TRANSPORTATION RESEARCH
CIRCULAR
Number E-C187 October 2014

Developing Freight Fluidity Performance Measures

Supply Chain Perspective on Freight System Performance

May 21–23, 2014
Washington, D.C.

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH BOARD
2014 EXECUTIVE COMMITTEE OFFICERS

Chair: Kirk T. Steudle, Director, Michigan Department of Transportation, Lansing
Vice Chair: Daniel Sperling, Professor of Civil Engineering and Environmental Science and Policy; Director, Institute of Transportation Studies, University of California, Davis
Division Chair for NRC Oversight: Susan Hanson, Distinguished University Professor Emerita, School of Geography, Clark University, Worcester, Massachusetts
Executive Director: Robert E. Skinner, Jr., Transportation Research Board

TRANSPORTATION RESEARCH BOARD
2014–2015 TECHNICAL ACTIVITIES COUNCIL

Chair: Daniel S. Turner, Emeritus Professor of Civil Engineering, University of Alabama, Tuscaloosa
Technical Activities Director: Mark R. Norman, Transportation Research Board

Peter M. Briglia, Jr., Consultant, Seattle, Washington, *Operations and Preservation Group Chair*
Alison Jane Conway, Assistant Professor, Department of Civil Engineering, City College of New York, New York, *Young Members Council Chair*
Mary Ellen Eagan, President and CEO, Harris Miller Miller and Hanson, Inc., Burlington, Massachusetts, *Aviation Group Chair*
Barbara A. Ivanov, Director, Freight Systems, Washington State Department of Transportation, Olympia, *Freight Systems Group Chair*
Paul P. Jovanis, Professor, Pennsylvania State University, University Park, *Safety and Systems Users Group Chair*
Thomas J. Kazmierowski, Senior Consultant, Golder Associates, Inc., Mississauga, Ontario, Canada, *Design and Construction Group Chair*
Mark S. Kross, Consultant, Jefferson City, Missouri, *Planning and Environment Group Chair*
Hyun-A C. Park, President, Spy Pond Partners, LLC, Arlington, Massachusetts, *Policy and Organization Group Chair*
Harold R. (Skip) Paul, Director, Louisiana Transportation Research Center, Louisiana Department of Transportation and Development, Baton Rouge, *State DOT Representative*
Stephen M. Popkin, Director, Safety Management and Human Factors, Office of the Assistant Secretary of Transportation for Research and Technology, Volpe National Transportation Systems Center, Cambridge, Massachusetts, *Rail Group Chair*
James S. Thiel, Consultant, Madison, Wisconsin, *Legal Resources Group Chair*
Thomas H. Wakeman III, Research Professor, Stevens Institute of Technology, Hoboken, New Jersey, *Marine Group Chair*
David C. Wilcock, Vice President and National Practice Leader for Rail and Transit, Michael Baker, Jr., Inc., Norwood, Massachusetts, *Public Transportation Group Chair*

TRANSPORTATION RESEARCH CIRCULAR E-C187

Developing Freight Fluidity Performance Measures

Supply Chain Perspective on Freight System Performance

Summary of a Workshop

Katherine F. Turnbull
Rapporteur

May 21–22, 2014
The Keck Center of the National Academies
Washington, D.C.

Organized by
Transportation Research Board

Supported by
Office of Freight Management and Operations
Federal Highway Administration

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C187
ISSN: 0097-8515

The **Transportation Research Board** is one of six major divisions of the National Research Council, which serves as an independent advisor to the federal government and others on scientific and technical questions of national importance. The National Research Council is jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal.

The **Transportation Research Board** is distributing this circular to make the information contained herein available for use by individual practitioners in state and local transportation agencies, researchers in academic institutions, and other members of the transportation research community. The information in this circular was taken directly from the submission of the authors. This document is not a report of the National Research Council or the National Academy of Sciences.

Transportation Research Board
500 Fifth Street, NW
Washington, D.C.
www.TRB.org

Lea Camarda, Production Editor; Jennifer Correro, Proofreading and Layout

Contents

Preface

The freight transportation system is key to the global competitiveness of the United States. While the performance of the freight system is invisible to most Americans, it is a major concern to businesses, manufacturers, shippers, carriers, and network managers. The multimodal freight transportation system is managed and operated by a variety of public and private entities that monitor and measure system performance in different ways.

TRB, in collaboration with the FHWA Office of Freight Management and Operations, hosted a workshop to examine freight fluidity as a measure of overall supply chain performance and to explore its use in managing and improving the performance of the freight system. The Developing Freight Fluidity Performance Measures: Supply Chain Perspective on Freight System Performance Workshop was held May 21–22, 2014, at the Keck Center of the National Academies in Washington, D.C.

The workshop brought together public agency personnel and private-sector supply chain managers to share information on monitoring and measuring different elements of the freight transportation system. The opportunities and challenges involved in expanding the use of the freight fluidity concept were discussed by participants.

The workshop included general sessions and breakout sessions. The first general session focused on private-sector perspectives on measuring supply chain performance. The Canadian experience with developing and using freight system fluidity measures was featured in the second general session. Speakers in the third session presented examples of applying freight fluidity in the United States. Breakout sessions provided participants with the opportunity to discuss stakeholders and users, scalability, performance measures, data characteristics, and research needs to help advance the development and use of freight fluidity.

TRB assembled a planning committee to help organize and develop the workshop program. The planning committee was chaired by Joseph L. Schofer, Northwestern University. Committee members provided expertise in freight fluidity, freight data, planning and modeling, performance measures, and policies.

The planning committee was responsible solely for organizing the workshop, identifying speakers, and developing breakout session topics. Katherine F. Turnbull, from the Texas A&M Transportation Institute, prepared this report as a factual summary of what occurred at the workshop. The conference PowerPoint presentations are available at http://onlinepubs.trb.org/onlinepubs/conferences/2014/FreightFluidity2014/Program.pdf.

The workshop attracted 91 participants, including representatives from businesses and corporations, federal agencies, state departments of transportation, metropolitan planning organizations, universities, consulting firms, and other groups. This document presents the proceedings from the workshop. The major topics addressed by speakers in the general sessions and the discussions in breakout sessions are summarized. The list of attendees is provided in Appendix A.

The workshop planning team thanks Katherine Turnbull for her work in preparing the workshop proceedings and extends a special thanks to the FHWA Office of Freight Management and Operations for providing the support that made the workshop possible.

The views expressed in the proceedings are those of the individual workshop participants, as attributed to them, and do not necessarily represent the views of all workshop participants, the workshop planning committee, TRB, or the National Research Council.

Introduction

Joseph L. Schofer
Northwestern University

Caitlin Hughes Rayman
Federal Highway Administration

Speakers in this session welcomed participants to the workshop and provided an overview of the background, purpose, and format of the workshop.

WORKSHOP WELCOME AND OBJECTIVES

Joseph L. Schofer

Joseph Schofer welcomed participants to the TRB Developing Freight Fluidity Performance Measures: A Supply Chain Perspective on Freight System Performance Workshop. Schofer covered the following topics in his welcome:

- Schofer recognized the FHWA Office of Freight Management and Operations for supporting the conference and thanked members of the Workshop Planning Committee. He also recognized and thanked TRB staff members Scott Babcock, Tom Palmerlee, Mai Q. Le, Brittney Gick, and Tyler Robertson for their help in organizing the workshop and providing on-site support.
- He reviewed the workshop objectives, which included learning about freight fluidity as a measure of overall supply chain performance, exploring ways freight fluidity is being used to manage and improve performance, and identifying the opportunities and challenges involved in making wider use of the fluidity concept in both the public and private sectors.
- Schofer provided an overview of the workshop program, which included both general sessions and breakout discussion groups. He noted that the three general sessions following the introduction focused on the private sector's perspective on measuring and managing supply chain performance, the experience in Canada with developing and using freight fluidity performance measures, and U.S. public-sector applications of freight fluidity measures. He described the breakout groups, noting that participants would have the opportunity to identify and discuss the stakeholders and users of freight fluidity measures, scalability, possible performance measures, and data needs and characteristics. He further noted that the closing session would feature reports from the breakout group moderators and an open discussion on data and model needs, potential research activities, and next steps.

WORKSHOP OVERVIEW

Caitlin Hughes Rayman

Rayman welcomed workshop participants on behalf of the FHWA Office of Freight Management and Operations. She summarized the importance of advancing the ability to analyze freight flows and supply chains at the international, national, regional, and local levels. Rayman covered the following topics in her presentation:

- Rayman recognized and thanked Nicole Katsikides and Ed Strocko from the FHWA Office of Freight Management and Operations for their hard work and innovative thinking in helping with the workshop. She also thanked the workshop planning committee and TRB staff for developing a targeted and informative workshop.
- Rayman suggested that the Moving Ahead for Progress in the 21st Century Act helped place a public-sector focus on freight policy, planning, and performance. As a result, state departments of transportation (DOTs), metropolitan planning organizations, regional partnerships, corridor coalitions, and the private sector are working together to advance the understanding and appreciation of freight flows and supply chains.
- Rayman noted that a body of research has been developed for measuring freight performance by mode based largely on techniques used to assess nonfreight transportation. These traditional methods have focused on the impacts of congestion, delays, and bottlenecks on the freight system. She suggested that while the current measures provide information on freight movement, volume, and value by mode, there is a need to link these measures together into more comprehensive, multimodal, end-to-end supply chains for various commodities.
- Rayman commented that since freight does not recognize jurisdictional boundaries, considering all the links in a supply chain is important. Further, the performance of the transportation system in one area frequently impacts business and customs in other locations. She suggested that the only way to understand the reach of freight and to work together to identify the most meaningful transportation needs for freight is to understand the supply chains and shared corridors from beginning to end and the performance of all modes. While doing so can be complicated, difficult, and challenging, with numerous elements to consider, she noted that the end results will be beneficial for the public and private sectors.
- Rayman stressed the importance of learning from others, noting that the workshop featured a mix of speakers from the public and the private sectors. She commented that Canada has been developing and using the freight fluidity concept for a number of years. Learning about the lessons learned in establishing the multimodal performance mechanisms and applying them in Canada would be beneficial. Further, she noted that Canada has been successful in applying freight fluidity to advance economic development and system performance, supporting businesses in Canada and North America.
- She suggested that the United States has numerous rail lines, corridors, entry points, airports, and freight facilities to consider in applying the freight fluidity model to better understand supply chains. Rayman indicated that the workshop can build on the Canada activities and identify ways to work with the private sector to establish multimodal supply chain performance analyses.
- She thanked the private sector representatives for participating in the workshop, noting that understanding their view of goods movement and the information they use in making supply chain decisions would be beneficial.
- Rayman reported that FHWA and TRB are working to advance freight performance measurement along with the other modal administrators at the U.S. DOT through the advancement of research, the development of tools and best practices, and the improvement of data quality and accessibility. Through the workshop and other research focusing freight on fluidity, FHWA is advancing the development of a multimodal, end-to-end freight fluidity

measurement approach. She further suggested that there are many ways or lenses through which to consider freight fluidity in the United States and North America. By helping to identify a research path forward, the workshop can further the development of a more comprehensive and multimodal freight measurement system, and foster improvements in the transportation system to address needs and issues.

Investment Decisions in Facilities and Services

Private-Sector Perspectives on Measuring the Performance of Supply Chains

KARL MORTENSEN
Chrysler Group, LLC

ROBERT UTZ
McCormick & Company, Inc.

SHARON CLARK
Perdue AgriBusiness, LLC

KEN ALLEN
H-E-B Stores (retired)

MICHELLE VANDERMEER
Whirlpool Corporation

TINA CASGAR
San Diego Association of Governments, moderator

This session featured speakers highlighting automobile, spice, agricultural product, grocery store, and home appliance supply chains.

AUTOMOTIVE SUPPLY CHAIN PERSPECTIVE ON FREIGHT SYSTEM PERFORMANCE

Karl Mortensen

Karl Mortensen discussed elements of the supply chain at Chrysler Group, LLC. He summarized the Chrysler group brands, recent growth in production, and global sales. He described the company's inbound network footprint and provided examples of supply chains supporting vehicle manufacturing. He also discussed some of the current challenges with the supply chain for finished vehicles. Mortensen covered the following points in his presentation:

- Mortensen noted that there have been a number of changes at Chrysler over the past 15 years. The company is now part of Fiat. The current five automotive bands are Chrysler, Ram, Jeep, Dodge, and Fiat. The company has experienced a 75% increase in global production recently. Global production in 2010 was approximately 1.6 million vehicles, compared to a projected 2.8 million vehicles in 2014, accounting for a 75% growth over the 5-year period. He suggested that this growth has been especially challenging for the supply chain group at the company.
- Mortensen indicated that global sales to date in 2014 are approximately 11% higher than 2013 levels. International sales are approximately 21% higher, while sales in the United States are experiencing an 11% increase. The only international market not experiencing growth

is Latin America. The Chrysler Group occupies a solid fourth behind General Motors, Ford, and Toyota, with approximately 12.5% market share through April 2014. He noted that the projected 2014 revenues are approximately $80 billion, with an operating profit of $4 billion.

- Mortensen described Figure 1, which illustrates the North American Free Trade Agreement (NAFTA) inbound parts supplier locations by transportation mode. He noted that the Chrysler Group inbound network footprint includes 12 assembly plants, 23 manufacturing plants, 22 domestic parts distribution centers (PDCs), and 11 international PDCs. Other footprint elements include 10 integrated logistics centers, three Chrysler Group Transport terminals, and one Chrysler Group Auto Transport (CGAT) terminal. There are seven U.S., Canada, and Mexico port processing centers. Chrysler Group ships finished vehicles and parts to 70 destination ports worldwide. The three CGAT terminals, which serve Chrysler's private truck fleet, are located in Detroit, Mich.; Windsor, Canada; and Toledo, Ohio.
- Mortensen discussed the supply-based freight flows supporting the Jefferson North assembly plant in Detroit, where the Grand Cherokee and Durango models are manufactured, and the Saltillo truck assembly plant in Mexico, which manufactures heavy- and light-duty trucks. Figure 2 illustrates the freight flow for the Jefferson North plant and Figure 3 presents the freight flows for the Saltillo plant. He noted that approximately 11% of the parts for the Jefferson North plant, including the engines, come from Mexico. As illustrated, approximately 46% of the parts used at the Saltillo plant come from Canada and states in the north and Midwest. He also noted that the light-duty truck frames used at the Warren, Michigan, truck assembly plant come from the Saltillo plant. As a result, he noted that there is a lot of freight moving north and south between plants.

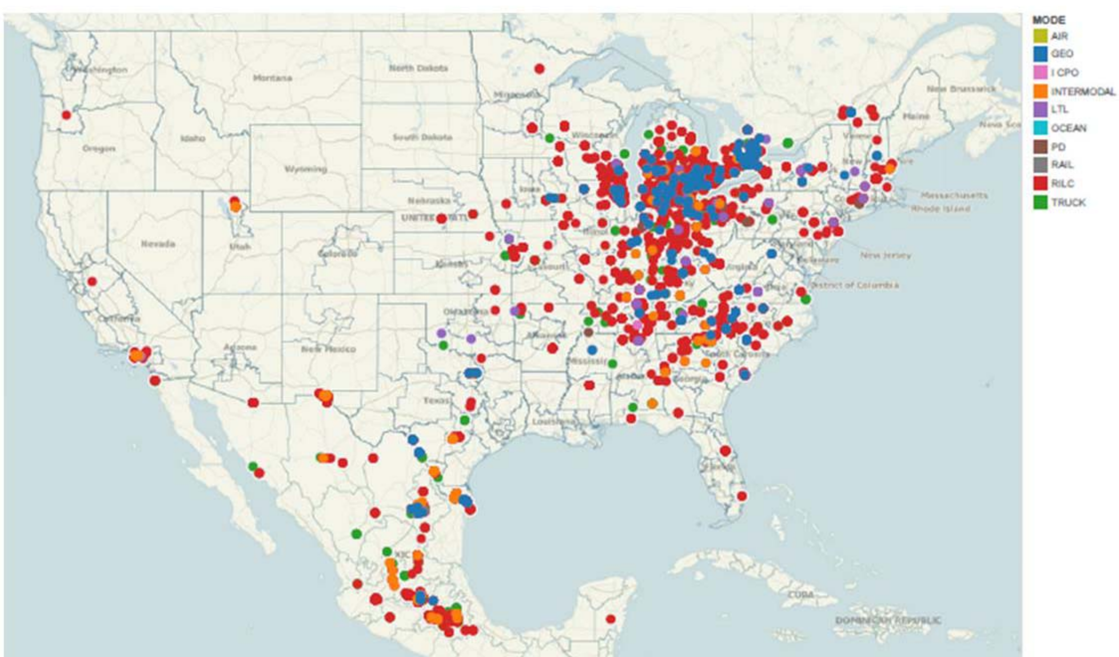

FIGURE 1 NAFTA inbound parts: supplier geography by transportation mode. (Source: Chrysler Group, LLC.)

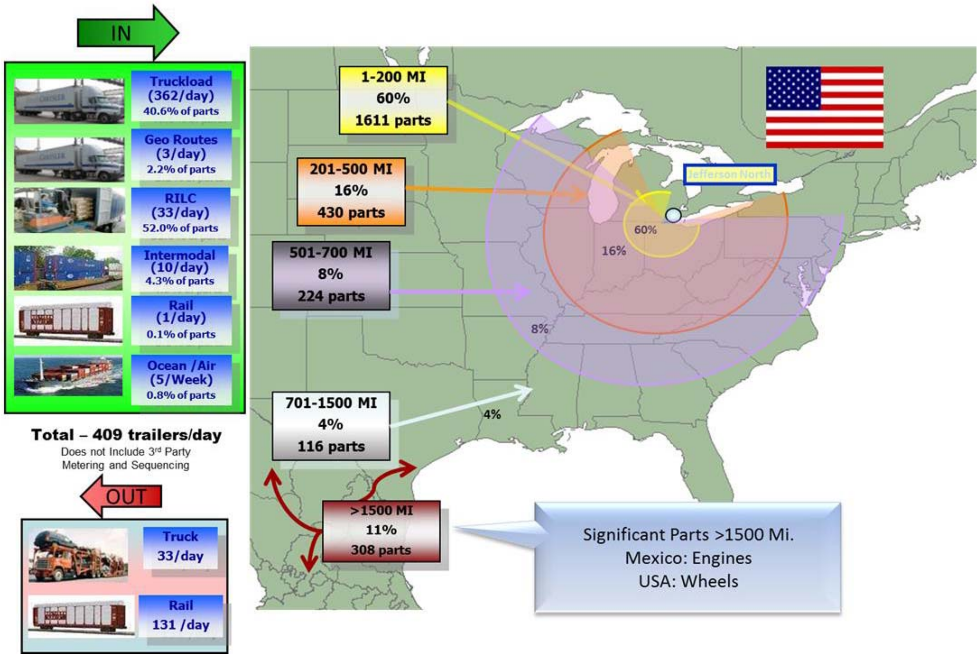

FIGURE 2 NAFTA: Jefferson North supply base geography. (Source: Chrysler Group, LLC.)

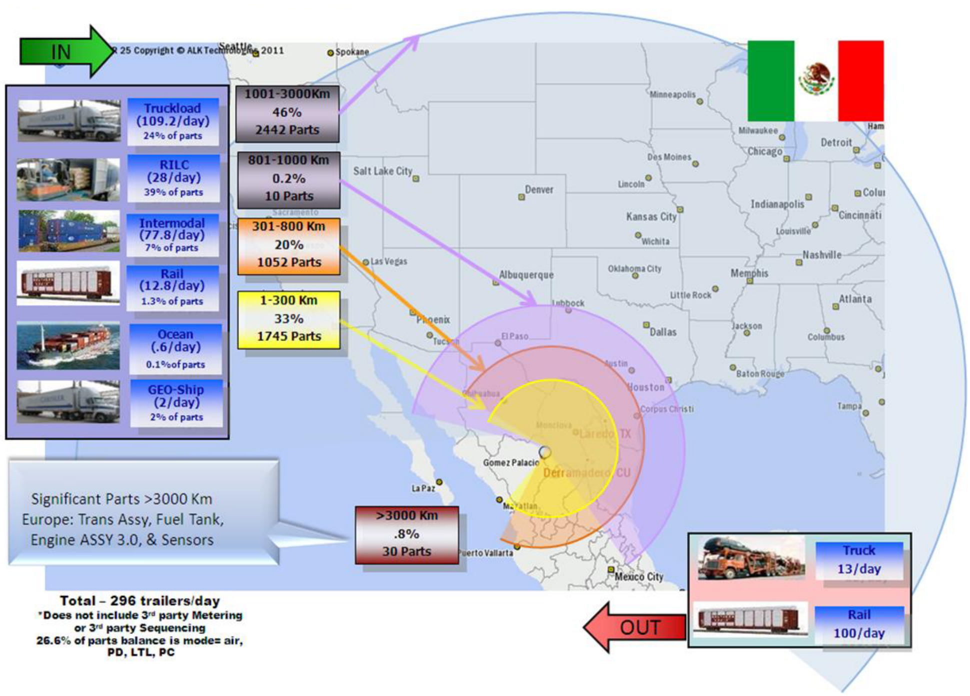

FIGURE 3 NAFTA: Saltillo truck supply base geography. (Source: Chrysler Group, LLC.)

