Innovations in Freight Demand Modeling and Data Improvement

DETAILS

69 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-43337-2 | DOI 10.17226/22336

AUTHORS

Brock, James M.; Phelan, Thomas; DeLine, Erik; and Jonathan Heilman

SHRP 2 Capacity Project C43

Innovations in Freight Demand Modeling and Data Improvement

James M. Brock
Dering Consulting Group, Inc.
Camp Hill, Pennsylvania

Thomas Phelan and Erik DeLine
Vanasse Hangen Brustlin, Inc.
Newark, New Jersey

Jonathan Heilman
Gannett Fleming, Inc.
Camp Hill, Pennsylvania

TRANSPORTATION RESEARCH BOARD
Washington, D.C.
2015
www.TRB.org

ACKNOWLEDGMENTS

This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program, which is administered by the Transportation Research Board of the National Academies. This project was managed by David Plazak, Senior Program Officer for SHRP 2 Capacity.

The symposium and associated findings and report were overseen by James Brock, Dering Consulting Group, Inc., as the principal investigator. The other authors of this report are Thomas Phelan and Erik DeLine of Vanasse Hangen Brustlin, Inc., and Jonathan Heilman of Gannett Fleming, Inc. The symposium was planned and executed with assistance from Richard Easley and Sharon Easley of E-Squared Engineering, Wade White of Whitehouse Group, Robert Handfield, Ph.D., and George List, Ph.D., of North Carolina State University, and Ram Pendyala, Ph.D., and Arnold Maltz, Ph.D., of Arizona State University.

Special appreciation is extended to all those who submitted presentations for consideration for the Innovations in Freight Demand Modeling and Data Improvement Symposium.

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CHAPTER 1
Background

The TRB SHRP 2 Second Symposium on Innovations in Freight Demand Modeling and Data (C43) was organized to assess the progress of freight modeling research initiatives advanced by the Freight Demand Modeling and Data Improvement Strategic Plan (C20), completed in 2013, and the 2010 Freight Modeling and Data Symposium, which was held in 2010 as part of the C20 project.

The symposium also acted to share insights on how the modeling practice has advanced and how C20 recommendations have been integrated into public-sector and private-sector practical research applications. Participants in the symposium represented a cross-section of the freight modeling community, including academic research institutions, states, metropolitan planning organizations, businesses that rely on logistics for their operations, and the international community.

A call for papers was advertised on June 18, 2013, through TRB's newsletter, with a deadline of August 15, 2013. This call for papers noted particular gaps in research that served as motivation for responses and selection of abstracts, including

- Lack of regional planning organizations incorporating freight into their transportation plans,
- Private-sector logistics decision makers assuming that the public sector can meet their needs,
- Private-sector decisions that reflect large-scale public decision making,
- Public-sector data accumulated on a national level that gets disaggregated to state, regional, and local areas, and
- Disconnect in knowledge, availability, and sharing of private-sector data with public-sector planners.

Topics suggested, but not limited to, were

- Public planning—private supply-chain linkages
- Modeling and logistics data integration
- Freight reliability
- Global logistics trends impacting freight modeling and data

Approximately 75 abstracts were submitted, of which 18 were chosen for presentation and eligibility for one of the two symposium awards: (1) the best private-sector idea that is most applicable to the public sector, and (2) the public-sector idea that best demonstrates linkage to private-sector models, data, or methods.

The symposium was held on October 21–22, 2013, at the Crowne Plaza in Herndon, Virginia. Approximately 65 participants attended, including the presenters. The 2-day symposium was broken down into six sessions, based on categories of areas of research interest. Each session was composed of two or three presentations, each followed by a question-and-answer discussion involving the entire audience and the presenter.

The symposium included a diverse audience representing academia, public-sector practitioners, and private industry. Participants examined, evaluated, and promoted innovative and promising advances in freight demand modeling, data collection, and freight forecasting research methods. Local, state-level, regional, and domestic and international models were presented. The agenda and list of presentations appear in Appendix A. The electronic files for the presentations and the papers can be retrieved from http://www.trb.org/strategichighwayresearchprogram2shrp2/pages/shrp2_freight_symposium_906.aspx and www.freightplanning.com.

The presentations were judged based on 13 parameters, including methodology, practicality, ease of use, clarity of purpose, research value, and results. A panel of experts, representing transportation modes, public and private sectors, geographies (international and domestic), technology, and analytical techniques judged the competition. Finally, feedback forms were handed out to the attendees and were collected on both days.

