 3, pp. 22–39.

Cutchin, C. 2005. *Freight and Commercial Vehicle Operations.* California Center for Innovative Transportation, University of California, Berkeley.

Deaton, J. P. 2008. *How Driverless Cars Will Work.* HowStuffWorks, Atlanta, Ga. http://auto.howstuffworks.com/under-the-hood/trends-innovations/driverless-car.htm. Accessed Nov. 12, 2012.

Decker, K. D. 2008. A World Without Trucks: Underground Freight Networks. *Low-Tech Magazine.* www.lowtechmagazine.com/2008/02/a-world-without.html. Accessed Nov. 12, 2012.

de Jong, G. C., H. F. Gunn, and W. Walker. 2004. National and International Freight Transport Models: Overview and Ideas for Further Development. *Transport Reviews,* Vol. 24, No. 1, pp. 103–124.

D'Hont, S. 2004. *The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution.* Texas Instruments, Dallas, Tex.

Donnell, E. T., M. L. Patten, A. Zineddin, and K. G. Goulias. 1998. *Work Order 5: Statewide Transportation Planning Public Involvement Program Design and Implementation, Phase 1, PennPlan: Making ITS/CVO Happen: Pennsylvania's ITS/CVO Business Plan.* Pennsylvania Transportation Institute, Pennsylvania State University, University Park.

Donnelly, R., A. H. Meyburg, H. Shen, and R. Leachman. 2008. Evaluation of Practice Today. In *Conference Proceedings 40: Freight Demand Modeling: Tools for Public-Sector Decision Making.* Transportation Research Board of the National Academies, Washington, D.C., pp. 27–30.

Donnelly, R., M. Wigan, and R. Thompson. 2010. A Hybrid Microsimulation Model of Urban Freight Travel Demand. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Dougherty, M. 1995. A Review of Neural Networks Applied to Transport. *Transportation Research Part C: Emerging Technologies,* Vol. 3, No. 4, pp. 247–260.

Eatough, C. J., S. C. Brich, and M. J. Demetsky. 1998. *A Methodology for Statewide Intermodal Freight Transportation Planning.* Report 99-R12. Virginia Transportation Research Council, Charlottesville.

Federal Highway Administration. 2009a. Freight Management and Operations. Conclusions. U.S. Department of Transportation.

Federal Highway Administration. 2009b. Freight Management and Operations. Summary of Benefits and Challenges. U.S. Department of Transportation.

Federal Highway Administration. 2009c. Freight Management and Operations. Swiss Heavy Goods Vehicle Control Sites Peer Exchange Meeting. U.S. Department of Transportation. http://ops.fhwa.dot.gov/freight/sw/doc/swisspeerexchgmtg/index.htm. Accessed Nov. 9, 2012.

Federal Highway Administration. 2010. Freight Management and Operations. Announcing a New Freight Course: Uses of Multimodal Freight Forecasting in Transportation Planning. U.S. Department of Transportation.

Federal Motor Carrier Safety Administration. 2010. Commercial Vehicle Information Systems and Networks (CVISN). U.S. Department of Transportation.

Federal Motor Carrier Safety Administration. 2011. Commercial Motor Vehicle (CMV) Roadside Technology Corridor. U.S. Department of Transportation. www.fmcsa.dot.gov/facts-research/art-CMV-Roadside-Technology-Corridor.htm. Accessed Nov. 12, 2012.

Fries, N., G. C. de Jong, Z. Patterson, and U. Weidmann. 2010. Shipper Willingness to Pay to Increase Environmental Performance in Freight Transportation. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2168,* Transportation Research Board of the National Academies, Washington, D.C., pp. 33–42.

Friesz, T. L., R. L. Tobin, and P. T. Harker. 1983. Predictive Intercity Freight Network Models: The State-of-the-Art. *Transportation Research Part A: Policy and Practice,* Vol. 17A, No. 6, pp. 409–417.