- Mortensen said that the supplier closest to different facilities is not always used due to a variety of factors. For example, Chrysler provides the base volume for a daily stack train between Chicago, Illinois, and Mexico. These daily trains carry 740 containers south per week and 817 containers north per week. Of this volume, an estimated 417 Detroit-area origin loads per week are trucked to and from a Chicago intermodal ramp. Using alternative intermodal ramps in Detroit and Marion, Ohio, would reduce truck traffic on I-94 by 115,000 truck miles per week, but a competitive solution for using the alternate intermodal ramps has not emerged based on current market dynamics.
- Mortensen described the delays experienced this year by the Chrysler Group and other original equipment manufacturers (OEMs) in the finished vehicle network. The winter snowstorms resulted in major delays in shipping finished automobiles and trucks and other vehicles by rail. As a result, the number of vehicles ready to be shipped is much higher than in previous years, resulting in a backlog of aged inventory. He noted that the average transit days for finished vehicles were 13.7 days in 2013, compared to the current 18.9 days. He indicated that the goal is delivery of vehicles within 15 days. With ongoing rail capacity constraints, Mortenson said that a 26-day delivery period may occur this year. The cost of this delayed inventory is high and is causing problems for the spring selling period. He explained that the vehicles are sold by the OEMs to dealers when they are built. Thus, the dealer's assets are sitting on the ground, not in the dealer's showroom or lot. The dealers are also incurring storage costs and repair expenses when vehicles are damaged during storms. He explained that the network of finished vehicle railcars is a shared pool among the OEMs, so problems in one part of the network causes problems for other parts of the network. Mortensen noted that the major delays are being experienced in the Chicago area rail network.

SPICE SUPPLY CHAINS

Robert Utz

Robert Utz discussed supply chain elements at McCormick & Company, Inc. He described the company's global operations, the supply chains for Indian black pepper and Indonesian cinnamon, and bottlenecks impacting imports and the outbound shipment of finished products. Utz covered the following topics in his presentation:

- Founded in 1889 in the Baltimore, Maryland, Inner Harbor, with spices from the West Indies arriving by clipper ships, McCormick celebrated its 125th anniversary in 2014. Utz noted that McCormick is a global leader in spices, seasonings, and flavors. McCormick sells to retail, food service, and industrial markets. McCormick has a cobranding agreement with Sysco, the largest food service distributor in the country, and provides a range of spices, seasonings, and condiments to fast food restaurants and to other food companies. McCormick headquarters is still in Maryland, but the company also uses operations around the world. McCormick annual sales are approximately $4.1 billion and the company has approximately 10,500 employees. McCormick is an S&P 500 company.
- Utz described McCormick's global presence, which is illustrated in Figure 4. The company has plants and distribution centers (DCs) in 32 countries and sells products through distributors and licenses in 110 countries. He noted that South America is a target for future growth. McCormick has plants and DC networks in the United States, Canada, Mexico, El

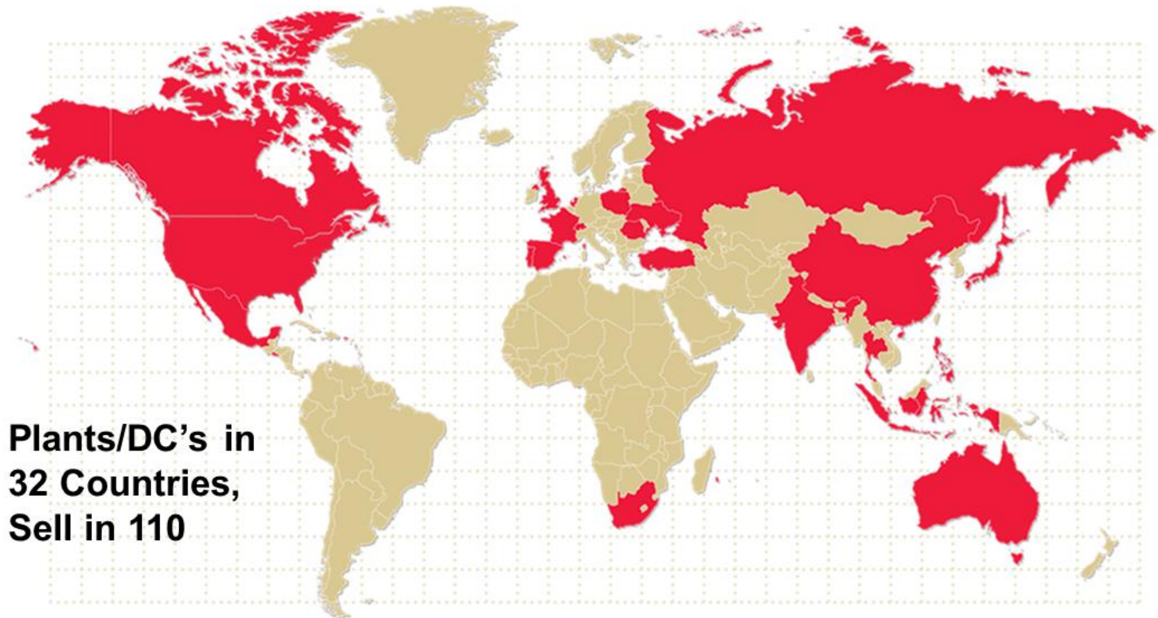

FIGURE 4 McCormick's global operations. Red denotes countries with plants and DCs. (Source: McCormick & Company, Inc.)

Salvador, and Europe. Countries with facilities include the United Kingdom, France, Poland, and Portugal. Recent growth has occurred in Asia, primarily Australia, China, India, Singapore, and Thailand. Utz noted that China is a strong developing market. McCormick recently purchased a company that is the major producer of chicken broth in China. Most of what McCormick produces in China remains in that country. McCormick's also has a significant presence in other parts of the world through consolidated, joint venture, and distributor operations.

- Figure 5 illustrates the origins of McCormick's spices. Black and white pepper represents the largest volume and highest dollar value of spices. Vanilla is also a major import. As highlighted in Figure 6, Utz noted that McCormick also uses ingredients from the United States. Approximately 65% of the ingredients used at the Maryland processing plants are domestic, with salt representing the major commodity.
- Utz described McCormick's supply chain flows for inbound imports to the United States. Spices from Indonesia, India, Brazil, China, Vietnam, Turkey, Egypt, and the Ivory Coast are shipped to North America and Europe via ocean container vessels. He noted that significant volumes of finished products are transported to the United States from Mexico, China, France, Thailand, and Canada by truck and ocean container vessels.
- Utz described some of the typical supply chains for spice imports. Indian black pepper sources out of Cochin, India. There is no direct shipping service from Cochin to the United States, so feeder service from Colombo, Sri Lanka, and then to Singapore is used. From Singapore it is shipped to Baltimore. This route involves three legs and two transfer points. Indonesian cinnamon is sourced in Padang, Sumatra, Indonesia. It is shipped to Jakarta, Java, Indonesia, on feeder service and then to Singapore. From Singapore it is shipped to Baltimore.

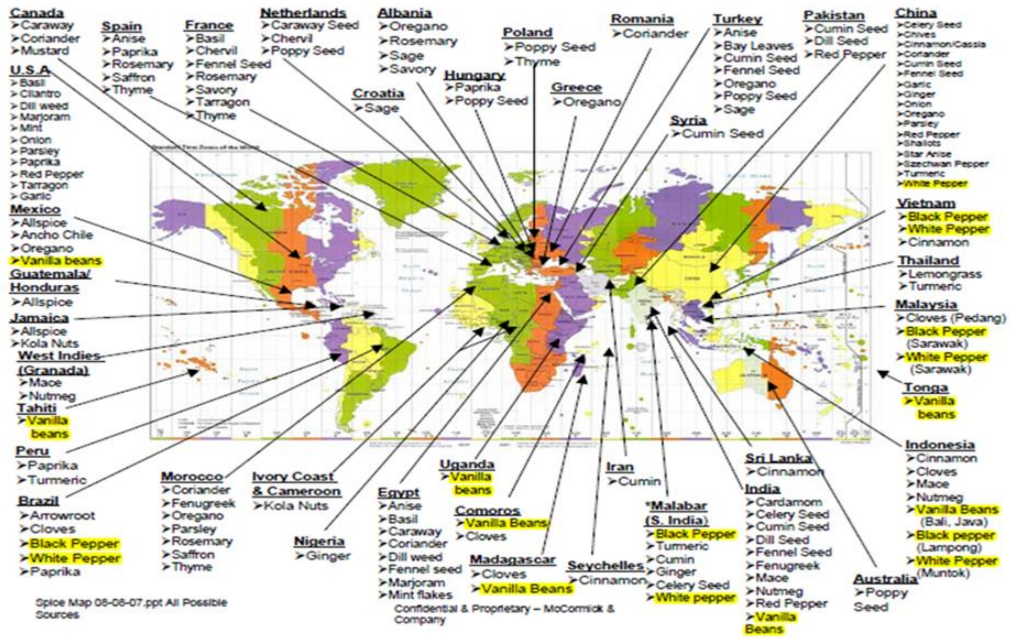

FIGURE 5 Origins of McCormick's Spices.
(Source: McCormick & Company, Inc.)

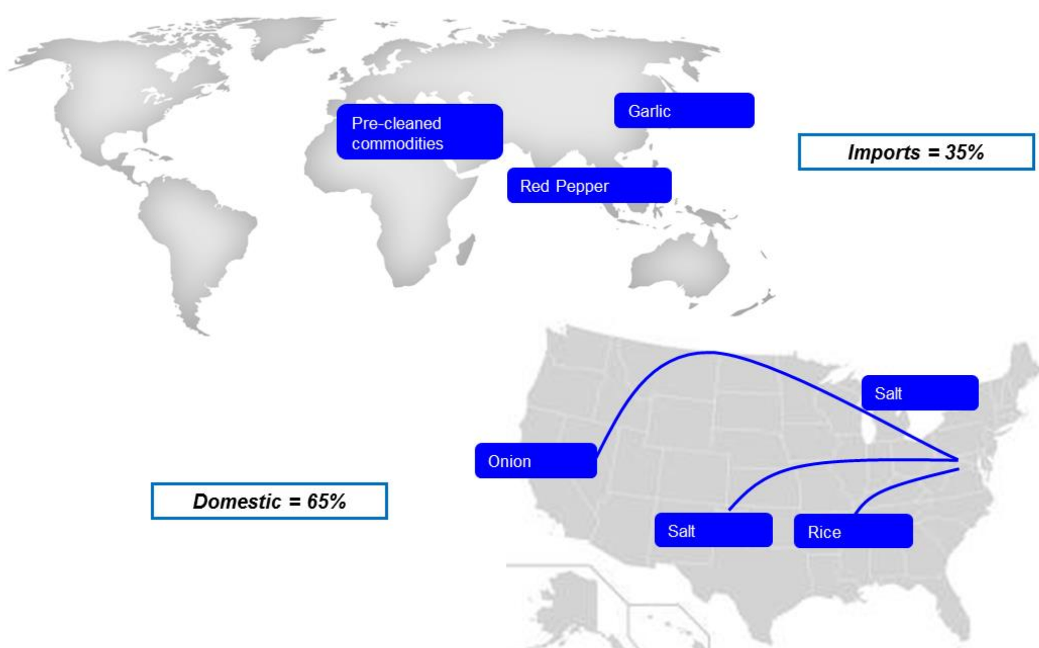

FIGURE 6 Major inbound moves to Maryland.
(Source: McCormick & Company, Inc.)

- Utz noted that although spices are relatively high volume, the supply chain is very long and time consuming. The ocean segment comprises the majority of the time. While the carrier is responsible for the port-to-port shipment, Utz indicated that McCormick also monitors the progress of shipments. Transload ports, with ship-to-ship transfers, add further potentials for delays. He noted that delays may also be encountered at the Port of Baltimore. Further, depending on the number of containers on a ship, not all may be picked up at the same time. Government agency inspections include U.S. Customs and Border Patrol, the U.S. Food and Drug Administration, and the U.S. Department of Agriculture (USDA). The container is unloaded at the destination warehouse or McCormick plant, and the container is returned to the pier in Baltimore. Delay charges can be issued if the container is not returned within the designated window. Utz reported that bottlenecks and delays result in increased cycle times, inventory levels, carrying costs, and expenses.
- Utz described McCormick's outbound supply chain flows in North America. Regional DCs are replenished using intermodal rail, while customer orders are delivered by truck. Consumer products are delivered to grocery or wholesaler warehouses, while industrial products are usually picked up by customers, using their own trucks or carriers. He noted that due to the high cost of trucking, rail intermodal is used for high-volume–long-distance finished goods replenishment loads from manufacturing plants to regional DCs. For example, outbound finished goods from Hunt Valley, Maryland, to Dallas, Texas, and Salinas, California, are transported by rail through Chicago ramps, where containers are transferred from eastern to western railroads. Finished products from plants in South Bend, Indiana, are trucked to Chicago and transferred to rail to reach Belcamp, Maryland, and Salinas.
- Utz indicated that McCormick uses JB Hunt, a company that is responsible for all movements, and total door-to-door transit times. All trip components are measured, including the dwell–transfer times at the origin ramp, the Chicago railroad transfer, the destination ramp, and trailer unloading at the destination warehouse or McCormick DC. He noted that the rail interchange in Chicago is often a bottleneck in the system. Both weather and congestion on the rail system are causes of delay. The storms, snow, and ice during the past winter caused major problems with railroad operations in Chicago. He noted that many companies, including McCormick, shipped more goods by truck this winter to avoid the delays in Chicago and to keep the West Coast supplied. This change drove up the demand and costs for shipping by truck. He again stressed that this bottleneck results in increased cycle times, inventory levels, carrying costs, and expenses.
- Utz reviewed some of the action steps used to reduce delays. First, where possible, McCormick's uses direct services without transloads or transfers for the ocean portion of the trip to reduce the possibility of delay. For example, shipping black pepper from Cochin, India, to Mumbai and then from Mumbai to Baltimore eliminated one of the transload points from the previous route to Sri Lanka and Singapore. He noted that Singapore can be a bottleneck in the system, citing a situation where black pepper had to be shipped by air from Singapore to keep the supply chain flowing and to meet production schedules. He further noted that working with shippers to monitor dwell times at ports, railroad yards, intermodal terminals, and unloading facilities is important. If delays occur it is important to determine and address the root cause. He also noted the importance of import inspection times. Joining voluntary programs, such as the U.S. Customs and Border Patrol's Customs–Trade Partnership Against Terrorism (C-TPAT) provides the benefits of reduced inspections and faster inspection turnarounds. He stressed the importance of measuring, analyzing, and acting to maintain and improve supply chains.

AGRICULTURAL SUPPLY CHAINS

Sharon Clark

Sharon Clark described Perdue AgriBusiness, LLC. She highlighted some of the recent agricultural trends, grain supply and demand dynamics, changes in the U.S. agricultural shipping patterns, and characteristics of the agricultural supply chain. Clark covered the following topics in her presentation:

- Clark reported that Perdue has grown to become the fourth largest poultry company and one of the largest grain companies in the country. Perdue businesses operate in 17 states, and the company has over 20,000 associates, with over $7 billion in sales annually. Perdue AgriBusiness originates, trades, and processes more than 350 million bushels of grains and oil seeds a year and over 2 million tons of soy meal and feed ingredients. Businesses include grain merchandising, soybean crushing and refining, trading, blending, and organic fertilizers, with sales to both domestic and international customers in the feed, pet food, fertilizer, and renewable fuels industries.
- Clark noted that Perdue operates on a 3-year strategic planning cycle. Three key agricultural trends were identified as part of the current strategic plan. These trends focus on world population growth, price volatility as a normal occurrence, and evolving trade patterns.
- The first trend described by Clark was that world population growth will continue to drive the demand for food. She noted that the world population is projected to continue to grow, reaching 7 to 9 billion by 2050. Much of this population growth is forecast to occur in China, India, Indonesia, and Nigeria. As part of this growth, 1 to 1.5 billion people are moving from subsistence existence to middle-income levels. These two factors will result in food demand doubling by 2050.
- The second agricultural trend described by Clark related to commodity price volatility becoming the normal situation. She noted that Perdue customers are coping with price volatility by finding new sources of supply and alternative ingredients. She also noted that customers want help with risk management related to price volatility.
- Changing historic world grain trade patterns represented the third key agricultural trend cited by Clark. She noted that in the past the United States has stored the world's grain supply. Today, driven by increased demand, lower stocks, and market volatility, the United States may be importing and exporting agricultural commodities in the same crop year.
- Figure 7 illustrates changes in U.S. agricultural production for the past 8 years. The total annual production of corn, soybeans, and wheat increased in 2013–2014, after 3 years of decline. Clark noted that the largest corn and soybean crops in U.S. history were harvested this past year. This record followed one of the lowest crop yields due to record drought in many parts of the country. She noted that record crop production is being forecast for the current year, which will put further pressure on the U.S. freight transportation system.
- Figure 8 highlights the major corn growing regions in the United States. Clark noted that a robust transportation network, including truck, rail, and barge is needed to move corn from supply areas to demand areas, which include feed, processing, and export. She noted that approximately 20% of the corn crop moves by barge, 30% by rail, and 50% by truck. She

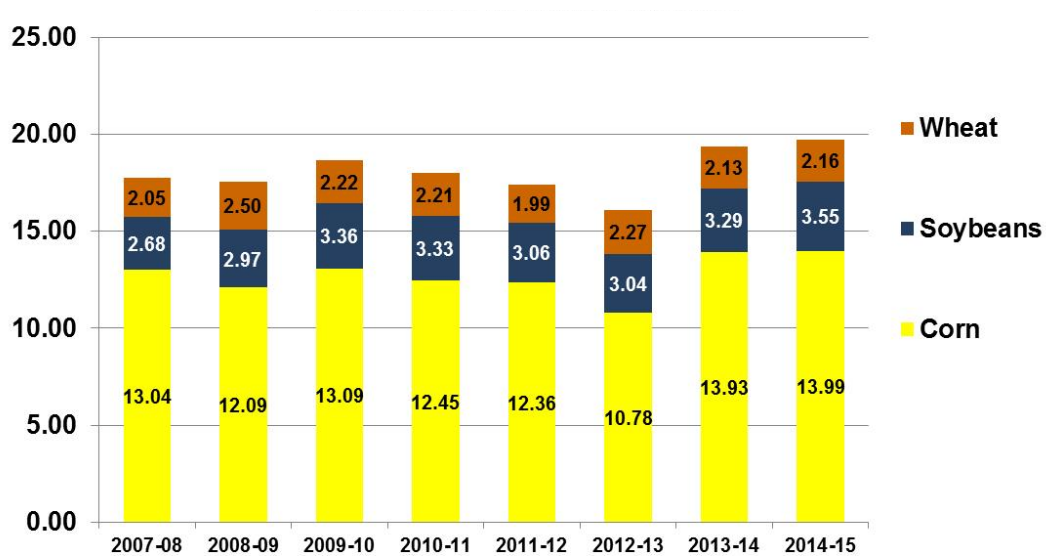

FIGURE 7 U.S. corn, soybean, and wheat production in billions of bushels. (Source: Perdue AgriBusiness, LLC.)

indicated that the dominant role of trucks is due to the dispersed nature of growing areas. Agricultural commodities are characterized by multiple origin and destination pairs, which differs from the nonstatic origin and destination pairs of many nonagricultural products.

- As highlighted in Figure 9, soybeans are also grown primarily in the Midwest and along the Mississippi River. Truck, barge, and rail are also used to transport soybeans. Ms. Clark noted that there are approximately 3.2 million farmers in the United States. Roads, rivers, and railroads are all important in shipping soybeans and other agricultural products. The secondary highway network plays a key role in supporting truck transportation from farms. She noted that routes, carriers, and modes are selected on the basis of price, service, availability of equipment, and infrastructure. As an example, Perdue AgriBusiness dispatches over 160,000 trucks, handles over 40,000 rail cars, dispatches over 350 barges, ships over 16,000 containers, and ships over 125 vessels a year.
- Clark described Figure 10 illustrating U.S. corn supply and demand for the current year. The major corn producing states include Nebraska, Wisconsin, Iowa, Illinois, and Indiana. The 2013 USDA corn demand projections include 5.3 billion bushels for the feed sector, 5.0 billion bushels for ethanol production, and 1.6 billion bushels for export. The remaining 12% of the corn crop is projected to go for seed, industrial use, or storage.
- Clark described the changing U.S. agricultural shipping patterns. She noted the projected world population growth of 2.3 billion more people by 2050 will further influence agricultural supply chains. She also noted that over 95% of this population growth is projected to occur in less-developed regions, with approximately half in Africa. Clark indicated that China is currently a major customer for U.S. soybeans.