CHAPTER 2
General Themes

The second symposium marked advances in research and practice since the first symposium in 2010, as well as attempted linkages to C20 research initiatives presented in its final report. Additionally, themes emerged and further gaps were identified, many consistent with those found in the first symposium. By comparison, where the ideas presented at the first symposium were more theoretical, those presented at this symposium illustrated attempts at practical application in resolving real-world problems. Key themes of the symposium included the following:

- The insight into supply-chain management that was provided by the private-sector participants was extremely interesting, according to feedback from the participants. In particular, participants recognized that some of the data and processes used by the private sector to reduce costs and streamline their own supply chains could have tremendous value to the public sector. In addition to traditional sources of data related to origins/destinations, transport mode, and commodities, the internal performance measures that the private-sector representatives discussed related to route choice, time-of-day deliveries, and load factors, which could all be great resources for the public-sector planning process.
- Another element of the public/private-sector interaction that was well received was the innovative use in public-sector planning efforts of private-sector data resources that were originally developed for purposes completely unrelated to transportation planning and forecasting. Several examples of this included the use of CropScape satellite imagery developed by agricultural interests for estimating tonnage of various agricultural commodity types, the fusion of land use geographic information system (GIS) data at the property/parcel level with on-board truck Global Positioning System (GPS) data to develop surrogate commodity types for urban truck touring, and GIS data used by the energy sector for active drilling sites to estimate future transportation of heavy machinery, equipment, and sand for hydraulic fracturing.
- A lot of interest was generated by the presentations on agent-based modeling. This approach to freight forecasting is still in its early stages, but the presentations illustrated several examples of freight forecasting in which the traditional commodity/mode/route approach is enhanced by incorporating elements of the decision-making process of shippers, carriers and even third-party logistics providers (3PLs).
- There is significant interest and research going on in relation to when freight travels as well. This temporal characteristic is being analyzed seasonally as well as by time of day to better provide insight on the effects of goods movement for congestion,

safety, and labor. This has potential impacts to policy making to incentivize freight movements to certain times or to address capacity at key periods.

- Modeling is being used for decision-making processes that have consequences beyond just freight transportation. Information derived from modeling is being utilized for public policymaking related to environmental considerations, safety, pavement management, resource utilization, and funding allocations. Inputs related to global supply-chain sources, packaging decisions, weight allocations, and trend changers are working their way into model development to better reflect real-world conditions.
- A recurring theme in this symposium was the need for better data at refined levels of geographic detail to address certain freight planning needs. While many participants expressed a need for better and more comprehensive Freight Analysis Framework (FAF) origin/destination and commodity flow data, some of the presenters demonstrated an ability to make do with different data resources for planning and modeling at smaller geographic scales. In some cases this involved the use of surrogate data such as those described previously (CropScape, land use, etc.), while in other cases the model was built on data for a smaller geographic scale than FAF but for a limited number of commodities that were of primary interest for a particular region (corn in Iowa, silica sand in Wisconsin, energy and wheat in North Dakota). However, modelers should be cognizant of the limitations associated with disaggregating large-scale data (i.e., Freight Analysis Framework, version 3 [FAF3]) down to a more localized level.
- Many of the presentations identified one of the key areas of disconnect between the public and private sectors as the large difference in planning-time horizons between the business community and the public sector. No clear avenues to bridge this gap were addressed, but some of the public-sector presentations demonstrated a remarkable ability to respond to the rapidly changing needs of industries such as energy extraction.
- Participants noted in several different sections of the symposium evaluation that they enjoyed the presentations by the private-sector participants. They also noted that public-sector modelers needed increased interaction with private shippers to understand the nuances of real-world shipping, to gain additional data from shippers, and to tailor model output to create data that are meaningful to shippers. Some of the participants were particularly interested in the strategies used by the private-sector participants to maximize the efficiency of their supply chains. Specific strategies that generated participant interest included efforts to reduce the weight and volume of packing materials and minimize empty shipments by tracking performance measures for trucks such as ton-miles traveled as a fraction of a truck’s loaded capacity for a full trip.
- When asked how to continue the interaction begun with this and the previous symposium, many participants simply stated that the symposia should continue. They noted that the competition aspect was well liked and made the symposium different from

other conferences. Participants overwhelmingly suggested that private-sector involvement should continue and be expanded.

CHAPTER 3
Relationship to C20

The SHRP 2 Second Symposium on Innovations in Freight Demand Modeling and Data (C43) follows in the footsteps of the C20 project, which resulted in the *Freight Demand Modeling and Data Improvement Strategic Plan* (2013). This plan advanced seven strategic objectives to stimulate innovative research for enhanced freight planning, forecasting, and data analysis. These objectives are

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

C43 accomplished a number of these objectives by bringing together practitioners and provided a platform for their research and a forum for knowledge transfer and education. Additionally, the symposium gave insight into the state of the practice three years after the first symposium and gave insight into how the field has advanced since then.