Guo, J., and Q. Gong. 2010. A Firm-Based Freight Demand Modeling Framework Capturing Intra-Firm Interaction and Joint Logistic Decision Making. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Hancock, K. 2008. *Conference Proceedings 40: Freight Demand Modeling: Tools for Public-Sector Decision Making.* Transportation Research Board of the National Academies, Washington, D.C.

Hansen, M., and S. Meissner. 2007. *Identification and Tracking of Individuals and Social Networks Using the Electronic Product Code on RFID Tags.* Independent Centre for Privacy Protections, Kiel, Germany.

Holguín-Veras, J. 2011. *NCFRP Project 25[Active]: Freight Trip Generation and Land Use.* Transportation Research Board of the National Academies, Washington, D.C.

Holguín-Veras, J., G. List, A. Meyburg, K. Ozbay, R. Paaswell, H. Teng, and S. Yahalom. 2001. *An Assessment of the Methodological Alternatives for a Regional Freight Model in the NYMTC Region.* New York Metropolitan Transportation Council, New York.

Holguín-Veras, J., and E. Thorson. 2000. Distributions in Commodity-Based and Trip-Based Freight Demand Modeling: Investigation of Relationships. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1707,* TRB, National Research Council, Washington, D.C., pp. 37–48.

Hovi, I. B., and W. Hansen. 2010. A Model System for Forecasting National and International Freight Transport in Norway. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Hyodo, T. 2010. Modeling Truck Route Choice Behavior by Traffic Electronic Application Data. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

IHS Global Insight. 2010. Transearch. Englewood, Colo. www.ihs.com/products/global-insight/industry-analysis/commerce-transport/database.aspx. Accessed Nov. 12, 2012.

IntelliDrive Program. 2010. Smart Roadside Initiative. U.S. Department of Transportation.

Intelligent Transportation Systems. 2008. CEFM Evaluation Report Overview. Research and Innovative Technology Administration, U.S. Department of Transportation.

Intelligent Transportation Systems Joint Program Office. 2009. ITS/Operations Resource Guide. Research and Innovative Technology Administration, U.S. Department of Transportation. www.its.dot.gov/press/announcement/resource_guide.htm. Accessed Nov. 9, 2012.

Jack Faucett Associates. 1999. *Research and Development of Destination, Mode, and Routing Choice Models for Freight.* Small Business Innovation Research Office, DTS-22, U.S. Department of Transportation.

Jinhua, X., K. L. Hancock, and F. Southworth. 2003. Dynamic Freight Traffic Simulation Providing Real-Time Information. *Proc., Winter Simulation Conference,* New Orleans, La., pp. 1711–1719.

John, L. 2009. *How the AVG System Works.* John Bean Technologies Corporation, Chalfont, Pa.

Kuzmyak, J. R. 2008. *NCHRP Synthesis of Highway Practice 384: Forecasting Metropolitan Commercial and Freight Travel.* Transportation Research Board of the National Academies, Washington, D.C.

Liao, C. 2010. Fusing Public and Private Truck Data to Support Regional Freight Planning and Modeling. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Lieb, R., and B. Bentz. 2005. The Use of Third-Party Logistics Services by Large American Manufacturers: The 2004 Survey. *Transportation Journal,* Vol. 44, No. 2, pp. 5–15.

Maes, T., and K. Ramaekers. 2010. Innovative Freight Transportation Framework for Flanders. Presented at Innovations in Freight

Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Marsh, Inc. 2007. *Third Party Logistics Providers Liability Risks.* New York.

Maryland Transportation Authority. 2008. E-ZPass® Is an Electronic Toll Collection (ETC) System. Baltimore. www.ezpassmd.com/en/about/about.shtml. Accessed Nov. 12, 2012.

Mas, I., and S. Rotman. 2008. *Going Cashless at the Point of Sale: Hits and Misses in Developed Countries.* The World Bank, Washington, D.C. http://documents.worldbank.org/curated/en/2008/12/10211903/going-cashless-point-sale-hits-misses-developed-countries. Accessed Jan. 31, 2013.