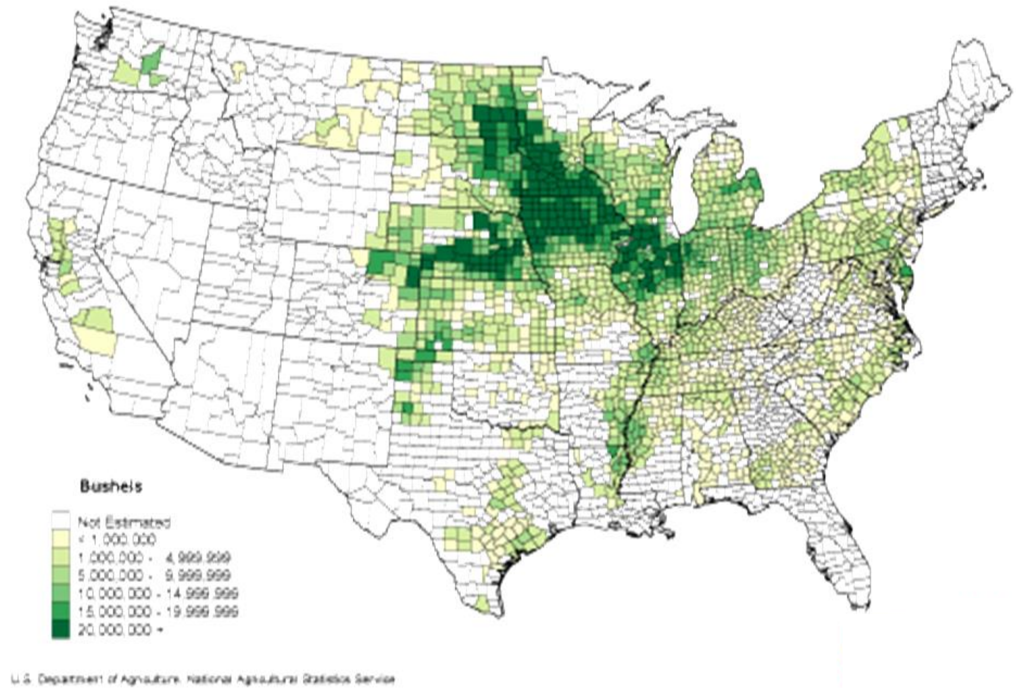

FIGURE 8 Corn for grain 2012 production for selected states. (Source: USDA, National Agricultural Statistics Service.)

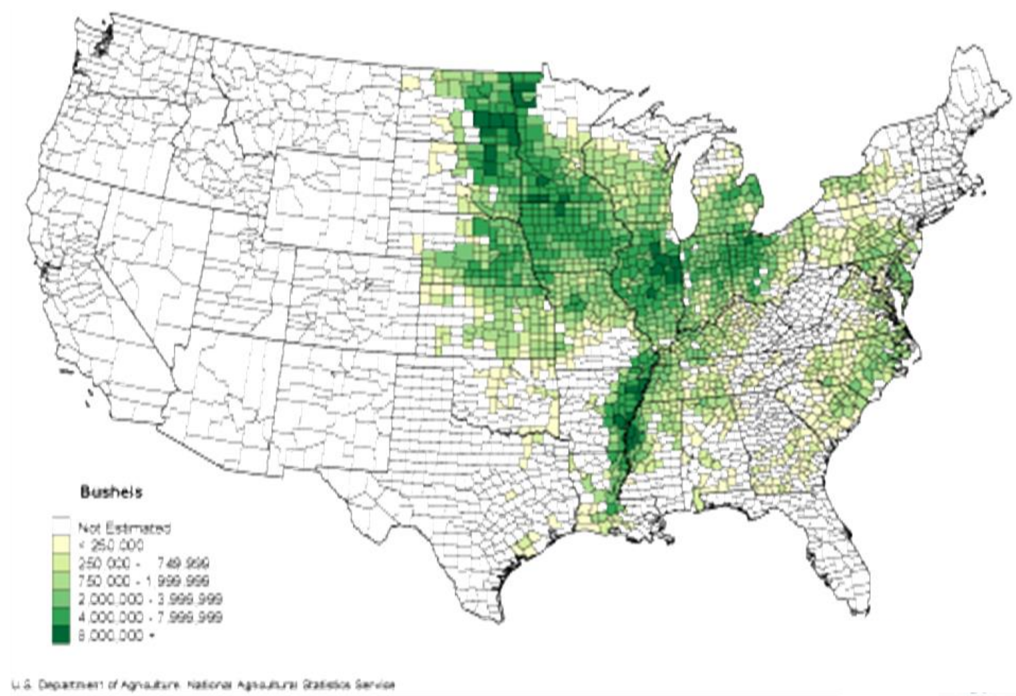

FIGURE 9 Soybeans for grain 2012 production by county for selected states. (Source: USDA, National Agricultural Statistics Service.)

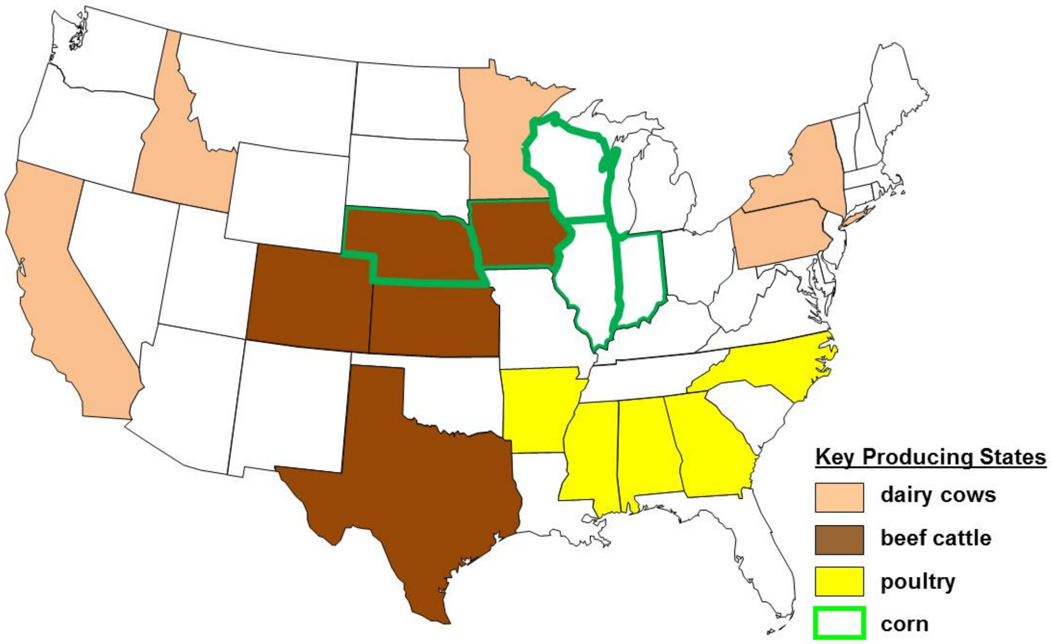

FIGURE 10 U.S. corn supply and demand.
(Source: Perdue AgriBusiness, LLC.)

- According to Clark, at the same time export demand is increasing, domestic demand is also increasing for food, feed, and biofuels. She described the changing shipping patterns for corn illustrated in Figure 11. She noted the increase in the use of corn for ethanol production since the passage of the Energy Independence and Security Act in 2007. In the 2011–2012 crop year, the USDA Supply and Demand Report noted for the first time that more corn would be used for ethanol production than to feed livestock. She noted that government mandates for ethanol production are shifting the corn crop from food supply to ethanol production. She suggested that with the economic and distribution challenges facing cellulosic ethanol, it is expected that corn will be the major source of ethanol production for the foreseeable future.
- Clark also noted the importance of agricultural products in feeding livestock. As incomes increase throughout the world, the demand for meat is also increasing, thereby increasing the demand for feed stock. She noted that each person in the United States eats an average of 203 lb of meat a year. In comparison, the annual per capita meat consumption is 201 lb in Brazil, 123 lb in Russia, 112 lb in China, and 8.7 lb in India. The Deutsche Bank estimates that global protein demand could double in the next 35 years from 210 million metric tons a year to over 450 million metric tons.
- Clark reported that the increase in worldwide demand, coupled with price uncertainty last year, resulted in new shipping patterns for agricultural commodities throughout the world. She also noted that drought conditions devastated crops in many parts of the world last year, including corn and soybeans in Brazil and Argentina, while India experienced its fourth drought in 12 years. The U.S. plains states, along with Texas and California, continue to suffer severe drought conditions, with this year's wheat crop being downgraded. As a result, she noted that significant imports of grains and oil seeds from South America, Europe, and the Black Sea occurred last year for the first time in U.S. history. She further noted that commodity markets are global in nature and hemispherically interdependent. For example, corn and soybeans harvested

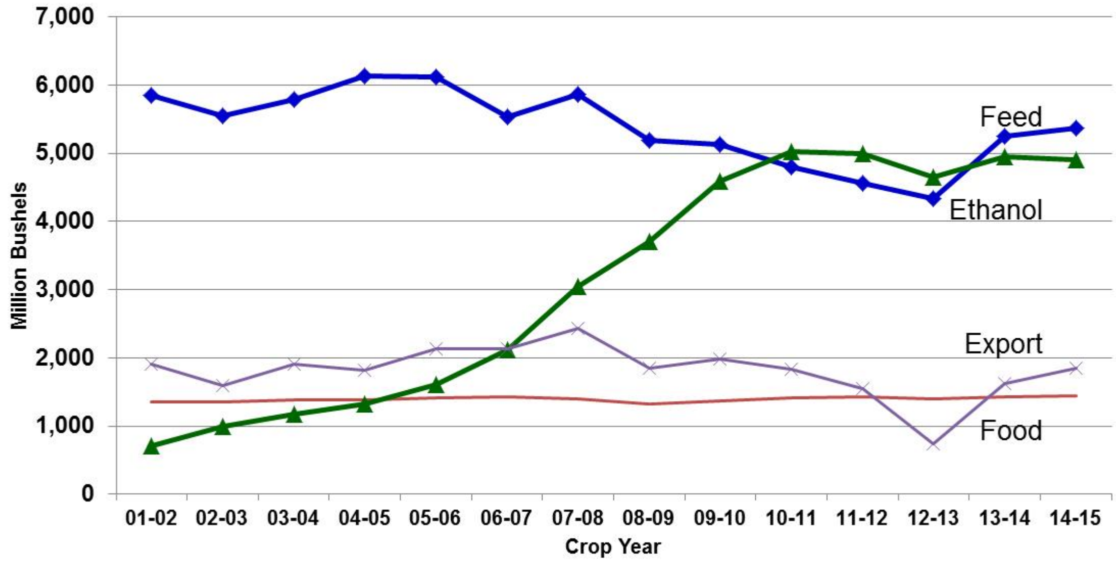

FIGURE 11 Changing U.S. agriculture shipping patterns: U.S. corn demand. (Source: Perdue AgriBusiness, LLC.)

in Argentina and Brazil in the spring give South America an advantage for exports worldwide from March through August. Corn and soybeans harvested in the United States in the fall gives the United States an advantage for worldwide exports from September through March. She suggested that this hemispheric interdependence results in an important import dynamic in which the United States can import grain from South America during March through August. She also said that it was important to remember in dealing with agricultural markets, "corn has no conscience" and that agricultural commodities will move to where price dictates.

- Clark described changes in the worldwide harvested acreage for soybeans and corn. She indicated that the total worldwide soybean harvested acreage was approximately 267 million acres. Soybean production in the United States accounts for approximately 74.6 million acres, compared to 67.9 million acres from Brazil. In comparison, the total worldwide corn harvested acreage is approximately 431.7 million acres, with the United States accounting for 87.3 million acres, Argentina accounting for 9.4 million acres, Brazil accounting for 39.5 million acres, and the Ukraine accounting for 11.1 million acres.
- Clark suggested that the agricultural supply chain can be thought of as a Rubik's Cube, with commodity, market, and transportation options. Each crop year is different based on growing conditions and crop yields. The agricultural supply chain relies on flexibility and options, as no crop year is the same. Multiple commodities are also being traded and transported, with Perdue handling over 67 different commodities. Commodity options include grains and other agricultural products. Market options include feed, processing, and export. Transportation options include truck, container, rail, barge, and ocean-going vessels. Like a Rubik's Cube, the color blocks represent these different supply chain options and the goal is to get a match of all three.
- Clark suggested that the changes in agricultural shipping patterns and the globalization of trade have implications for public-sector transportation agencies. First, the U.S. agricultural transportation system was developed to export commodities and agricultural

products that are now being imported. Focusing port, inland, waterways, railroads, and highways to support a two-way flow of bulk agricultural commodities is needed. She further suggested that all modes must work together to provide an efficient and effective transportation network.

- In conclusion, Clark discussed suggestions for maintaining freight fluidity in the agricultural market given its dynamic nature. First, she suggested that inventory management strategies should consider freight demand increases and tightening transportation capacity and the ability to hold inventory as a practical hedge again transportation constraints. Second, she suggested ways to continue to focus on achieving resiliency and flexibility in the agricultural supply chain, to avoid rising costs, congestion, and equipment shortages from crippling the supply chain. Her third suggestion was working collaboratively and collectively to develop and adapt a new comprehensive national freight transportation policy that addresses all modes. She suggested that the future economic and growth prospects from U.S. agriculture are very bright.

GROCERY STORE SUPPLY CHAINS

Ken Allen

Ken Allen discussed the supply chains for H-E-B grocery stores. He summarized the location and scale of H-E-B stores, dairy and bread processing plants, and distribution centers. He described some of the supply chains for different grocery store items and the transportation challenges the company faces. Allen covered the following points in his presentation:

- Allen noted that H-E-B is a privately held grocery retail company owned by one family. Founded in 1905, the company's headquarters are in San Antonio, Texas. H-E-B has 330 stores in Texas and 49 stores in northeastern Mexico. In 2013, H-E-B had 85,000 employees and $21 billion in annual revenues.
- Allen described the explosive population growth in Texas. The population increased from approximately 14 million people in 1980 to 27 million in 2010. Most of the growth has occurred in the major metropolitan areas of Houston, the Dallas–Fort Worth metroplex, Austin, and San Antonio, as well as south Texas. Other areas throughout the state are also experiencing population increases and continued growth is forecast. The location of H-E-B stores follows the population. The company has 49 stores in San Antonio, 33 in the Austin area, and 116 in Houston. There are also H-E-B stores in medium-to-small communities throughout the state.
- He noted that while this population growth is great for the grocery store business, the size of Texas presents a supply chain challenge. The distance across Texas from east to west is 850 mi, and 800 mi north to south. The Dallas–Fort Worth metroplex is 250 mi north of Houston and 300 mi north of San Antonio. The distance from San Antonio to Houston is 200 mi and San Antonio to south Texas is 300 mi. With the stores in Mexico, Allen reported that it is approximately 1,000 mi from the northernmost store to the southernmost store.
- Allen described the supply chains for different products H-E-B sells, which begins with the forecasting and replenishment team. These individuals monitor the movement of every item in every store on a daily basis. This information is used to forecast future inventory needs, to write purchase orders, and to manage product movement from domestic and foreign sources to H-E-B warehouses. He noted that H-E-B owns and operates 28 warehouses in six Texas cities, and in Monterrey and Mexico City. H-E-B owns and operates the two largest volume dairy plants in Texas, which are located in Houston and San Antonio. H-E-B also owns and operates

the two largest volume bread bakeries in the state, located in Houston and Corpus Christi. He noted that with monthly expenditures of $30 million, maintaining the supply chains for different items is critical.

- Allen described the mix of store sizes from large new stores in major metropolitan areas to smaller older stores in small towns. He noted that weekly sales from the smaller stores may average around only $200,000, while the new large stores, which have more complex delivery schedules and supply chains, generate about $4 million per week.
- Allen reported that the time of delivery is critical to grocery stores. Approximately 50 deliveries per store per week are from H-E-B warehouses. Beverage companies and other major product suppliers make deliveries directly to stores. Larger stores require more targeted deliveries. Deliveries too early congest traffic in a store, while deliveries too late result in empty shelves and unhappy customers. The expectation at H-E-B is 99% on-time deliveries, which is measured and reported daily to senior management. Volumes at the beginning of the month are typically 25% higher than average and holiday volumes are 35% to 40% higher than average. H-E-B stores need dependable deliveries at peak times, including holidays. He described a grand opening of a new large store, which required hourly deliveries of chicken, which was on special. H-E-B has its own fleet of semi-trucks and drivers. The fleet includes 700 tractor-power units and 3,500 trailers. H-E-B employs 1,100 drivers. The fleet travels over 100 million miles a year.
- Allen noted that the company maximizes the use of its fleet through back-haul and inbound freight management. He provided examples to illustrate the freight management system. Bread is shipped by truck from the H-E-B Houston bakery to Dallas area H-E-B stores. The trucks return to Houston with loads picked up from a Dallas area supplier, such as McCormick or Kraft Foods. Milk is shipped by truck from San Antonio to H-E-B stores in Waco with the trucks returning to San Antonio with M&M and Mars candy bars which are produced in the Waco area.
- Allen described a supply chain problem initially encountered a number of years ago. During the peak of the West Coast produce season it was nearly impossible or very expensive to find a truck available to carry a load to Texas. As a result, H-E-B formed a wholly owned subsidiary trucking company—Parkway Transport—within the company to provide “for hire” services to other entities. Approximately 150 times a week, Parkway trucks carry loads “for hire” to California and return to Texas with fresh produce for H-E-B stores. This approach provides for the dependable movement of H-E-B produce and helps manage costs.
- Allen discussed the major freeway bottleneck for H-E-B trucks in Texas: I-35 in Austin. He noted that I-35 in Austin is well known as one of the most congested highways in the country, where a crosstown trip can take anywhere from 45 min to 4 h. He indicated that this lack of dependability led H-E-B to invest in a new $100 million distribution complex in Temple just 55 mi north of Austin. H-E-B serves southside Austin stores from San Antonio, while northside Austin stores are served from Temple. This system results in far fewer trips on the congested segments of I-35 in Austin.
- Allen noted that H-E-B does use multimodal freight services for some commodities, including ocean-going vessels, rail, and air. Trucks still represent the main form of transportation, however. He suggested that given the current lack of adequate funding for needed roadway improvements, it is important to examine ways to operate the system more efficiently. He noted that H-E-B also supports new technologies, such as the Texas A&M Transportation Institute (TTI) Freight Shuttle, which is an electric fixed guideway system.
- Other approaches outlined by Allen included the use of 57-ft trailers for transporting bread in Texas, which, with a day cab, are within the 65-ft limit used in the state. He noted that

the company supports legislation at the national level allowing trucks to operate above the current 80,000 lb weight limit. He noted the company also favors increasing fuel tax rates and indexing the fuel tax to help fund critical transportation infrastructure, operation, and maintenance needs. He suggested that time lost by drivers stuck in traffic, and late deliveries, emissions, and safety concerns due to congestion represent hidden taxes.

- In closing, Allen stressed the complex and critical nature of grocery store supply chains. He noted that traffic congestion is expanding in metropolitan and urban areas throughout Texas. He also stressed the importance of the private and public sectors working together to inform policy makers at all levels of the issues facing the freight system in the United States, the importance of freight transportation to the economy, and the need for adequate funding of transportation infrastructure, operations, and maintenance.