Furthermore, presentations were selected with their applicability to the C20 research initiatives. The list of presentations made at C43 is shown in Table 3.1. Many of the selected topics met multiple research initiatives, as illustrated in Figure 3.1. In many cases, the presentation may have fulfilled a research initiative indirectly or as a secondary consideration to its primary research focus.

The best presentations graded by the panel of experts were not necessarily the ones that met the most research initiatives, but those that did the most to advance freight data modeling innovation in their selected topics.

In particular, research presented at C43 made strides in some but not all research areas.

The three research initiatives that were most evident in the presentations were

- **Research Initiative C: Establish modeling approaches for behavior-based freight movement.**

Most presentations, with the exception of a few, showed developed models that went beyond the traditional four-step transportation model by utilizing other data to project how freight transportation providers utilized the transportation network. The presentations included the application of agent-based, tour-based models using GPS data, or other methods that factored in discrete data to account for other variables, such as agricultural cycles.

- **Research Initiative E: Develop a range of freight forecasting methods and tools that address decision-making needs and that can be applied at all levels (i.e., national, regional, state, MPO, and municipal).**

The presentations encompassed a variety of models that were tailored to the diverse geographic scales of their topic. While many of the methods or tools could be customized to meet the needs of a higher or lower geographic scale, other models were best applied to smaller geographic areas like cities, where their detail or applicability would be lost if data was aggregated to a larger level. Likewise, other models were tuned to address data collected at a state level, but applying the same method while disaggregating the data would be problematic. Instead of applying one type of method or tool to meet all levels, practitioners are developing models that are most appropriate to the scale of their research.

- **Research Initiative I: Develop freight data resources for application at sub-regional levels.**

As previously discussed, the need to refine models to a more suitable geographic scale has also led to innovation in the types of data resources that are being utilized to similarly provide models with robust information that can be used for the scale of analysis. Parcel data and raster data are two such examples of freight data resources utilized to inform models at a sub-regional level.

On the other hand, several other research initiatives were not as well advanced in C43, including

- **Research Initiative D: Develop methods that predict mode shift and highway capacity implications of various "what-if" scenarios.**

Very few models attempted to develop “what-if” scenarios, including factoring risk, into their research. As supply chains become more complex, and, as a result, potentially more susceptible to shocks to the system, this initiative will be increasingly important to manage how freight transportation is utilized when the network is not operating under optimized conditions.

- **Research Initiative F: Develop robust tools for freight cost-benefit analysis that go beyond financial to the full range of benefits, costs, and externalities.**

Similar to the development of scenario-based freight modeling, the application of cost-benefit analysis was not well represented throughout the presentations. Some models did attempt to factor it into their research, though not necessarily directly. For public policymakers, a robust model that can further inform the true costs of decisions will be necessary to advance the needs of transportation planning and the freight modeling practice.

- **Research Initiative K: Develop procedures for applying freight forecasting to the design of transportation infrastructure such as pavement and bridges.**

None of the presentations at C43 addressed this research initiative. In practice, utilizing freight modeling research into asset management may have not yet made its way into the conversations because of the different planning communities that make these types of decisions. This can also be a function of the typical utility of these datasets where their development is based on the need to address a specific issue, though there are opportunities to adapt this information to other models with different objectives. As costs for maintenance of infrastructure continue to grow and available funding competes with other modes, the ability to determine how freight movements affect the transportation network and the relationship between this and the infrastructure it utilizes are becoming increasingly important.

C43 illustrated that several advances in freight modeling and data have been made in a relatively short period of time. While these presentations are encouraging steps in the right direction, emphasis on all levels of C20 research initiatives should be maintained.