Mello, J., T. Stank, and T. Esper. 2008. A Model of Logistics Outsourcing Strategy. *Transportation Journal,* Vol. 47, No. 4, pp. 5–25.

Miklius, W., K. L. Casavant, and P. V. Garrod. 1976. Estimation of Demand for Transportation of Agricultural Commodities. *American Journal of Agricultural Economics,* Vol. 58, No. 2, pp. 217–223.

Murray, M. 2012. Logistics/Supply Chain. Selecting A Third Party Logistics (3PL) Provider. http://logistics.about.com/od/strategicsupplychain/a/select_3PL.htm. Accessed Nov. 12.

Norikane, S. 2008. *Technical Overview.* California Department of Transportation, Sacramento.

Oregon Department of Transportation. 2008. *Commercial Vehicle Information Systems and Networks.* Salem.

Pak Mail WorldWide. 2010. *Freight Forwarding and Logistics.* Packaging Services & Shipping Services, Tampa, Fla.

Peterson, B., and F. Southworth. 2010. Generation of a U.S. Commodity Flows Matrix Using Log-Linear Modeling and Iterative Proportional Fitting (Freight Analysis Framework 3). Oak Ridge National Laboratory, Oak Ridge, Tenn.

Pratyush, B. 2003. *ITS/Commercial Vehicle Operations.* University of California Transportation Center, Berkeley.

Prozzi, J., P. Siegesmund, and R. Harrison. 2006. *Estimating Truck Travel Data for Texas.* Report No. 5-4713-01-1. Center for Transportation Research at the University of Texas, Austin.

Quiroga, C., N. Koncz, E. Kraus, J. Villa, J. Warner, Y. Li, D. Winterich, T. Trego, and J. Short. 2011. *NCFRP Report 9: Guidance for Developing a Freight Transportation Data Architecture.* Transportation Research Board of the National Academies, Washington, D.C.

Reino, R. 2010. Zippity-Do-Dah; I-95 High Speed E-ZPass Lanes Open in Hampton. Fosters News. June 18. www.fosters.com/apps/pbcs.dll/article?AID=/20100618/GJNEWS_01/706189934/-1/fosnews. Accessed Nov. 12, 2012.

Research and Innovative Technology Administration. 2009. *2007 Commodity Flow Survey United States.* Bureau of Transportation Statistics, U.S. Department of Transportation. www.rita.dot.gov/bts/publications/commodity_flow_survey/final_tables_december_2009/index.html. Accessed Jan. 31, 2013.

Research and Innovative Technology Administration. 2012. National Transportation Atlas Database. Bureau of Transportation Statistics, U.S. Department of Transportation. www.rita.dot.gov/bts/publications/national_transportation_atlas_database/. Accessed Jan. 31, 2013.

Ruan, M., J. Lin, and K. Kawamura. 2010. Modeling Commercial Vehicle Daily Tour Chaining. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Safefreight Technology. 2010. Our GPS Tracking System: Your Fleet Management System for Visibility on Demand. Edmonton, Alberta, Canada. www.safefreight.com/gps-tracking-system. Accessed Nov. 12, 2012.

Sharman, B., and Roorda, M. 2010. Analysis Tool to Process Passively Collected GPS Data for Commercial Vehicle Demand Modeling Applications. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Sivakumar, A., and C. R. Bhat. 2002. Fractional Split Distribution Model for Statewide Commodity-Flow Analysis. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1790,* Transportation Research Board of the National Academies, Washington, D.C., pp. 80–88.

Southworth, F., D. Davidson, H. Hwang, B. E. Peterson, S. Chin. 2010. Freight Management and Operations. The Freight Analysis Framework, Version 3: Overview of the FAF^3 National Freight Flow Tables. Federal Highway Administration, U.S. Department of Transportation.

Spasovic, L. N. 2004. *Study to Determine the Need for Innovative Technologies for Container Transportation System.* National Center for Transportation and Industrial Productivity, New Jersey Institute of Technology, Newark.