SUPPLY CHAINS FOR HOME APPLIANCE MANUFACTURING: WHIRLPOOL CORPORATION

Michelle VanderMeer

Michelle VanderMeer discussed the supply chains at Whirlpool Corporation. She provided an overview of Whirlpool products, manufacturing and distribution facilities, and supply chains. She described the results of recent surveys of truck operators and some of the issues facing the trucking industry. VanderMeer covered the following topics in her presentation:

- VanderMeer noted that Whirlpool Corporation is the largest home appliance manufacturing company in the world. Whirlpool also has a robust portfolio in consumer packaged goods, water filtration systems, and related products.
- Figure 12 highlights the major Whirlpool facilities in the United States, which include eight manufacturing facilities, eight factory distribution centers, and nine regional distribution centers. VanderMeer agreed with other speakers that the winter of 2014 caused major transportation problems throughout the country. She noted that the five manufacturing facilities in Ohio experienced shipping delays due to the snow and ice associated with the storms. She also noted that 80% of the appliances sold by Whirlpool in the United States are made in the United States, 15% are made in Mexico, and 5% are made in other parts of the world. She indicated that the factory distribution centers have two major functions. The first is to distribute finished goods to retailers. The second is to supply the regional DCs (RDCs). She noted that some deliveries are made directly to builders. She agreed with other speakers that Austin, Texas, which has a growing housing market, is one of the most congested cities for delivery of goods by truck.
- VanderMeer described the Whirlpool distribution network highlighted in Figure 13, which includes 90 local DCs. The network has a total storage capacity of 2.5 million appliances, which requires the equivalent of 302 football fields of storage. Whirlpool also has two RDCs in Canada and four manufacturing facilities in Mexico. The company has two RDCs in Canada: one in Milton serving eastern Canada and one in Calgary serving western Canada. Manufacturing facilities in Mexico are located in Monterey, Apadaca, Celaya, and Ramos Arizpe. These plants produce appliances for both the Mexican and the U.S. markets. VanderMeer noted that the U.S.–Mexico border is a bottleneck for transporting goods. She indicated that Whirlpool leverages 30 different trading partners to maintain a diversified multimodal transportation system, which includes rail, truck, and intermodal. Crossing the border over the road is typically a 4-to-5–day

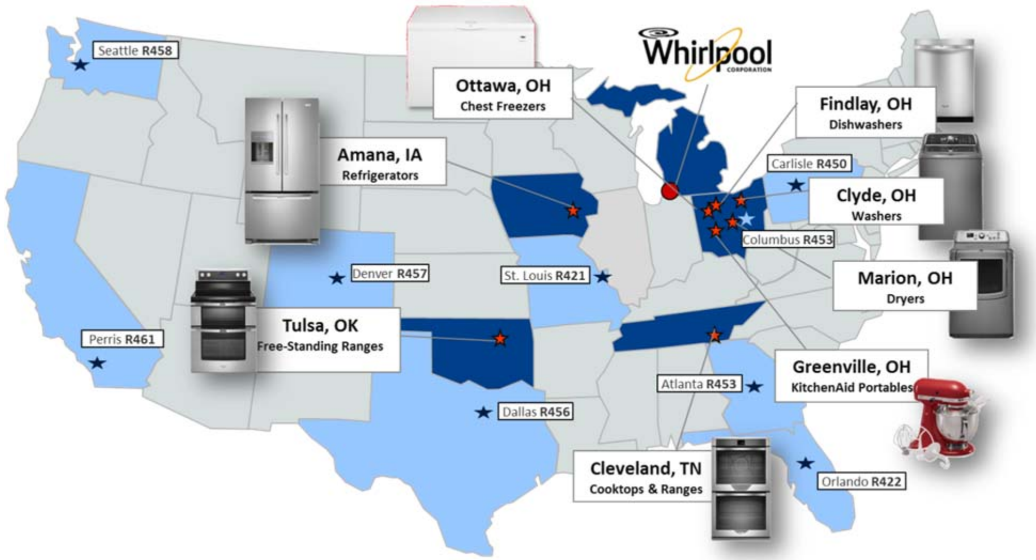

FIGURE 12 Whirlpool facilities. Dark blue states are home to manufacturing facilities and Whirlpool corporate headquarters. Light blue states are home to RDCs (Ohio is home to manufacturing facilities and to an RDC). (Source: Whirlpool Corporation.)

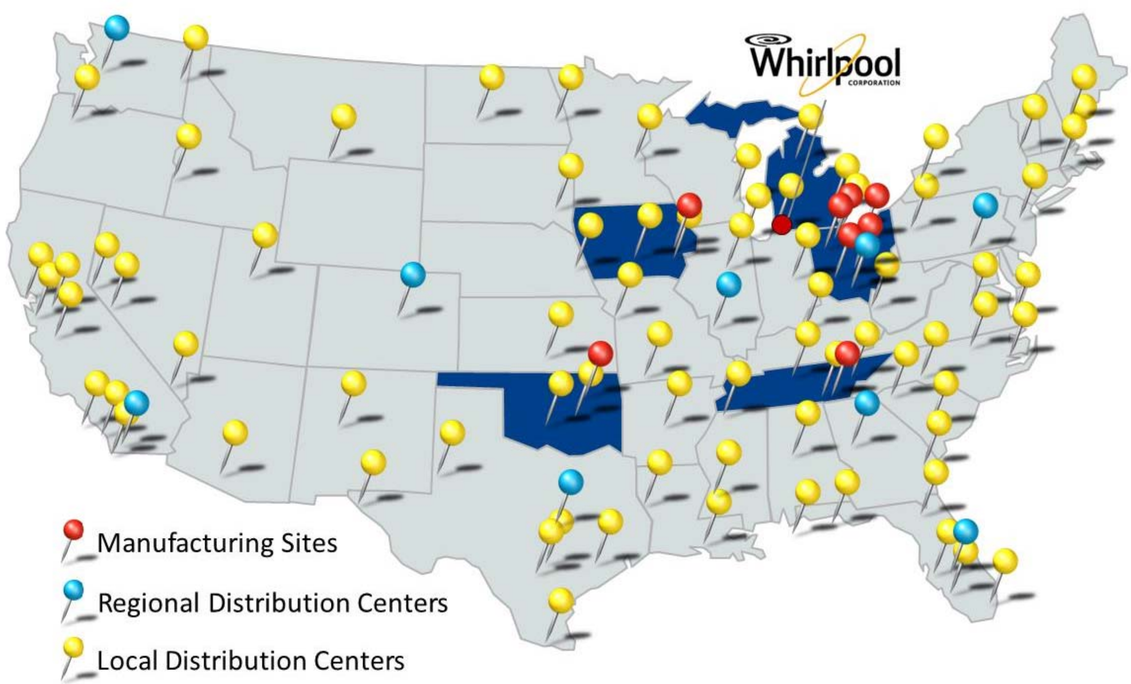

FIGURE 13 Whirlpool distribution network. Dark blue states are home to manufacturing facilities and Whirlpool corporate headquarters. (Source: Whirlpool Corporation.)

process involving customs and inspections. Whirlpool is a member of the C-TPAT and trucks use the Free and Secure Trade (FAST) lanes. Intermodal crossings take approximately 3 to4 days. She noted that the Kansas City Southern Railroad has indicated they will be able to cross the border in 1 day by the end of the year.

- VanderMeer described elements of the Whirlpool supply chain for North America operations. She noted that almost 2 billion pounds of components and raw materials are transported annually, comprising approximately 305,000 shipments. Some 30 million units are transported in 250,000 shipments. American consumers buy approximately 18 million appliances a year. Shipments from the local distribution centers are made to trade partner distribution centers, trade partner stores, builders' houses, and consumers' homes. She noted the traffic congestion in urban areas causes delays in shipments to all of these markets.
- VanderMeer discussed the results of an October 2013 survey of 3,000 truck owners–operators conducted by the American Transportation Research Institute (ATRI) of the American Trucking Association (ATA) and the Freight Transportation Leadership Academy at the the University of Memphis. The survey focused on identifying and ranking the top trucking issues. The top four issues were hours-of-service; compliance, safety, and accountability (CSA); driver shortage; and the economy. Driver retention was ranked seventh, and infrastructure funding and congestion was ranked ninth. The survey results indicate that 67% of drivers reported a decrease in pay due to the changes in hours of service. She noted that ATRI estimated the cost of the 34-h restart to the trucking industry at almost $200 million. The goal of the CSA is to reduce commercial motor vehicle crashes, fatalities, and injuries on the nation's highways. It includes peer comparisons of normalized data for seven elements: unsafe driving, hours-of-service compliance, driver fitness, controlled substances, vehicle maintenance, hazardous materials compliance, and a crash indicator. The crash indicator, which is the crash rate per power unit (with mileage considered) compared to other carriers that have similar number of crashes, is calculated.
- VanderMeer discussed driver shortage concerns, which was the third-rated issue. She estimated a 3% to 6% loss in driver capacity due to hours of service. She also noted that the average driver is 55 years old and that a shortage of truck drivers is predicted; this shortage will be due to a narrowing supply of incoming commercial driver's license-age drivers and an increasing numbers of drivers reaching retirement age. The ATA 2013 driver turnover estimates are 96% in fleets with over $30 million in revenue, 82% in fleets with under $30 million in revenue, and 11% among less-than-truck-load carriers.
- The ninth-ranked issue in the study was highway infrastructure and congestion. VanderMeer reviewed the 2013 Report Card for America's Infrastructure issued by the American Society of Civil Engineers (ASCE), which estimated $3.6 trillion in needed investments by 2020. The ASCE report found one-third of roads in poor or mediocre condition and one-fourth of bridges structurally deficient or functionally obsolete. The 2013 estimate from ATRI of the loss in trucking productivity while trucks sit idle in traffic was 141 million hours and $9.2 billion in fuel and delay. She also noted the need for risk management, which further increases transportation costs. The expedited movement of goods is expensive, especially on long supply chains. The last-mile delivery is also important from a customer service perspective. A builder or consumer who has had a bad experience with a late delivery due to traffic congestion may be less likely to purchase products from that company in the future.

Fluidity Overview and Implementation
The Canadian Experience

LOUIS-PAUL TARDIF
Transport Canada

RUSSELL T. ADISE
U.S. Department of Commerce, moderator

This session featured the development and use of freight fluidity measurements by Transport Canada.

GATEWAY AND TRADE CORRIDORS FLUIDITY INDICATOR
Louis-Paul Tardif

Tardif discussed the development and use of the freight fluidity indicator by Transport Canada. He described the interest in better understanding freight flows in Canada, the development of the freight fluidity concept, and applications examining system performance and import, export, and internal supply chains. Tardif covered the following topics in his presentation:

- Tardif noted that tracking the performance of strategic freight routes provides governments and stakeholders in Canada with impartial evidence-based information on the competitiveness of the country's supply chains. The fluidity indicator is a web-based, multimodal tool that measures the performance of individual segments of supply chains in near real-time, as well as the end-to-end transit time of freight flows. The focus is on bottlenecks and impediments along major trade corridors, with special attention to port infrastructure. He indicated that it is an interactive tool in the context of the North America marketplace.
- According to Tardif, interest in developing trade gateways and corridors in Canada emerged during 2007 and 2008. As trade volumes into and out of West Coast ports increased, so did traffic congestion and bottlenecks on the roadway system. There was a need to address these bottlenecks to maximize the Canadian governments' investments in the Port of Prince Rupert, as well as Port Metro Vancouver. He noted there was interest in developing an evidence-based system to analyze supply chains and freight movements to help grow the economic competiveness of the country. The tool had to be easily accessible by analysts for use in policy development.
- Based on information from the American Association of Port Authorities (AAPA), and the Canadian Port Authorities, Tardif reviewed the growth in North America container port traffic. As illustrated in Figure 14, Canada has increased its port traffic market share between the years of 2001 and 2012. The ports of Metro Vancouver and Prince Rupert have been responsible for most of this growth in market share.
- Tardif discussed the importance of the interaction of freight moved through the U.S. and Canadian ports and the need to consider North American trade as a whole. In 2012, approximately 3% of total laden U.S. imports and 2.6% of total freight exports came via Canadian ports. Canadian containerized imports and exports transiting through U.S. ports

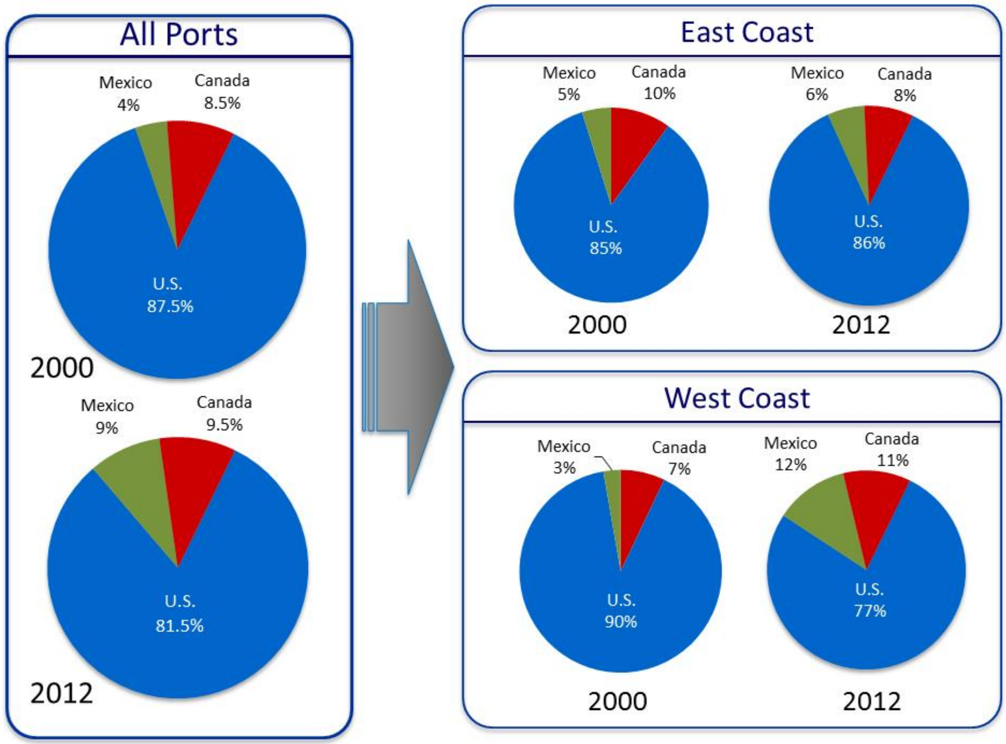

FIGURE 14 North American container port traffic market share by country, 2000 to 2012. (Source: AAPA and Canada Port Authorities.)

represented a higher share of Canadian cargo, averaging 6% and 11%, respectively in 2012. He noted that the economic benefit analysis conducted by Transport Canada indicates that every ton of containerized freight carried through a port brings in $100 to the economy. The total impact on the Canadian economy from containerized shipments is approximately $5 billion per year.

- Tardif suggested that policy makers are interested in knowing what the added value to the economy is from addressing transportation bottlenecks in the supply chain. The data from the freight fluidity measures are used to help increase wealth and to add value to the Canadian economy.
- Tardif described the examples of fluidity analyses conducted by Transport Canada. The examples included measuring and analyzing the reliability and the variability in transit times for different commodities and supply chains, identifying bottlenecks and impediments in the transportation system, and analyzing immediate and residual impacts of disruptions to the transportation network. Other examples focused on estimating wait times at border crossings between Canada and the United States and measuring the carbon footprint of freight supply chains.
- Tardif described the identification of the first end-to-end supply chain, which focused on imports from the Asia–Pacific region through the ports of Metro Vancouver and Prince Rupert. The points of origin were Hong Kong, Shanghai, Qingdao, and Tokyo. Containers were shipped through Vancouver and Prince Rupert and then sent by rail and truck to Calgary, Winnipeg, Toronto, Montreal, and Chicago. He noted that Prince Rupert has the advantage of being the shortest route to North America from Asia, with a transit time of approximately 11

days. While Metro Vancouver is the highest volume port in Canada, it has a disadvantage that it is often not the first port of call in a supply chain.

- The second supply chain identified by Transport Canada focused on imports from Europe. The ports of origin were Antwerp and Valencia, with containers shipped through Montreal. Toronto and Chicago are the two dominant destinations for these imported containers.
- Tardif described the data and the fluidity measures that are available to the public. He noted that averages are used for much of the information due to the sensitive data from rail carriers, trucking firms, shipping lines, and other modes. In presenting annual information from 2010 through 2013, he noted the impact of bad winter weather in 2013 on many supply chains. For example, the extremely cold temperatures experienced in many parts of the country required trains to be shortened and had other negative impacts on supply chains. He also noted that in 2011, South Korea lowered their transshipment rates for shipments from Asia, resulting in more shipping companies stopping in South Korea and longer transit times to Canadian and West Coast ports. He noted that the ports of Metro Vancouver and Prince Rupert are combined into a weighted average for most of the publically available data. He indicated that the 95th percentile transit time reliability results indicate issues with the marine, port, and inland portions of a trip.
- Tardif discussed some of the analyses conducted to inform policy makers. In one example, container dwell time and port throughput at the Port of Metro Vancouver were examined. A target of three days transit time was identified from the analysis. The data are re-examined on a monthly basis. When a bottleneck is identified, possible approaches for resolving the bottleneck can be identified, evaluated, and implemented.
- Tardif described the use of U.S. Customs data in the fluidity process and for better transportation planning. He noted that the Canadian government receives all of the U.S. Customs data for all imports and exports. For the past 3 years, the Canada Border Security has been providing data on all imported containers on a daily basis. Transport Canada works with partners to use the data to provide a 14-day forecast of container traffic. Numerous legal agreements were needed for this process, but the data are now available on a regular basis.
- Similar to other countries, Tardif reported that the resilience of supply chains is under continuous stress. The data set allows Transport Canada to conduct a variety of analyses of supply chains responding to various disruptions. For example, the immediate and residual impacts of disruptions on the rail network from strikes and weather events have been examined. Transport Canada can track incoming containers to railroads, allowing the detection of the full supply chain on the rail side. Information on commodities, transit time, and the impact of disruptions can be examined. He noted that this information is provided to Canadian trade representatives in China and other countries to share with customers and trading partners. Customers can then make decisions on diverting traffic, using alternative supply chains, or making other adjustments.
- Transport Canada obtains truck transit GPS travel time data from a third-party provider. Information on approximately 50,000 trucks is provided on a daily basis. Tardif offered a word of caution that the data reflect the larger fleets and operators who are more sensitive about transit times, transit reliability, and cost. The data are used to analyze travel times and trip-time reliability between major origin and destinations, as well as at border crossings with the United States.
- Tardif explained some of the challenges encountered in identifying supply chains for exports. A first challenge was the unit of measurement with exports. Unlike imports, which are largely shipped in containers, exports cover a wide range of commodities. The identification of

the first export supply chain, which focused on grain, is close to completion. Supply chains for exporting forest products, iron ore, and coal will be identified next. Estimating border wait times is needed for many exports. He suggested that from a policy perspective, narrowing the focus to address critical infrastructure for strategic commodities is important.

- Tardif described major elements of the grain supply chain from Canada to Japan, which accounts for approximately 25% of the Canadian grain export market. Grain is shipped by truck and train from the western Provinces of Alberta, Saskatchewan, and Manitoba to marine terminals at Port Metro Vancouver and the Port of Prince Rupert. From there the grain is transported to Japan and other Asian countries by ocean vessels. A second set of grain export supply chain is from Canada to Italy and Venezuela. In this case, grain is shipped by rail from the western provinces to Thunder Bay on Lake Superior. There, the grain is loaded onto ships and transported through the Great Lakes to marine terminals and transshipment ports at Baie–Comeau and Quebec City and from there to Italy and Venezuela via ship.
- Tardif explained the data and process used to analyze border wait times. Transport Canada defines border wait times as the elapsed time from the last geospatial observation before a trip enters the geofence, or the virtual perimeter, marking the border crossing to first observation when a trip exits the geofence. Trucks with wait times above 90 min are assumed to have been sent for a secondary inspection and removed from the sample. Trips where the time difference between the last geospatial observation before entering the geofence and the first one inside is greater than 15 min are also removed from the sample. A web-based approach is used to provide the wait time data to users.
- Tardif noted that the Great Lakes and the St. Lawrence Seaway are strategic elements of many North America export supply chains. Transport Canada is examining supply chains and critical infrastructure needs in these areas.
- In closing, Tardif stated that the fluidity indicator provides evidence-based information to assess and analyze the efficiency of supply chains and assists Transport Canada's work in identifying constraints in the transportation system. He noted that a future activity is to assist small and medium-sized enterprises through the Canadian Manufacturers and Exporters Association's Enterprise Project with accessing available information on supply chains. A tool, called a widget, is being developed that can be added to their web portal to provide basic supply chain information. Many small businesses do not currently have access to this type of information. He noted that the fluidity indicator provides strategic information on the resilience of Canadian supply chains by measuring the recovery rates after major disruptions. He also noted the importance of the fluidity indicator as a horizontal project serving other government departments and initiatives, including the Department of Foreign Affairs and International Trade and Development, public safety and critical infrastructure initiatives, and the various provincial governments. Tardif suggested that there is a need for more trained professionals in data analytics, especially the ability to manage and analyze Big Data. He noted that skills in these areas are in high demand.

Fluidity Overview and Implementation
The U.S. Perspective

LANCE GRENZEBACK
Cambridge Systematics, Inc.

JOSEPH BRYAN
Parsons Brinkerhoff

JEFF SHORT
American Transportation Research Institute

KENNETH NED MITCHELL
U.S. Army Corps of Engineers

JUAN CARLOS VILLA
Texas A&M Transportation Institute

NICOLE KATSIKIDES
Federal Highway Administration, moderator

Speakers in this session highlighted freight fluidity applications in different settings and with different modes in the United States.

FREIGHT PERFORMANCE MANAGEMENT AND MEASUREMENT ACROSS MULTISTATE JURISDICTIONS: SUPPLY CHAIN CASE STUDIES
Lance Grenzeback and Joseph Bryan

Grenzeback and Bryan discussed a study conducted for the I-95 Corridor Coalition developing and applying a methodology to examine supply chains for different commodities and different geographies. They described the study objective, methodology, and preliminary results. They also noted some of the issues encountered in conducting the analysis. Grenzeback and Bryan covered the following topics in their presentation:

- Grenzeback reviewed the project objective, which was to demonstrate the measurement of freight transportation performance using a supply chain perspective. He noted that other sponsors, in addition to the I-95 Corridor Coalition, were the U.S. Department of Commerce Advisory Committee on Supply Chain Competitiveness and the FHWA Office of Freight Management and Operations. Grenzeback suggested that the use of the freight fluidity measures, as well as other related measures, could refocus transportation investments targeted to those benefiting economic development and the economy.
- The study included five supply chain case studies focusing on retail, automotive, food processing, agricultural, and electronic products. The retail case study examined transporting Target consumer goods from the Port of Seattle and the Ports of Los Angeles and Long Beach to

New York by rail via Chicago. The automotive case study focused on the movement of General Motors automobile parts by truck from suppliers in Canada and by rail from suppliers in Mexico to the General Motors automobile assembly plant in Spring Hill, Tennessee. The food case study examined transporting Perdue processed chicken by truck from facilities on the DelMarVa Peninsula through a consolidation center in Delaware to a wholesale distribution center in New York City. The electronics case study examined the movement of Panasonic electronics by truck between manufacturing and assembly facilities in San Diego and Tijuana, Mexico. The agricultural case study examined transporting soybeans from Illinois farms to a Louisiana port for export by barge.

- Grenzeback noted that the study was not intended to duplicate supply chain data available to the various companies. Rather, the intent was to assess if available public-sector data could be used to identify major supply chains and possible bottlenecks in the transportation system. The scope focused on examining the performance of overall supply chains and the public and quasi-public links and nodes, including ports, highways, railroads, and airports. It did not include the private-sector manufacturing, warehousing, or distribution nodes. He noted that the focus was on using measures and metrics that were common across supply chains and that provided the ability to examine some elements in more detail. He also indicated the study was intended to address the high-level performance of representative supply chains to inform national policy.
- Grenzeback reviewed the five performance measures and metrics used in the study. The first measure was transit time, with the related metric of travel time in days or hours. The second measure was reliability, with a metric of 95% travel time in days or hours. The third measure was safety, with the fatality and injury rates as the metric. Cost was the fourth measure, with the dollar amount as the metric. Risk was the fifth measure. Cargo loss and damage, disruption, and capacity expansion delays are the three metrics with this measure.
- Bryan reviewed the retail and automotive case studies. He discussed Figure 15, which illustrates examples of freight flows for Target. Goods are imported through the Port of Seattle and the Ports of Los Angeles and Long Beach. He noted that representatives from Target indicated that using multiple ports was part of their risk management portfolio. As shown in the insert, goods are unloaded at the Port of Seattle and taken to an import distribution center and then to an intermodal yard by truck. From there, the goods travel to Chicago by rail. At Chicago there is a change to an eastern railroad, which travels to an intermodal terminal in the Harrisburg, Pennsylvania, area. From there the goods are trucked to a regional distribution center where they are staged for delivery to stores in the east by truck.
- Bryan commented there are numerous stages in the supply chains from the West Coast ports to the eastern stores. In addition, he said that risks, exposures, and delays are possible at every stage, especially the connections in urban areas, such Chicago. As other speakers mentioned, he noted that reducing the number of stages or links in a supply chain is often not possible.
- Bryan described the analysis of the transit time and reliability measures for the truck portion of the retail supply chain. Table 1 presents the analysis for the supply chain using the Port of Seattle as an example. He indicated that the transit time was obtained using Google Maps and the TTI's Urban Mobility Report. The transit time reliability metric for the truck portions of the trip in Seattle and from the east coast distribution center to stores reflect traffic congestion in those areas. The planning time index contained in Table 3 of the Urban Mobility Report was used to calculate the reliability measure. A similar table was developed for the Ports of Los Angeles and Long Beach. Bryan reported that work is underway to estimate the rail travel times.

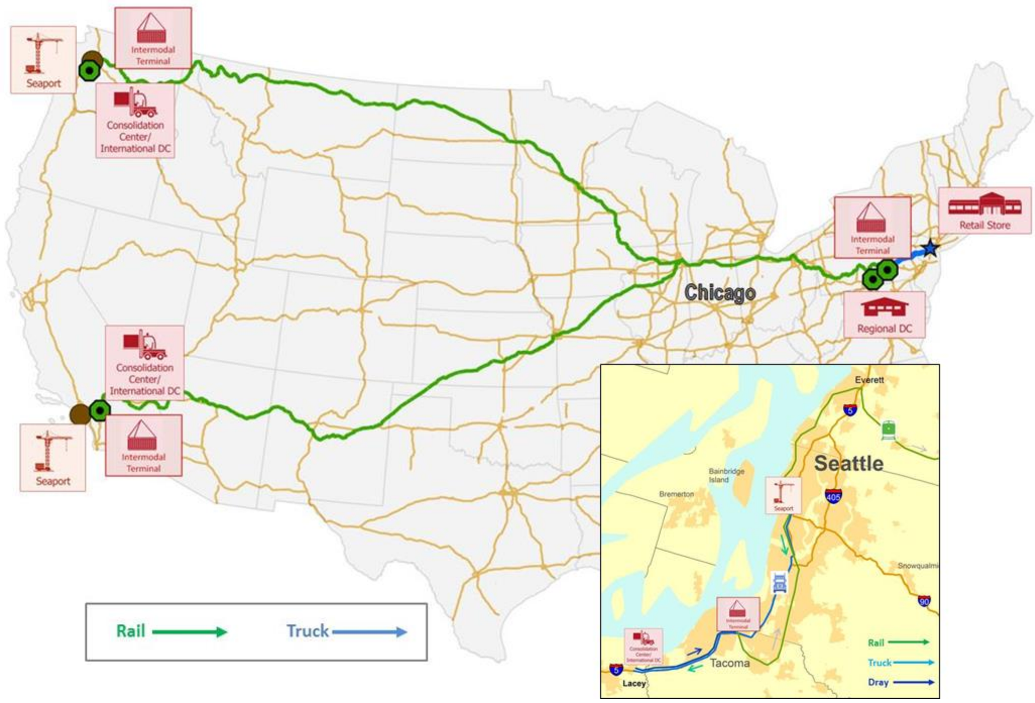

FIGURE 15 Examples of Target retail supply chains. (Source: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.)

TABLE 1 Retail Supply Chain Measures: Port of Seattle Case Study

Links and Nodes	Transit Time/Dwell Time (hours)	Reliability (95% travel time)
West Coast port (Seattle)		
Dray move	1.1	4.3
Transload or Consolidation Center		
Dray move	0.8	3.3
West Coast rail intermodal terminal		
Rail move		
Midwest rail intermodal interchange		
Rail move		
East Coast rail intermodal terminal		
Dray move	1.0	2.7
East Coast Regional Distribution Center		
Truck P&D move	3.5	6.5
Retail store		
Totals		

NOTE: Total figures for transit and dwell time and for reliability are being analyzed and have not been added to this table.
SOURCE: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.

- The automotive supply chain case study focused on transporting automobile parts from suppliers to the General Motors Assembly Plant in Spring Hill, Tennessee. Two supply chains were examined. Since the vehicle being manufactured in Tennessee uses the platform of a vehicle produced in Canada, a number of Canadian suppliers provide parts to the Spring Hill facility. Parts from a Tier 1 supplier in Mexico are also used at the plant. The Ontario shipments are by truck, while the Mexico shipments are by rail and truck.
- Figure 16 illustrates the supply chain from Ontario. Trucks from the Tier 1 supplier in Ontario cross the Ambassador Bridge to enter the United States. The transit times and reliability measures used in the analysis are based on truck travel time data from the ATRI. Bryan noted the benefit of using the ATRI data is that it reflects actual truck movements following the appropriate route. As presented in Table 2, the analysis presents the transit time in two ways—total transit time from Canada though to Spring Hill, and transit time to Spring Hill starting from the international crossing—in order to help isolate the border crossing time on the international bridge.
- Bryan described Figure 17, which illustrates the variability in trip time for trucks traveling between Ontario and Spring Hill. He noted that it indicates the impact of the hours of service regulation on the 567-mi trip. The travel time for the trip with no delays is approximately 10 h, which is within the normal 11-h day for a truck driver. Drivers experiencing delays and those who have been driving prior to beginning this trip will reach the 11-h limit and will need to stop for a rest break, resulting in a longer trip. As illustrated in the figure, the greatest frequency of trips is reported to be 20 and 21 h.

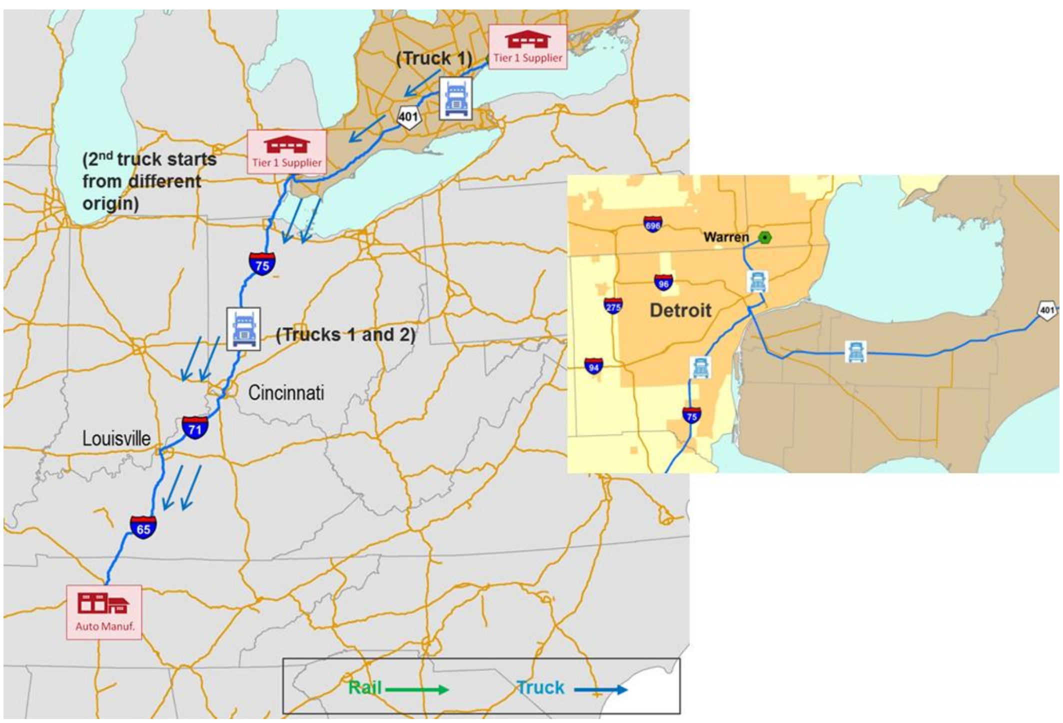

FIGURE 16 GM automotive supply chain example: Ontario to Spring Hill by truck. (Source: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.)

TABLE 2 Automotive Supply Chain Measures: Ontario to Spring Hill

Links and Nodes	Transit Time/Dwell Time (days)	Reliability (95% travel time)
Parts supplier plant, Chatham, Ontario		
Truckload move (through)	20.3	28.5
General Motors plant, Spring Hill, Tenn.		
Totals	20.3	28.5
Parts supplier plant, Chatham, Ontario		
Truckload move		
International border crossing	⬇	⬇
Truckload move	*17.6*	*24.5*
General Motors Assembly Plant, Spring Hill, Tenn.		
Totals		

NOTE: Total figures for transit and dwell time and for reliability are being analyzed and have not been added to this table.
SOURCE: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.

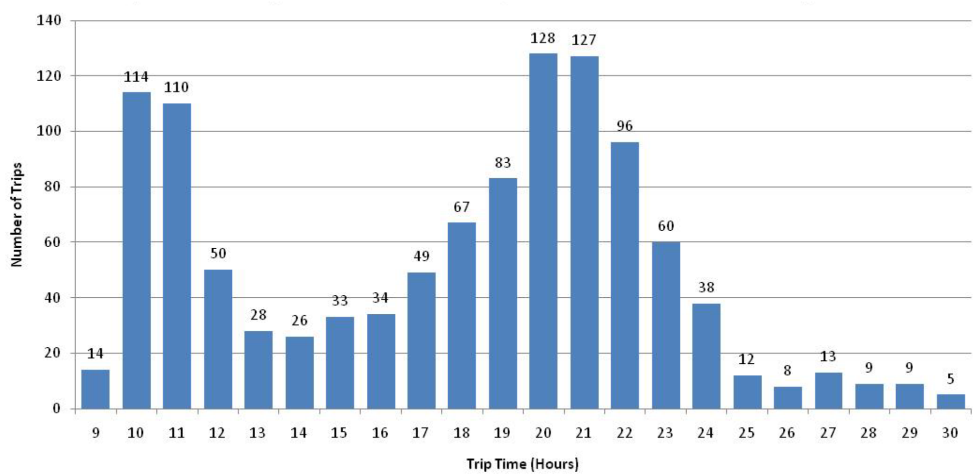

FIGURE 17 Trip time analysis: Ambassador Bridge to and from the Tennessee Assembly Plant. (Source: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.)

- Figure 18 illustrates the second freight flow to the Tennessee GM Assembly Plant described by Bryan. In this example, parts are shipped by the Kansas City Southern Railroad from a Tier 1 supplier in Mexico, though Laredo, Texas, to Kansas City, Missouri. The parts are transferred to trucks in Kansas City for the trip to Spring Hill. He noted that information on the portion of the trip in Mexico, which included truck, an intermodal terminal, rail, and the international border crossing at Laredo, was not available. The trip from Kansas City to Spring Hill by truck is approximately 9 h. When the TTI factors for delay in Kansas City and St. Louis, Missouri, and Nashville, Tennessee, are factored in, however, the trip time exceeds the 11-h service requirement limit, which means it may take an extra day to reach Spring Hill for some trucks. The 95% travel time reliability measure for this segment was 24.1 h, reflecting the potential for delays. He noted that this example illustrates the importance of understanding the potential impacts of traffic delays on supply chains and economic productivity.

FIGURE 18 General Motors automotive supply chain example: Mexico to Spring Hill by rail and truck. (Source: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.)

- Grenzeback reviewed the processed food supply chain example illustrated in Figure 19. The example focused on transporting processed chicken from Perdue facilities across the DelMarVa Peninsula to a consolidation facility in Delaware, and on to a distribution facility in New York. He noted that the National Performance Measure Research Data Set, which is provided by HERE, was used in this analysis. HERE, formerly Ovi Maps and Nokia Maps, is a Nokia business unit that combines Nokia's mapping and location assets under one brand. The data includes travel times by highway links throughout the country. The total transit time for trucks in this case study was 5.3 h, with a 95% reliability travel time of 6.2 h.
- The electronic supply chain example described by Grenzeback focused on the movement of Panasonic electronic parts from a production facility in San Diego by truck across the California–Mexico border at the Otay Mesa International Border Crossing to an assembly production facility in Tijuana. The finished products are shipped by truck back through the Otay Mesa Border Crossing for distribution throughout California and the country. In light traffic, it takes approximately 6 min for trucks to travel from either San Diego or Tijuana to the Otay Mesa International Border Crossing. Crossing the border can take anywhere from 1 to 3 h. The travel time northbound is generally significantly longer than the travel time and delay southbound.

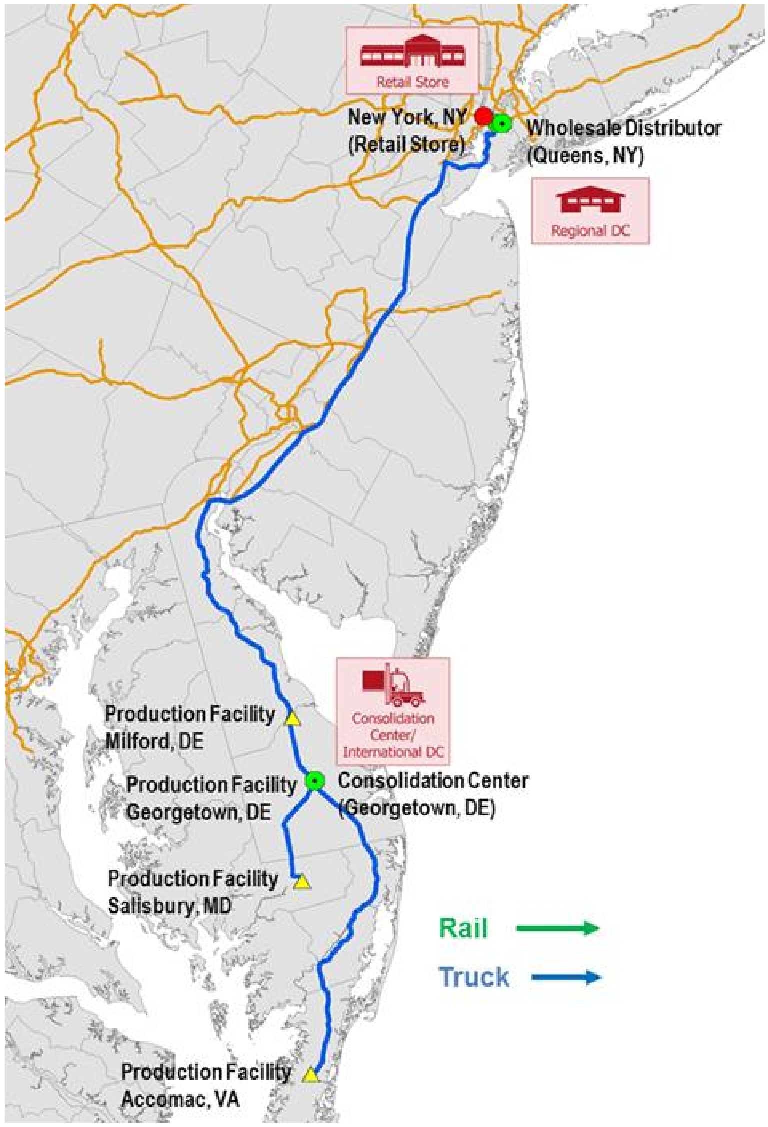

FIGURE 19 Processed food supply chain example: Perdue Chicken. (Source: Prepared by Cambridge Systematics, Inc., and Parsons Brinckerhoff for the I-95 Coalition.)

- The final case study was the agricultural export supply chain transporting soybeans from farms around Peoria, Illinois, by barge to ocean-going ships loaded in south Louisiana. Grenzeback noted that soybeans grown within 70 to 100 mi of a navigable river are typically shipped by barge, while soybeans grown in other areas are most often shipped by rail to a West Coast port. In this example, the transit time for trucks from the farm to the ADM–Growmark Terminal Wharf Port facility in Peoria is a little under 1 h. Using the TTI Mobility Report for small urban areas, the reliability transit time is 1.7 h. Based on data from the U.S. Army Corps of Engineers (USACE), the barge transit time from Peoria to the Cargill Loading facility in Reserve, Louisiana, is 8.2 days, with a reliability transit time of 14.5 days.
- According to Grenzeback, the case studies show that the high-level performance of representative supply chains for different industries and different geographies can be measured.

He further suggested that the results of these analyses would be beneficial in the public-sector transportation planning, programming, and project-selection processes and in operations and maintenance. He indicated that the key measures and metrics are common across supply chains and can be scaled for national, multistate, and metropolitan use. Travel time and travel-time reliability are available from public and private sources, though some additional data manipulation is currently needed. He noted that safety data are available, but not readily accessible for highway segments. Cost data can be purchased from private suppliers. Risk data can be estimated, but are not readily available to the public sector.