Stefan, K., J. McMillan, and J. Hunt. 2005. Urban Commercial Vehicle Movement Model for Calgary, Alberta, Canada. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1921,* Transportation Research Board of the National Academies, Washington, D.C., pp. 1–10.

Swedburg, C. 2009. MicroSD Card Brings NFC to Phones for Credit Card Companies, Banks. *RFID Journal.* www.rfidjournal.com/article/view/7224. Accessed Nov. 12, 2012.

Ta, C., A. V. Goodchild, and B. Ivanov. 2010. Building Resilience into Freight Transportation Systems. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2168,* Transportation Research Board of the National Academies, Washington, D.C., pp. 129–135.

Tarnoff, P. J., D. M. Bullock, S. E. Young, J. Wasson, N. Ganig, and J. R. Sturdevant. 2009. *Continuing Evolution of Travel Time Data Information Collection and Processing.* Presented at 88th Annual Meeting of the Transportation Research Board, Washington, D.C.

Tavasszy, L. A. 2008. Freight Modeling: An Overview of International Experiences. In *Conference Proceedings 40: Freight Demand Modeling: Tools for Public-Sector Decision Making.* Transportation Research Board of the National Academies, Washington, D.C., pp. 47–55.

Tay, L. P. 2007. HDB Introduces RFID Season Parking Ticket. *RFID Asia Journal.* Singapore. www.rfid-asia.info/2007/11/hdb-introduce-rfid-season-parking.htm. Accessed Nov. 12, 2012.

Tri-State Transportation Campaign. 2002. E-ZPass Gains New Customers. *Mobilizing the Region,* No. 386, October 7. www.tstc.org/bulletin/20021007/mtr38609.htm. Accessed Nov. 9, 2012.

Trucking Industry Mobility & Technology Coalition. 2008. Programs/Initiatives. Arlington, Va. www.freightmobility.com/Programs_Initiatives.html. Accessed Nov. 9, 2012.

U.S. Census Bureau. 2009. *Service Annual Survey: 2007.* U.S. Department of Commerce.

Valdehueza, G. D. E. 2008. *The Circular Flow of Economic Activity.* Lourdes College, Sylvania, Ohio.

Vilain, P., and T. Muhammad. 2010. Freight Demand Modeling Using Econometric Models. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Wang, H., K. Jang, and C. Chan. 2010. Analysis and Multi-Level Modeling of Truck Freight Demand. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Wang, Q., and J. Holguín-Veras. 2010. A Tour-Based Urban Freight Demand Model Using Entropy Maximization. Presented at Innovations in Freight Demand Modeling and Data Symposium, Second Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C.

Washington State Department of Transportation. 2010a. Commercial Vehicle Information Systems and Networks. Olympia. http://wsdot.wa.gov/CommercialVehicle/CVISN/. Accessed Nov. 12, 2012.

Washington State Department of Transportation. 2010b. Weigh-in-Motion (WIM) Systems. University of Washington, Seattle.

Wiegmans, B. 2010. The Freight Transport Portfolio: A New Way to Analyze Intermodal Freight Transport As Compared to Single-Mode Road Transport. *Transportation Journal,* Vol. 49, No. 2, pp. 44–52.

Wilson, G. W. 1980. *Economic Analysis of Intercity Freight Transportation.* Indiana University Press, Bloomington.

Winston, C. 1983. The Demand for Freight Transportation: Models and Applications. *Transportation Research Part A: Policy and Practice,* Vol. 17A, No. 6, pp. 419–427.

Zsidisin, G., M. D. Voss, and M. Schlosser. 2007. Shipper–Carrier Relationships and Their Effect on Carrier Performance. *Transportation Journal,* Vol. 46, No. 2, pp. 5–18.

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Related SHRP 2 Research

Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10A)

Partnership to Develop an Integrated, Advanced Travel Demand Model with Mode Choice Capability and Fine-Grained, Time-Sensitive Networks (C10B)

Integrating Freight Considerations into Collaborative Decision Making for Additions to Highway Capacity (C15)