- Grenzeback discussed some of the data issues identified during the study. Developing common definitions and approaches, such as using hours or days for travel times, and using continuous, periodic, seasonal, or historic data represents one set of issues. Data availability, access, costs, reliability, and validity were a second set of issues highlighted during the study. He noted that urban freight stages, including transfers, deliveries, and pick-ups are important to capture and are generally less readily available than intercity data. Developing appropriate risk measures based on available data was also identified as an issue.
- Application issues discussed by Grenzeback included the scope and scale of public-sector supply-chain analyses. The approach in the study was to focus on a representative market basket of supply chains. He suggested that discussing the number of industries, supply chains, and geographies needed to provide bellweather measures for public policy at the national, state, regional, and local levels would be beneficial. Possible public-sector applications of the supply chain data include inventory and diagnostics for the conditions and performance reports, planning and programming for freight plans and programs, and performance management. A possible private-sector application suggested by Grenzeback was competitive benchmarking.

THE U.S. PERSPECTIVE: COASTAL PORTS AND INLAND WATERWAYS
Kenneth Ned Mitchell

Mitchell discussed available marine transportation data for use in monitoring the performance of coastal ports and inland waterways and developing freight fluidity measures. He described the roles and responsibilities of the USACE and the different data sources. He presented examples of analyses using various data sets. Mitchell covered the following topics in his presentation:

- The USACE is tasked with maintaining the navigational channels, locks, and dams of the inland waterway system, and coastal ports through dredging and other projects. The inland waterway system includes approximately 200 inland locks and dams.
- Mitchell reviewed the elements of the marine transportation data spectrum. On one end of the spectrum is reported data from shippers or carriers and at the other end of the spectrum is data derived from direct observations of vessels in transit. Data from the U.S. Customs, commercial providers such as the Port Import–Export Reporting Service, and reporting from inland barge companies provide examples of reported (i.e., not directly observed) data. The USACE Lock Performance Management System (LPMS), which records information on all vessels traveling through USACE-maintained locks, is in the middle of the spectrum, with some direct observation and limited visibility into commodities being carried. The Automatic Information System (AIS) is an example at the direct-observation end of the spectrum, with

information transferred between vessels, ship-to-shore, and shore-to-ship. He noted that mining the archived data in AIS is just being initiated by the USACE.

- Mitchell described some of the tradeoffs with the different data sets. The reported manifest datasets provide very rich data with detailed information on the vessel and the commodities being shipped. The directly observed data provide less detail on commodities, but richer data on operating characteristics including vessel speed and channel measurability issues. He commented that no individual dataset is perfect and that combining data sets can provide a more comprehensive picture of water-borne commerce and supply chains.
- Mitchell explained the elements of the AIS. The U. S. Coast Guard (USCG) mandates that commercial vessels in U.S. coastal waters have and maintain AIS as part of a maritime domain awareness system. While the AIS is not currently required for vessels on the inland waterways, many vessels are using an AIS, which uses a 6-s sampling rate. Uses of the system, which include situational awareness, navigation information, and monitoring and operating, are highlighted in Figure 20. He noted that, as reflected by the mandate, the USCG is focusing on the coastal waters. The USACE has been locating AIS towers at inland locks to obtain data at inland navigation locks. The USACE has a data-sharing memorandum of understanding with the USCG that allows common storage and access to archived data via web services. He reported that the USCG retains data for at least 3 years.
- Mitchell indicated that the aggregated AIS records provide a direct way of observing complex marine transportation system behavior and usage patterns. He said that the USACE was just beginning to analyze the archived and current AIS records. Analyses to date have focused on traffic density, origin–destination travel times, dwell and wait times at locks, fleet movements and seasonal variations, system response to disruptions, and incident investigations. He presented examples of these analyses.
- Mitchell highlighted vessel traffic density patterns, which are created by plotting on a map the spatial densities of the received reports. Origin–destination travel times represent another basic analysis. He noted that developing dwell times and wait times are a little more

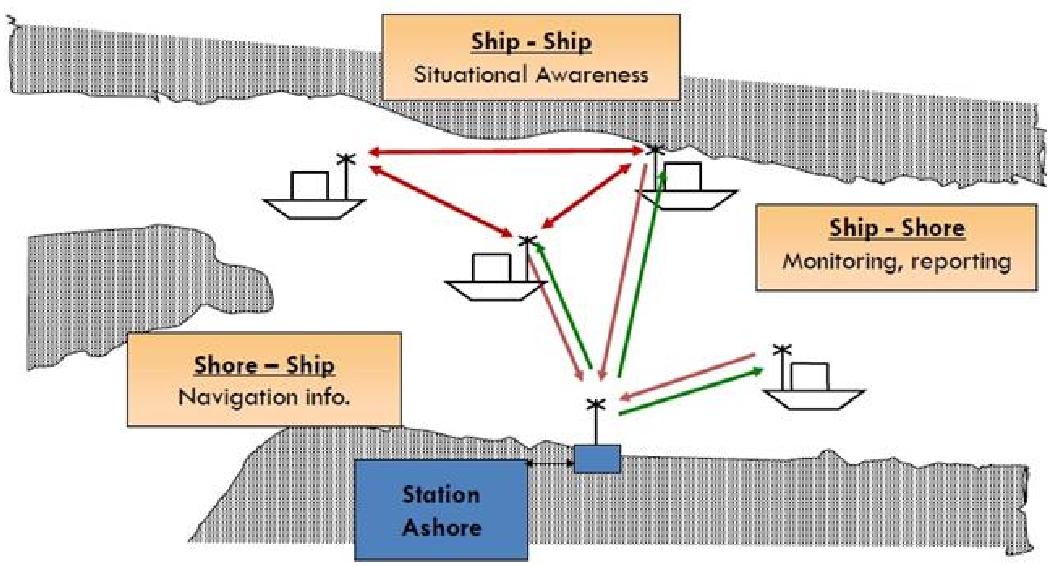

FIGURE 20 AIS components and uses. (Source: USACE.)

complicated. He also commented that examining seasonal variation on fleet movements was in the early stages, as was assessing the system response to disruptions. One example he cited was an out-of-service lock chamber on the Ohio River, which caused a major disruption. While the LPMS previously provided information on wait times at locks and dams along the Ohio River, the AIS provides origin-to-destination travel times, including the measuring of the improvement of the out-of-service lock chamber.

- Mitchell described Figure 21, which highlights average daily vessel speeds on the Great Lakes system. He noted that the observations were based on approximately 200 vessels over a 3-year time period. The impact of the lakes icing over in the winter months is highlighted by the shaded areas. He further noted that the data is scalable to focus on small areas, such as one lock, or a major section of the inland waterway system. Travel times can be calculated for various links and the full system.
- Mitchell described travel time and dwell time analysis, which is similar to the fluidity analysis, but there are some fundamentally different data processing steps. It provides the capability to set performance baselines and also monitor performance going forward. The analysis provides travel time variability (i.e., reliability), not just mean values. He illustrated the ability to analyze the impact of a recent collision at the Port of Galveston.
- In summary, Mitchell noted that the archived AIS data can be used to set freight fluidity baselines for the inland waterway system, as well as coastal port systems. The system monitoring capability is the real breakthrough, however. It provides actual origin–destination travel times, as opposed to point-specific delays and slowdowns. It further helps fill the need for better voyage planning tools for inland waterway performance improvements identified by industry stakeholders. He indicated that the capability is still needed to factor in river stages, weather conditions, and traffic congestion delays in order to predict travel times 3 to 10 days out.
- In closing, Mitchell indicted that developing a means of evaluating the performance of the entire intermodal freight supply chains was the ultimate goal. He suggested that the opportunity exists to merge AIS and GPS probe data sets with traditional reported data to

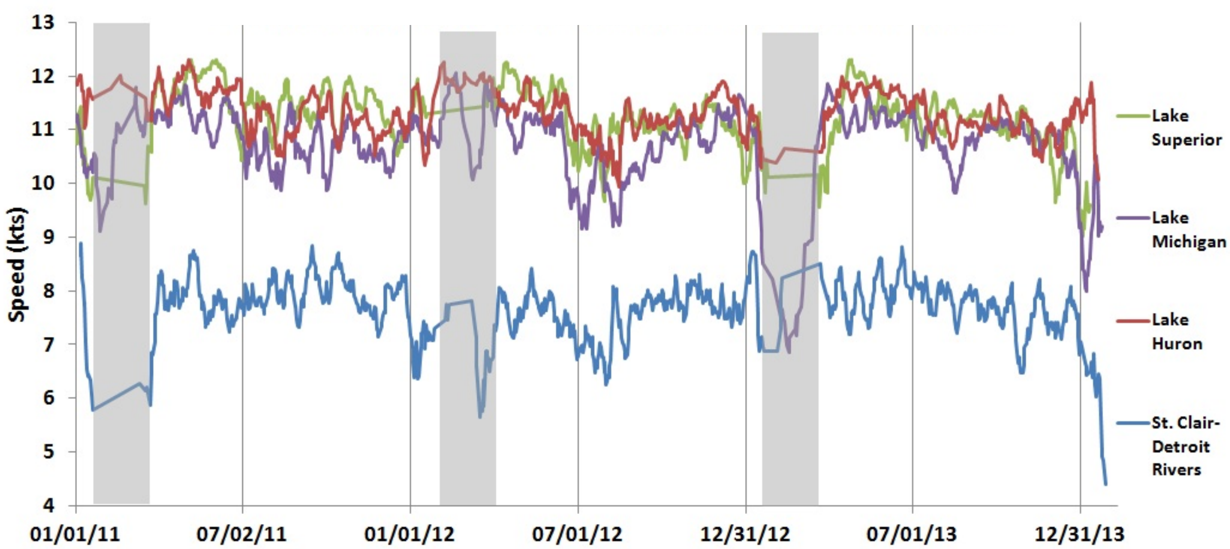

FIGURE 21 10-day moving average of daily vessel speeds for the Great Lakes system. (Source: USACE.)

provide a more complete picture of intermodal freight fluidity. From a USACE perspective, Mitchell noted that considering how the fluidity monitoring system can help inform dredging decisions and navigation lock operations and maintenance was the motivation behind this research.

TRUCK GPS DATA FOR TRACKING FREIGHT FLOWS

Jeff Short

Short discussed the application of truck GPS data to analyze freight flows. He highlighted the use of truck GPS data for different planning and analysis applications. He also described the results of the 2013 ATRI survey of truck owner–operators. Short covered the following topics in his presentation.

- Short explained that ATRI is part of the American Trucking Associations and is a nonprofit research organization. He noted that ATRI's research focuses on all aspects of trucking. He described the role and members of ATRI's Research Advisory Committee and Board of Directors.
- Short indicated that ATRI has access to and maintains a number of unique and anonymous trucking industry data sets, including operational and economic, finance, GPS and performance, and safety data. He noted that his presentation focused on GPS data from trucks.
- Short reviewed the 2013 top industry issues from the ATRI survey of truck owner–operators, which Michelle VanderMeer from Whirlpool also highlighted in her presentation. He connected some of the issues to the freight fluidity discussion. He suggested that the new hours-of-service regulation means less flexibility for some drivers' schedules and more daytime driving, which may add to congestion in urban areas. He further suggested that the issues related to the shortage of drivers and driver retention may be linked in part to congestion. The survey results also highlighted the need for efficient access to truck parking, and matching truck parking availability to hours of service requirements. He noted that congestion wastes fuel, which relates directly to fuel costs.
- Short described the cooperative relationship between ATRI and FHWA that uses ATRI truck GPS data for a variety of purposes. The scope of the GPS data has expanded over the years, from five corridors and GPS reads every 90 min to almost universal coverage every 30 s. He noted ATRI collects approximately 1 billion truck position reads every 1 to 2 weeks. A great deal has been invested in collecting, storing, processing, and analyzing the data, and turning the data into useful information.
- Short highlighted examples of using the truck GPS data for different purposes. Figure 22 illustrates the average weekday afternoon peak period truck speeds on the Interstate system in January 2011. The analysis highlights the segments experiencing congestion, which are primarily in the major metropolitan areas. He reported that ATRI also compiles a bottleneck report, which focuses on the most congested links. He described Figure 23, which illustrates truck flows from Miami over a 7-day period and noted it is possible to examine these types of data in more detail. These data were used in an automotive plant case study described earlier, including obtaining the truck travel times across the Ambassador Bridge.
- Short described Figure 24, which presents truck travel time data between Orlando and Tampa, Florida, for January, February, and March 2012. The results indicate the impact of

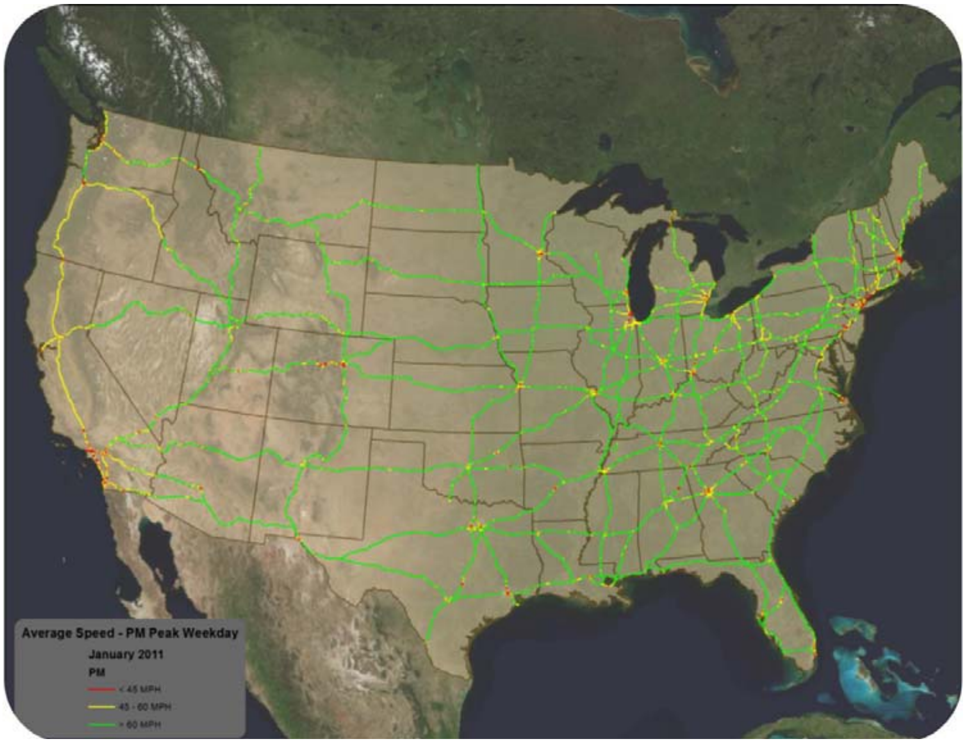

FIGURE 22 Average weekday afternoon peak period truck speeds on the Interstate system, January 2011. (Source: ATRI.)

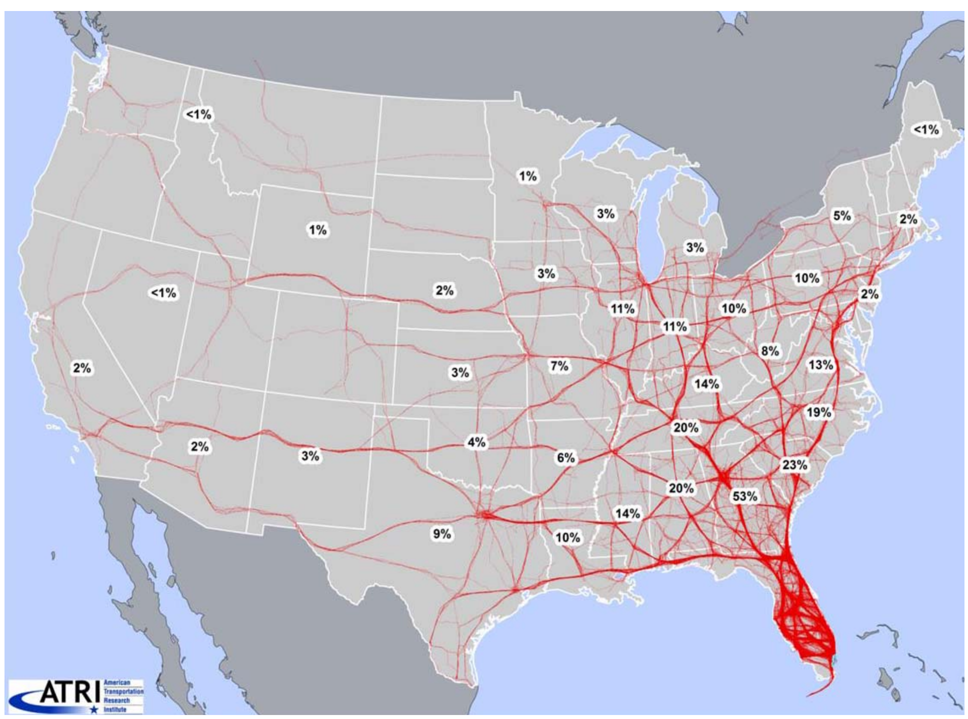

FIGURE 23 Truck flows from Miami during a 7-day period. (Source: ATRI.)

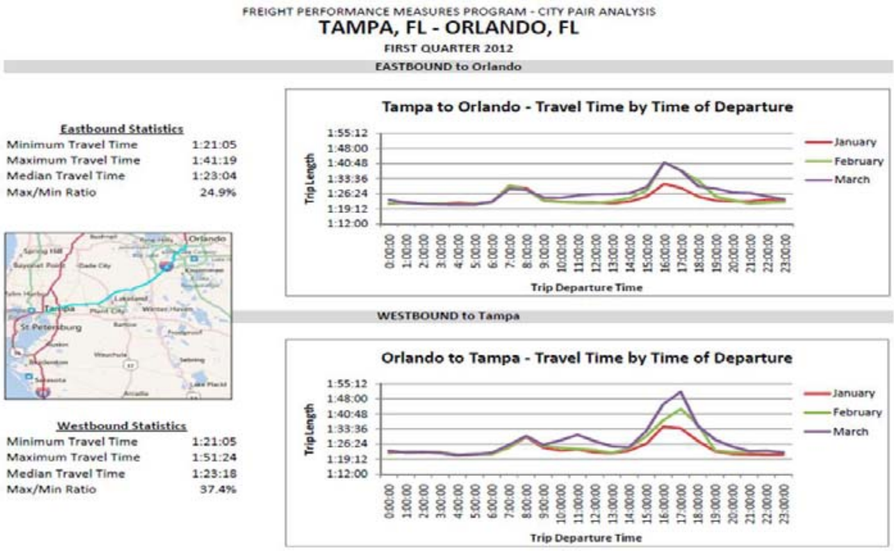

FIGURE 24 Truck travel time data between Orlando and Tampa for January–March 2012. (Source: ATRI.)

congestion levels in the peak periods on travel times, especially in the afternoon peak period. In particular, the chart shows the ideal time for leaving the origin city.

- Short discussed Figures 25 and 26 which present the truck freight flows on I-40 along the border of North Carolina and Tennessee before and after the closing of the freeway due to a major rockslide. Trucks had to detour around the closed Interstate section for approximately 6 months. The detour added 83 mi to the trip, resulting in increased travel time and costs.

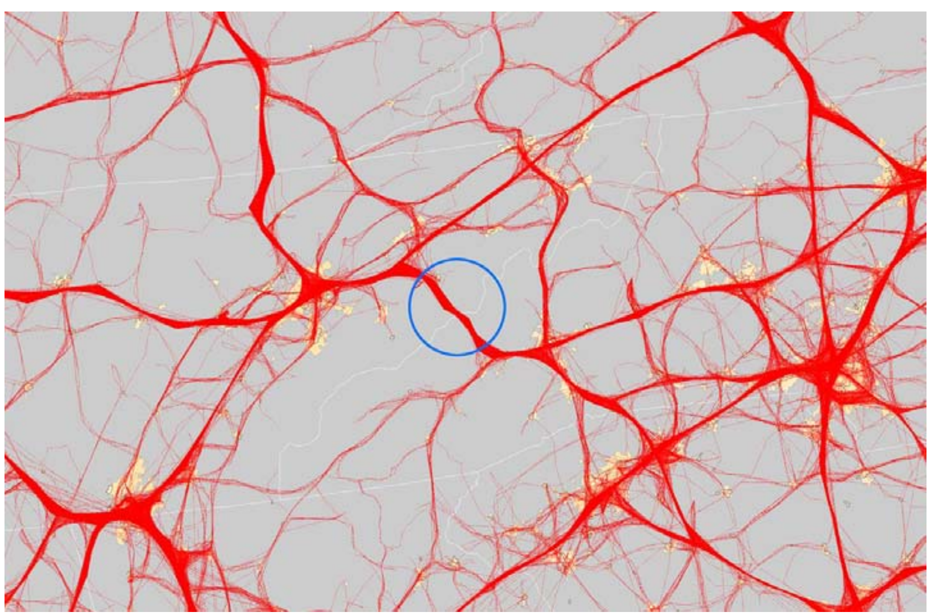

FIGURE 25 Truck flow analysis before I-40 rockslide. (Source: ATRI.)

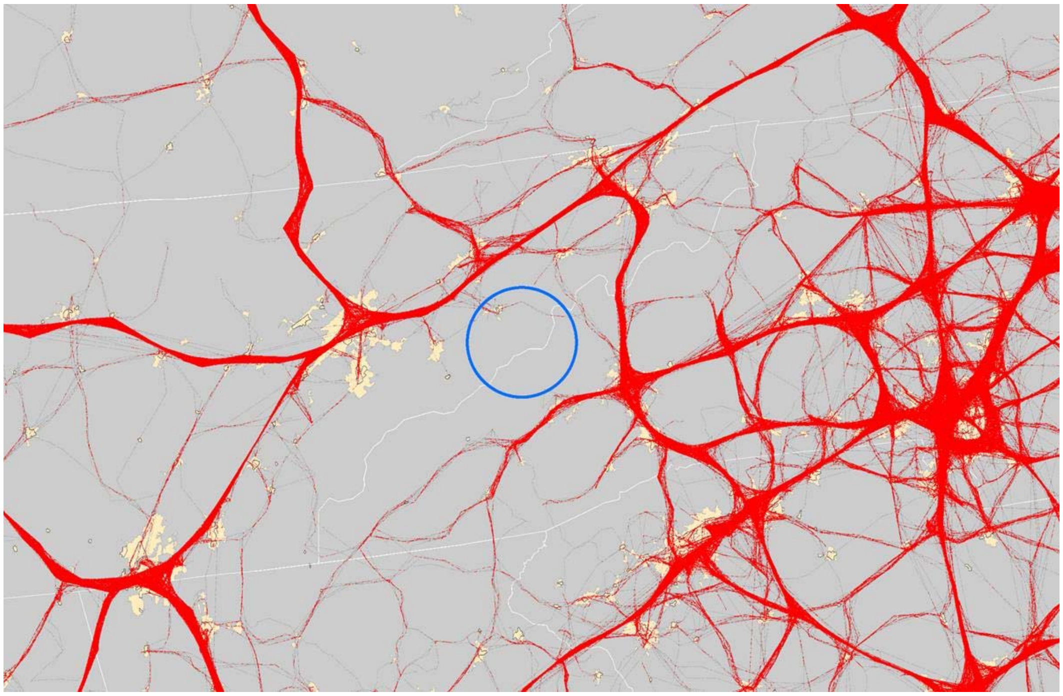

FIGURE 26 Truck flow analysis after I-40 rockslide. (Source: ATRI.)

- Short described the impact of a bridge collapse on I-5 near Mt. Vernon, Washington, on May 20, 2013. The bridge was temporarily reopened June 19, 2013, and permanently repaired on September 15, 2013. As illustrated in Figure 27, the cost of congestion in Mt. Vernon during the period the bridge was closed was significant. Other examples highlighted by Short included a case study of freight flows for high-technology industries in Portland, Oregon, and an annual cost of congestion report, which included an analysis of the cost of congestion by state and metropolitan area, and the cost per mile for different segments.

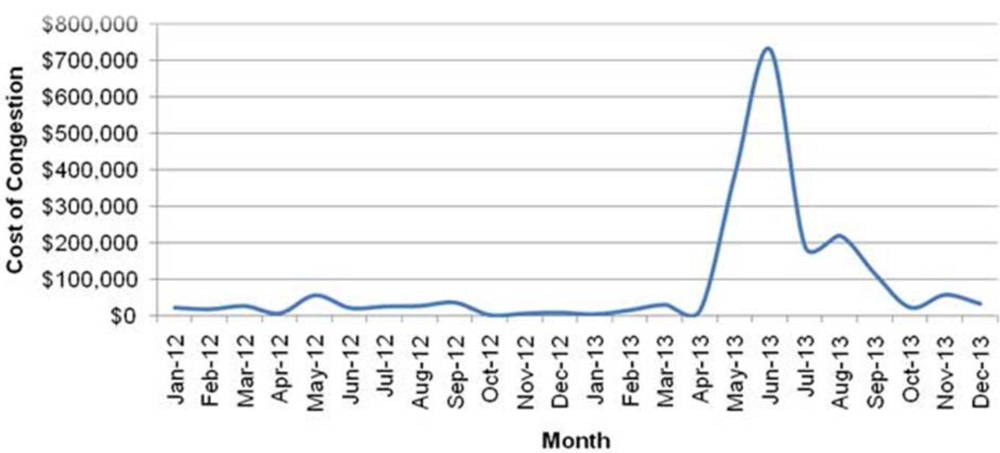

FIGURE 27 Monthly cost of congestion: Mt. Vernon metropolitan area. (Source: ATRI.)

THE U.S. BORDER PERSPECTIVE
Juan Carlos Villa

Juan Carlos Villa discussed the operations of the land border crossings between the United States and Mexico and the United States and Canada, the development of land border crossings performance measures for commercial vehicles at the Texas–Mexico border, and the challenges and opportunities associated with additional research, pilot tests, and full deployment. Villa covered the following topics in his presentation:

- Villa discussed the importance of trade and freight flows between the United States and Mexico and the United States and Canada. Figure 28 illustrates the growth in commercial vehicle crossings from Canada and Mexico into the United States from 1995 to 2011. He noted that approximately 10.5 million commercial vehicles crossed the borders from Canada and Mexico into the United States, This cross-border trade accounts for approximately $50 billion in trade on a monthly basis. As highlighted in Figure 29, he also noted that land border truck crossings from Mexico to the United States grew from 2.8 million in 1995 to more than 5 million in 2012. These figures represent a 3.5% annual average growth over the 17-year period. Thus, Villa noted, both the volume and value of cross-border trade has been increasing.
- Villa described the current process for commercial vehicles entering the United States from Mexico and some of the challenges associated with this process. As illustrated in Figure 30, there are three potential inspection points and multiple stakeholders at each border crossing. The three possible inspection points are the Mexican Export Lot, the U.S. Federal Compound, and the

FIGURE 28 Commercial vehicle crossings from Canada and Mexico into the United States. (Source: U.S. DOT, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Border Crossing–Entry Data; based on data from U.S. Department of Homeland Security, Customs and Border Protection, OMR database.)

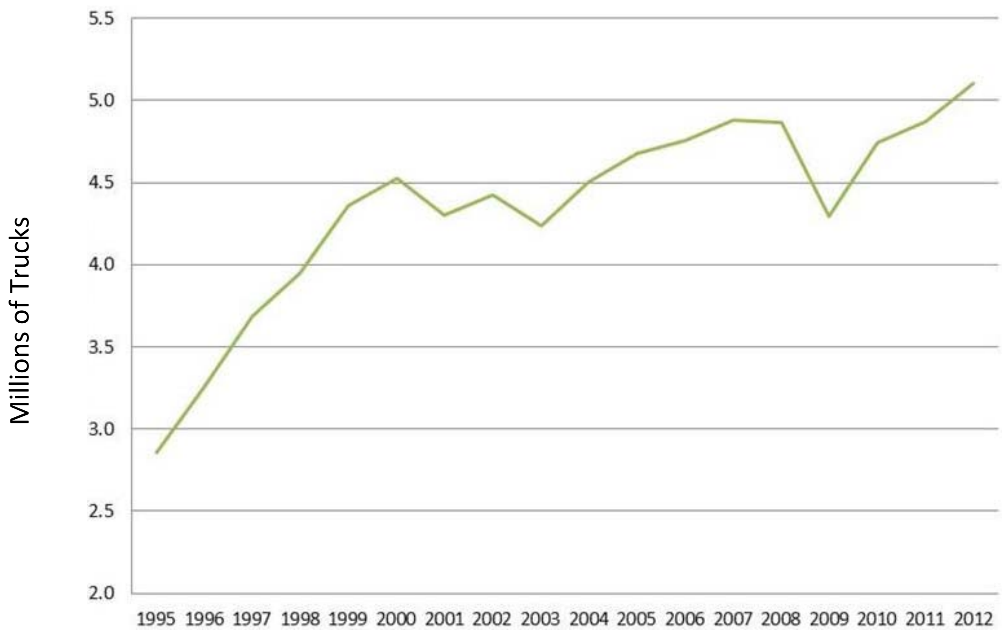

FIGURE 29 Truck crossings from Mexico into the United States (millions). (Source: U.S. DOT, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Border Crossing–Entry Data; based on data from U.S. Department of Homeland Security, Customs and Border Protection, OMR database.)

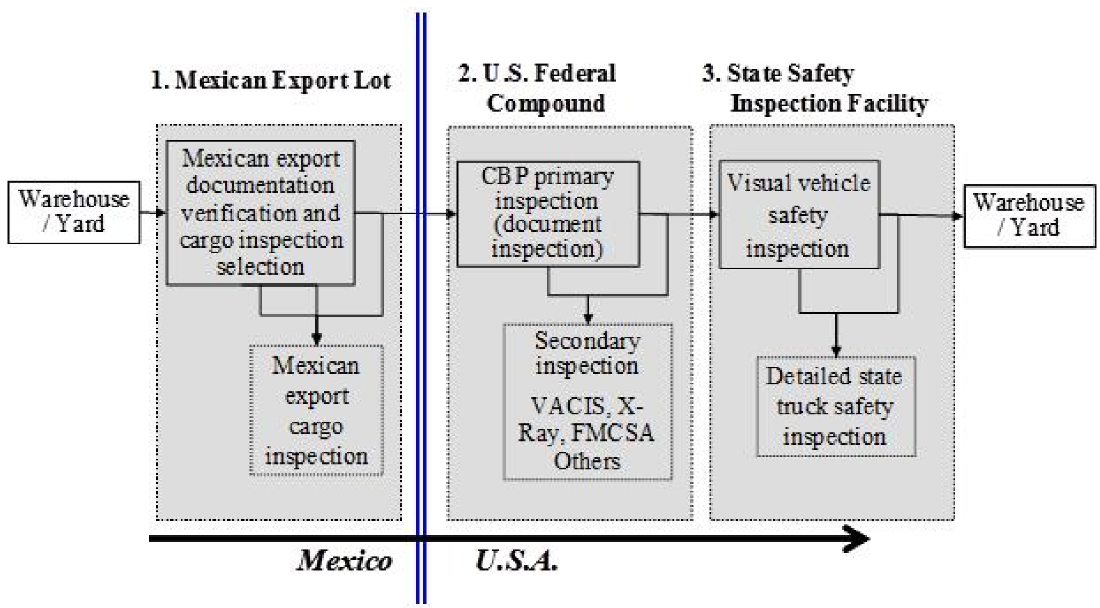

FIGURE 30 Land border crossing operations: U.S.-bound commercial vehicles. (Source: Villa, J. C. Status of the U.S.–Mexico Commercial Border Crossing Process: Analysis of Recent Studies and Research. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1966*, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 10–15.)

State Safety Inspection Facility. The stakeholders include federal, state, and local agencies in both countries as well as businesses and private-sector groups. He noted that these stakeholders often have different goals, objectives, and responsibilities and that coordination among all these entities is important.

- Villa reviewed the current U.S.–Mexico border crossing operations and the operating scenario under the NAFTA plan, which is illustrated in Figure 31. Since Mexican trucks are not currently allowed to travel beyond a commercial zone in the United States, drayage trucks are needed, which adds unnecessary freight movement that further complicates the process. Trucks traveling south into Mexico need to use a Mexican customs broker. He noted that the unreliability of travel times at land border crossings has negative impacts on supply chain performance, inventory costs, vehicle emissions, and regional economies. He suggested that continuing to examine methods to reduce delays and increase the speed of trucks traveling across the border would be beneficial.
- Villa described a study conducted by TTI for the Texas DOT and FHWA developing land border performance measures and a system to measure northbound commercial vehicle travel times. Prior to development of the system only anecdotal information from truck operators was available on travel times and travel speeds. The system, which uses RFID technology, is now deployed at 96% of the Texas–Mexico border crossings. In addition, he noted that the system is in operation at border crossings in Arizona and work is underway to add the same system in California. Villa noted that the system measures wait times and total crossing times. Both real time and archived data are available. The two performance measures being used in the project are delays, as measured by the annual hours of delay per crossing, and the Planning Time Index, which measures reliability and is the ratio of 95th percentile travel time to the uncongested travel time. The border crossing system, which is available at http://bcis.tamu.edu, provides users with both real-time and archived travel time data. Figure 32 illustrates an example of the webpage. He noted that at least 1 year of data is available for all border crossings, with a few having 2 years of data.

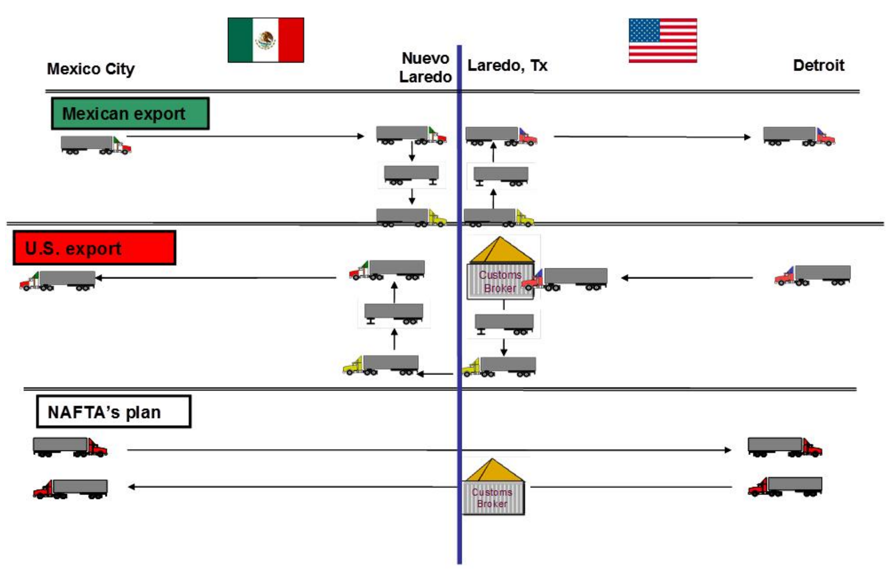

FIGURE 31 U.S.–Mexico commercial vehicle crossing process. (Source: TTI.)

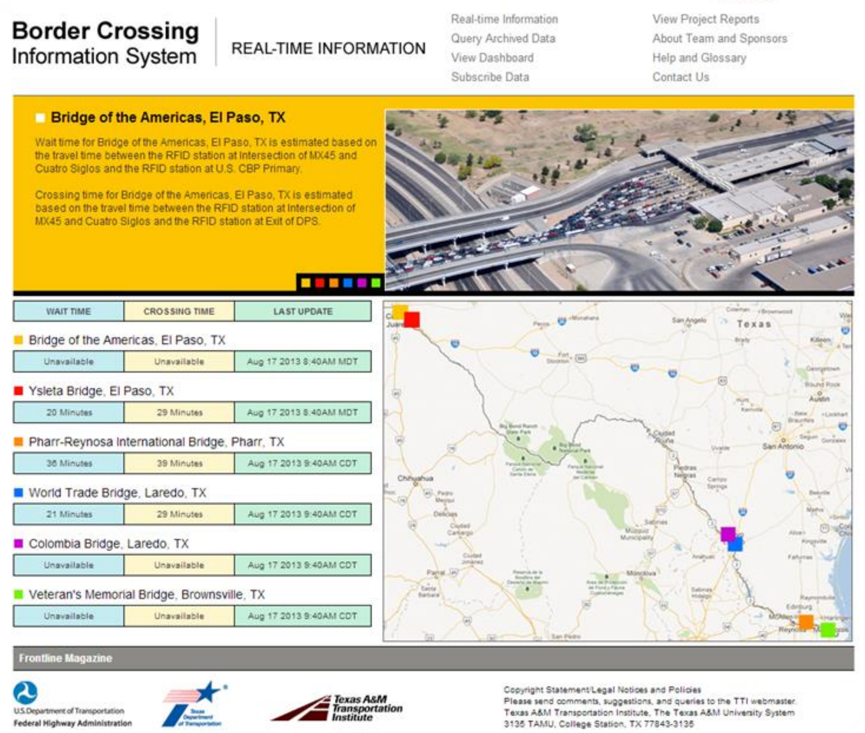

FIGURE 32 Border crossing information system web page. (Source: http://bcis.tamu.edu.)

- Villa provided examples of the different ways to analyze and present the data. Figure 33 shows the northbound average monthly wait times in minutes at five border crossings from January 2012 through July 2013. Figure 34 illustrates the truck wait times in percent of days over a 6-month period: low (defined as 30 min or less), medium (defined as 31 to 60 min), and high (defined as over 60 min). Figure 35 presents a comparison of truck wait times at the Bridge of the Americas with those at the Zaragoza International Bridge. Both bridges are in El Paso, Texas. The Zaragoza International Bridge is tolled, while the Bridge of the Americas is not. He noted that some interesting trends have been identified through analysis of the data. For example, the last Friday of the month is very busy, resulting in longer truck wait times. Since the Maquiladora facilities in Mexico do not operate on Sundays, Monday is typically a lighter day for truck crossings. He suggested that this information should be of benefit to shippers and carriers in trip planning.
- Villa described some of the challenges with the system. First, binational cooperation is important as the system includes sensors on both sides of the border to identify trucks. Currently, only northbound traffic is monitored. Southbound traffic could be monitored if more resources were available. He noted that resources are also needed to support the ongoing operation of the system. A third challenge identified by Villa was capturing additional information to supplement the current measures. Examples of other beneficial information he suggested included truck volumes by empty, loaded, FAST, non-FAST, and commodity categories. Developing an annual congestion cost, including the value of truck operating costs plus the cost of wasted fuel, would be possible with additional data. Villa suggested the most important challenge was to develop other complementary measures for the entire supply chain.

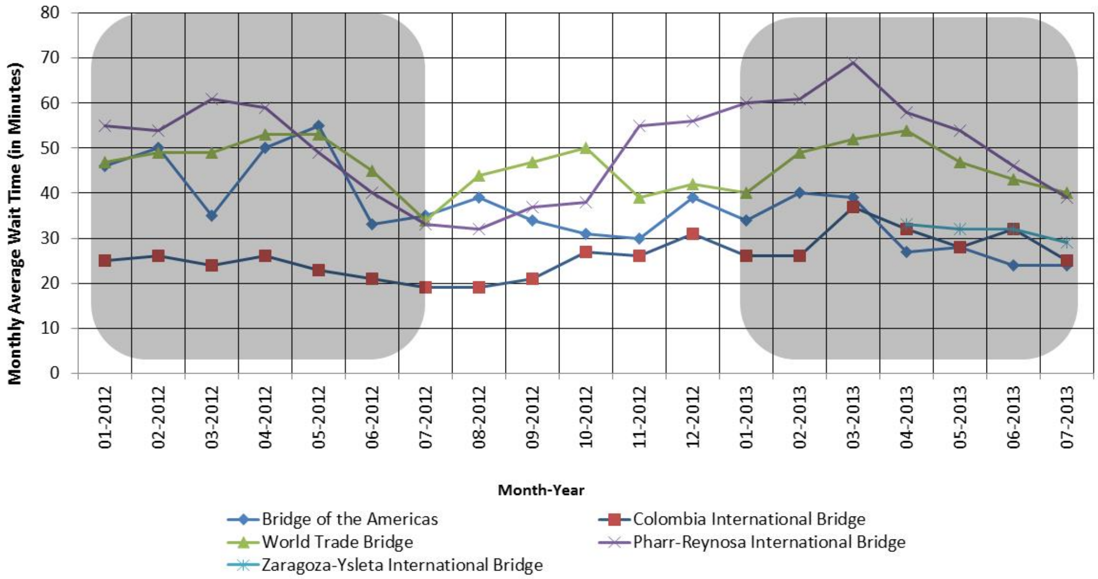

FIGURE 33 U.S.-bound truck wait time trends: average northbound monthly wait times in minutes. (Source: TTI.)

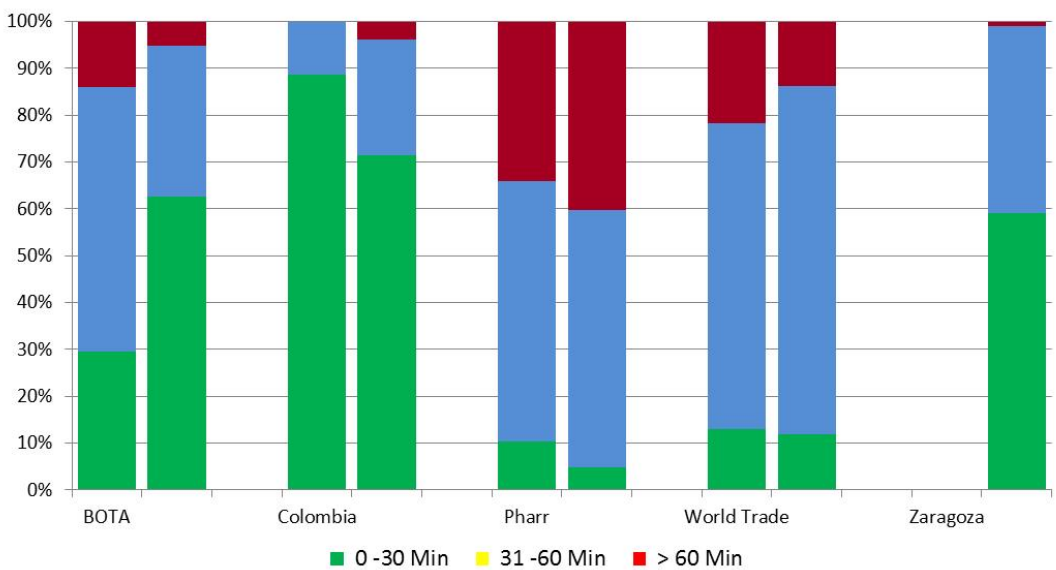

FIGURE 34 U.S.-bound truck wait time (low–medium–high) trends: percent of days during a 6-month period. (Source: TTI.)

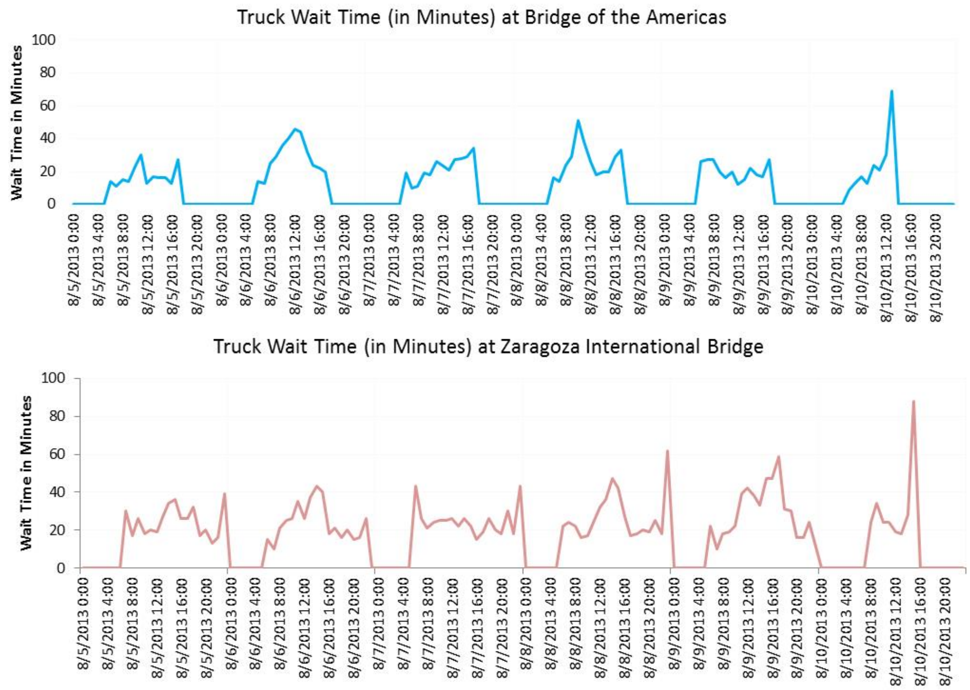

FIGURE 35 Truck wait times at the Bridge of the Americas (*top*) and Zaragoza International Bridge in El Paso (*bottom*). (Source: TTI.)

- In closing, Villa also identified opportunities for expanding the use of the existing system and combining the results with data from other sources. He noted there are also opportunities to take advantage of additional technologies, such as GPS, Bluetooth, and wi-fi to expand and enhance the current system. He suggested that developing additional applications with input from private and public-sector stakeholders, including the annual congestion cost, would also be beneficial. A final opportunity noted by Villa was providing targeted information on border crossing operations to carriers, shippers, federal and state agencies, and other groups.

Breakout Group Reports and Open Discussion

NICOLE KATSIKIDES
Federal Highway Administration, moderator

Participants had the opportunity to discuss freight fluidity in more detail in breakout sessions. Topics covered in the breakout groups included freight fluidity stakeholders and users, scalability, performance measures, data characteristics, research needs, and follow-up activities. The members of the workshop planning team acted as moderators and reporters for the breakout groups. The moderators and reporters summarized the major topics of discussion in their groups after the first breakout group session and at the workshop closing session after the second breakout session. The topics covered in the breakout group reports are summarized in this section. Additional comments and suggestions voiced by participants during the open discussion are also highlighted, along with closing comments from the workshop chair and the FHWA session moderator.

GROUP 1

Christina S. Casgar, moderator, and Russell T. Adise, reporter

- Participants in the group discussed the need to develop a clear concept for freight fluidity that can be expressed in economic terms and that is understood by a wide range of stakeholders. Some participants thought it would be a good idea if stakeholders included suppliers, shippers, carriers, industry trade associations, transportation and economic development agencies at all levels, environmental groups, policy makers, and the public. Sharing freight fluidity information at the NAFTA level was also suggested by group participants as a potentially important activity. Others thought that the performance measures used in the I-95 Corridor Coalition Study were appropriate. These performance measures focused on transit time, dwell time, reliability, variability, safety, cost, and risk. A few participants also suggested adding the resilience of the transportation system, as measured by system redundancy, as a metric.
- Participants discussed conducting pilot studies to gain experience applying the freight fluidity concept and to explore different applications. Using transit time, dwell time, and transit time variability as the major metrics with the pilot studies was further suggested by some, as was adding resilience and redundancy. Another topic that many participants discussed was assigning a value of time to transit time, dwell time, and variability. Possible pilot or proof-of-concept projects suggested included corridor segments where problems currently exist, such as the Ports of Los Angeles and Long Beach to the Inland Empire, Central Pennsylvania, the I-95 corridor, the I-75 corridor, north from the Port of Savanna, and the Port of New York and New Jersey. Other suggested pilots were supply chains for soybeans on the Mississippi River, GM vehicle manufacturing supply chains, and supply chains using the international border crossings in Mexico and Canada. A number of participants noted that the results from these pilots could be used to highlight the fluidity concept, the analysis process, and applications in the decision-making process for transportation operational improvements and new infrastructure.

GROUP 2

Lance Grenzeback, moderator, and Stuart P. Anderson, reporter

- Participants in this group discussed the need to develop a methodology or agreed-upon definition of critical or important supply chains. Three different perspectives on defining critical or important supply chains were suggested by some participants. The first perspective was a high-value supply chain. The second perspective was a high-volume supply chain. The third perspective was a high-impact supply chain. The propane supply chain and propane shortage in the Midwest during the winter, which impacted numerous people, was cited as one example of a high-impact supply chain. It was noted that as a result of this situation, the Iowa DOT undertook analyses of the propane supply chain. Some participants suggested that the energy sector supply chains fit into the high-impact category. Other participants suggested that stakeholder involvement in identifying critical supply chains was very important. Providing a national perspective on the critical supply chains was also noted as important.
- The second topic discussed by participants was the need to conduct pilot studies focusing on the practical application of freight fluidity and supply chains. Exploring different geographic scales, such as regional, corridor, state, metropolitan, and national pilot studies was suggested by some as potentially beneficial. Possible activities included identifying key supply chains for the different geographies, conducting the analyses, and linking the results with performance measurement and decision making. Travel-time and trip-time reliability were suggested by a few as two potentially important measures. Examining the practical applications of the supply chain information was noted as a key element of the pilot studies. Suggested applications of freight fluidity information included bottleneck identification, freight and long-range planning, infrastructure investment decisions, federal program applications, and federal and state regulations.

GROUP 3

Ned Mitchell, moderator, and Nicole Katsikides, reporter

- Participants in this breakout group discussed focusing on national gateways and corridors and using fluidity as a measure of system performance. It was suggested that this information would be of benefit in exploring funding needs to support national gateways and corridors, which enhance the global competiveness of the country. Some participants thought that travel-time reliability represented an important goal that freight fluidity could help measure.
- Participants discussed methods to identify key corridors at the national, regional, and local levels for possible pilot studies. Having different levels of data aggregation to support different geographic scales was also discussed. Matching available data to different applications and scales was suggested as a first step.

GROUP 4

Scott Drumm, moderator, and Caroline Mays, reporter

- Participants in this group discussed the importance of developing a matrix with the transit time by segment and in total for a specific supply chain. A second matrix with the cost of delay by segment was also suggested by some participants in the group. Although participants identified the need for a wide variety of data on transit times, transit-time reliability, customs clearance time, and other factors, there was also interest in moving forward using available data and filling the data gaps as resources become available. A few participants thought that the framework for conducting a freight fluidity analysis can be established now. This framework can be modified as experience is gained in using it and as more diverse data becomes available. Participants pointed out that developing an agreed upon analysis protocol that can be used at the international, national, regional, state, metropolitan, and local levels is important. Being able to scale freight fluidity analysis to different geographical and jurisdictional levels was also noted as important. Providing information that can be used in the decision-making process—both public and private—was also noted as a worthy activity.

- Participants identified four potential research areas. Conducting an assessment of available data for use in freight fluidity analyses at different scales and for different modes represented one area. Identifying data gaps and possible approaches to obtain missing data was suggested by some participants as part of this research. A second research area was conducting pilot studies using innovative data collection methods and technologies. Examples of possible pilots included tracking containers and shipments using different technologies and data sharing with railroads, ports, trucking firms, freight forwarders, third-party logistics providers and businesses. It was noted that establishing a business case for why data are needed, how data will be used, and the benefits to all groups need to be made. A third research area focused on developing a data architecture for freight fluidity, which would provide a map for data needs, data integration, and data gaps. A final research topic suggested by some participants was conducting smaller scale pilots or demonstration projects, which could build off *NCHRP Report 26*: *Guidebook for Developing Subnational Commodity Flow Data*.
- Participants discussed the importance of telling the freight story to policy makers and the public. Communicating the need for transportation improvements to better serve all freight modes was suggested by some as a key part of the story, including using examples that policy makers and the public can relate to.

OPEN DISCUSSION

An open discussion followed the breakout group summaries, with workshop participants providing additional ideas for research studies, pilot projects, and outreach activities. The following topics were addressed during the session:

- Participants discussed the need for multiple pilot studies addressing different scales, geographies, and commodities. Focusing the pilot studies on corridors with documented bottlenecks and on commodities and supply chains where the global competiveness of the United States is at risk was also suggested. A number of potential pilot studies meeting these criteria were identified, including studies on the Mexico–United States–Canada trade corridors. It was also suggested that there was a difference between supply chains and the segments of the infrastructure used by these supply chains.
- Participants considered the need to agree on a common methodology for use in the pilot studies. Documenting and sharing the methodology used in the I-95 Corridor Coalition analysis was thought to be appropriate first step. Identifying existing data for use in freight

fluidity was also noted as important. Documenting the data sources used was pointed out as important, as the results may vary if different data are used. Identifying data gaps and ways to obtain improved data was also suggested by a few of the participants.

- The need to develop and share innovative and informative methods to present freight fluidity performance measures was discussed. Explaining the freight fluidity concept, potential applications, and the benefits from the information was noted as important by participants.
- Ensuring that the freight fluidity performance measures are of benefit to both the public and private sectors was also noted as important by many participants. One public-sector application cited was state DOTs using the fluidity measures to identify projects that would address freight bottlenecks and improve supply chain trip times and reliability. Based on the experience in Canada, it was suggested that small to medium businesses would benefit from the fluidity information, as large companies devote resources to monitoring and measuring supply chains and system performance. The freight fluidity measures can assist the business community in better understanding the operation of the transportation systems and possible bottlenecks for different commodities.
- Participants discussed possibilities for continuing outreach efforts on freight fluidity with transportation professionals, policy makers, and the public. It was suggested that incorporating freight into the planning process and considering freight needs in state and local transportation plans and operations was still relatively new. Participants noted that the freight fluidity concept may help with explaining the importance of freight to the economy and the importance of addressing bottlenecks to maintain global competiveness.
- In closing, Rayman and Schofer thanked attendees for their active participation in the workshop. They noted that the discussions in the breakout sessions and in the closing session provided a number of common topics for future activities. Conducting pilot studies to confirm the feasibility of the freight fluidity process and to illustrate the benefits and value to public and private sector technical staff and decision makers, as well as the public, was a common next step among the groups.

Moving Freight Fluidity Forward

KATHERINE F. TURNBULL
Texas A&M Transportation Institute, rapporteur

The summaries of the breakout group discussions provided a number of suggestions for additional research, pilot studies, and outreach activities to move the development and use of freight fluidity measures forward. A number of common needs emerged from these discussions. Based on the comments from the workshop participants, the workshop rapporteur developed the following possible approaches for continuing to move freight fluidity forward into practice. Potential research projects, pilot studies, and outreach activities are highlighted.

RESEARCH PROJECTS

A number of potential research areas were identified during the breakout sessions. Possible research projects related to developing a common methodology for freight fluidity, examining innovative data collection and analysis methods for future freight fluidity applications, and developing methods and techniques to present freight fluidity measures to public and private sector stakeholders were discussed.

- **Develop a common methodology for freight fluidity**. This research project would develop a methodology for conducting freight fluidity measurement and be built on the work undertaken by the I-95 Corridor Coalition. The process and data used for the I-95 Corridor Coalition supply chain analysis would be documented as part of the project, with additional enhancements based on initial project work. The methodology would use data that is readily available to all user groups while also addressing performance measures (transit-time reliability, redundancy, etc.) and presenting the results in a common format. The outcome of this research would be a guide to conducting freight fluidity for use by public agencies, consultants, universities, private sector groups, and other organizations. The results would be used in the pilot studies described later in this section.
- **Explore innovative data collection and analysis.** This research project would examine innovative data collection methods and analysis techniques that could be used to enhance the freight fluidity methodology developed in the previous project. Ongoing technology advancements provide numerous opportunities to enhance data collection on freight movements by all modes, as well as intermodal connections. Multiple research efforts may be appropriate exploring the applications of new technologies to enhance freight fluidity measurement. Partnerships among these groups may be an option to promote research benefitting all entities.
- **Communicating freight fluidity to stakeholders.** This research project would focus on developing informative and useful methods to display and present freight fluidity measures to various stakeholders. The information presented and the methods used to display key data would be targeted to various stakeholders. For example, more detailed information would be available for technical and operations staff, with more general information for policy makers and the public. The project would also develop tips and best practice examples for communicating the

importance of freight supply chains to the economy and the need for transportation improvements to address bottlenecks and impediments to the flow of freight by all modes.

PILOT STUDIES

Conducting freight fluidity pilot studies was identified in all four breakout groups as important. Numerous suggestions were provided on methods to identify possible pilot studies and for candidate pilot projects. As outlined below, gaining experience through numerous coordinated pilots would likely be beneficial.

- **Conduct freight fluidity pilot studies.** A number of freight fluidity pilot studies could be conducted under a general coordinating mechanism, utilizing the freight fluidity methodology developed under the research project described previously. The pilot studies could address different scales, geographies, commodities, and modes. Methods for identifying possible case studies include focusing on corridors and supply chains with documented bottlenecks, national and NAFTA gateways and corridors, supply chains which enhance global competiveness, supply chains at risk of losing market share to non-U.S. competitors, high-value supply chains, high-volume supply chains, high-impact supply chains, and emerging supply chains.

OUTREACH ACTIVITIES

Workshop participants talked about a number of methods to continue the dialog and information sharing on freight fluidity. As noted below, TRB could continue to play a role in these ongoing outreach and technology transfer activities.

- **Ongoing outreach activities.** A number of methods can be used to continue to share information and best practices related to freight fluidity, as well as helping to inform transportation professionals, policy makers, and the public on the use and benefits of freight fluidity measures. Examples of ongoing outreach efforts include articles in *TR News* and newsletters of other organizations, webinars highlighting speakers at this workshop, and workshops and sessions at TRB’s Annual Meeting. Additional outreach methods could include future workshops and sponsoring sessions at conferences hosted by other organizations.

APPENDIX

Workshop Attendees

Russell Adise
U.S. Department of Commerce

Bala Akundi
Baltimore Metropolitan Council

Basak Aldemir Bektas
Iowa State University

Ken Allen
H-E-B Stores (retired)

Stuart Anderson
Iowa Department of Transportation

Susan Atherton
CH2M HILL

Scott Babcock
Transportation Research Board

Peter Bang
Federal Highway Administration

Mark Berndt
Olsson Associates

Thomas Bolle
Office of the Assistant Secretary for Research and Technology of the U.S. Department of Transportation

Robert Bouchard
U.S. Department of Transportation, Maritime Administration

Bowden, Deborah
Maryland Department of Transportation

James Brock
Avant IMC, LLC

Scott Brotemarkle
Transportation Research Board

Daniel Brown
MITRE Corporation

Joe Bryan
Parsons Brinckerhoff

Tina Casgar
San Diego Association of Governments

Christopher Chang
Federal Highway Administration

Sharon Clark
Perdue AgriBusiness, LLC

Joseph Dack
HDR Milford, CT

Ted Dahlburg
Delaware Valley Regional Planning Commission

David Damm-Luhr
U.S. Department of Transportation

Tyler Dick
RailTEC

Patricia DiJoseph
U.S. Army Corps of Engineers

Michael Dinning
U.S. Department of Transportation, Volpe Center

Federico Dominguez Zuloaga
Ministry of Communications and Transportation

Paula Dowell
Cambridge Systematics, Inc.

Scott Drumm
Port of Portland

Bill Eisele
Texas A&M Transportation Institute

Ryan Endorf
U.S. Department of Transportation

Jim FitzGerald
BNSF Railway

Stephen Fitzroy
EDR Group

Carl Fowler
Menlo Worldwide Logistics

Deborah Freund
Federal Motor Carrier Safety Administration

Garrett Fullerton
RailTEC

Brittney Gick
Transportation Research Board

Scott Greene
Federal Railroad Administration

Lance Grenzeback
Cambridge Systematics, Inc.

Hardy, Matthew
American Association of State Highway and Transportation Officials

Patricia Hu
U.S. Department of Transportation
RITA

Barbara Ivanov
Washington State Department of Transportation

Brian Jacob
U.S. Department of Transportation, RITA

Tiffany Julien
Federal Highway Administration

Nicole Katsikides
Federal Highway Administration

Jack Kimmerling
Indiana Department of Transportation

Matthew Klein
Federal Aviation Administration

Ed Lee
Florida Department of Transportation

Donald Ludlow
Cambridge Systematics, Inc.

Marwan Madi
CDM Smith

Subrat Mahapatra
Maryland State Highway Administration

Caroline Mays
Texas Department of Transportation

Douglas McDonald
U.S. Maritime Administration

Mark Meitzen
Christensen Associates

Alan Meyers
Parsons Brinckerhoff

Kenneth Mitchell
U.S. Army Corps of Engineers

Karl Mortensen
Chrysler Group, LLC

Vida Mysore
Federal Highway Administration

Roy Nunnally
Indiana Department of Transportation

Roseann O'Laughlin
Oregon Department of Transportation

Thomas Palmerlee
Transportation Research Board

Marygrace Parker
I-95 Corridor Coalition

Roger Petzold
U.S. Department of Transportation

Lisa Randall
Federal Highway Administration
OTS, Resource Center

Caitlin Rayman
Federal Highway Administration

Ali Rezvani
Moffatt & Nichol

Tyler Robertson
Transportation Research Board

Matt Roorda
University of Toronto

Rolf Schmitt
U.S. Department of Transportation
RITA

Joe Schofer
Northwestern University

Tyrone Scorsone
Cambridge Systematics, Inc.

Jeffrey Short
American Transportation Research Institute

Alejandro Solis
HDR

Michael Sprung
Bureau of Transportation Statistics

Ed Strocko
Federal Highway Administration

Louis Paul Tardif
Transport Canada

Robert Tardif
Ministry of Transportation Toronto

John Tompkins
Minnesota Department of Transportation

Katherine Turnbull
Texas A&M Transportation Institute

Robert Utz
McCormick & Company, Inc.

Kimberly Vachal
North Dakota State University

Michelle VanderMeer
Whirlpool Corporation

Juan Carlos Villa
Texas A&M Transportation Institute

Ivan Villarreal Camero
Ministry of Communications and Transportation

Jack Wells
Office of the Assistant Secretary of Transportation

Karen White
Federal Highway Administration

Kuilin Zhang
Michigan Technological University

Ben Zietlow
University of Wisconsin–Madison
National Center for Freight and Infrastructure
Research and Education

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

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

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

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

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

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

www.national-academies.org

TRB

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