Table 3.1. SHRP 2 Second Symposium on Innovations in Freight Demand Modeling and Data Improvement: Speaker List

SESSION 1: State DOT Freight Modeling	**A**	*Creating a Supply-Chain Methodology for Freight Forecasting in Wisconsin* Jennifer Murray, Wisconsin Department of Transportation
	B	*Rail Freight Commodity Models: A First Generation Effort in Iowa* Phillip Mescher, Iowa State Department of Transportation
SESSION 2: Regional/Urban Tour Modeling	**A**	*Innovative Tour-Based Truck Travel Model Using Truck GPS Data* Arun Kuppam, Cambridge Systematics Inc.
	B	*Design of an Agent-Based Computational Economies Approach to Forecasting Future Freight Flows for the Chicago Region* John Gliebe, Resource Systems Group Inc.
	C	*Florida Multimodal Statewide Freight Model: A Model Incorporating Supply-Chain Methods and Providing Linkages to Regional Tour-Based Truck Models* Colin Smith, Resource Systems Group Inc.
SESSION 3: International Models	**A**	***Logistics in Freight Modeling—A Report from the Delft Group*** **Lori Tavasszy, Delft University of Technology and TNO (Award Winner)**
	B	*Discrete Model of Freight Mode and Shipment Size Choice* Magersa Abate, The Swedish National Road and Transport Research Institute (VTI)
	C	*Freight Models, Constrained Economic Models and Natural Resource Data* Ming Chen, TNO
SESSION 4: Private-Sector Supply-Chain Decision Making	**A**	***NMHG Shipment Modeling*** **Andy Street, NACCO Materials Handling, Inc. (Award Winner)**
	B	*The Caterpillar Building Construction Products (BCP) Transportation Strategy: Thinking Outside AND Inside the Box* William Lucas, Caterpillar, Inc. and Matthew Drown, Caterpillar, Inc.

SESSION 5: Freight Data Innovations	**A**	*Exploratory Use of Raster Images for Freight Modeling* Pedro Camargo, University of California, Irvine
	B	*Disaggregate State-Level Freight Data to County Level* Ho-Ling Hwang, Oak Ridge National Laboratory
	C	*Statewide Freight Demand Modeling to Support Long-Range Transportation Planning in North Dakota* EunSu Lee, North Dakota State University
SESSION 6: Business Implications	**A**	*On the Evaluation of Incentive Structures Fostering Off-Hour Deliveries* Felipe Aros-Vera, Rensselaer Polytechnic Institute
	B	*Analyzing Future Freight Challenges in Maryland Using Freight Data Sources and the Maryland Statewide Transportation Model (MSTM)* Subrat Mahapatra, Maryland Department of Transportation
	C	*Examining Carrier Transportation Characteristics along the Supply Chain* Anne Goodchild, University of Washington

C20 Research Initiatives	● – Primary Research Focus ○ – Secondary Research Focus	C43 Symposium Research Category															
		State DOT Freight Modeling		Region/Urban Tour Modeling			International Models			Private Sector Supply Chain		Freight Data Innovations			Business Implications		
		1A	1B	2A	2B	2C	3A	3B	3C	4A	4B	5A	5B	5C	6A	6B	6C
A: Determine the freight and logistics knowledge and skill requirements for transportation decision makers and professional and technical personnel. Develop the associated learning systems to address knowledge and skill deficits.																	
B: Establish techniques and standard practices to validate freight forecasts.							○		○								
C: Establish modeling approaches for behavior-based freight movement.		●	●	●	●	●	●	●		●	●			●	○	●	●
D: Develop methods that predict mode shift and highway capacity implications of various "what-if" scenarios.							●							○	●	●	
E: Develop a range of freight forecasting methods and tools that address decision making needs and that can be applied at all levels (i.e., national, regional, state, MPO, municipal).		○	○	○		○	○	○	○			○		○	○	●	○
F: Develop robust tools for freight cost-benefit analysis that go beyond financial to the full range of benefits, costs, and externalities.							●		●		○						
G: Establish analytical approaches that describe how elements of the freight transportation system operate, perform, and impact the larger overall transportation system.		●	○			○	○							●	○	●	
H: Determine how economic, demographic, and other factors and conditions drive freight patterns and characteristics. Document economic and demographic changes related to freight choices.			○	○					●	○		○	○				
I: Develop freight data resources for application at sub-regional levels.			●	●	●	●		○		○	○	●	●	○	●		

J: Establish, pool, and standardize a portfolio of core freight data sources/sets that support planning, programming, and project prioritization.			○					○			●	●	○		○	
K: Develop procedures for applying freight forecasting to the design of transportation infrastructure such as pavement and bridges.																
L: Advance research to integrate logistics practices (private sector) with transportation policy, planning, and programming (public sector).	●	○	○	●	●	●	○		●	●			●	●		●
M: Develop visualization tools for freight planning and modeling through a two-pronged approach of discovery and addressing known decision-making needs.											○		●		○	

BOLD indicates priority research topics.

Figure 3.1. C43 Symposium research focus relationship to C20 research initiatives.

CHAPTER 4
Next Steps

C20 and C43 represent strong, strategic advances toward improved freight modeling and data to support these tools. SHRP 2 ends in 2015, and further steps should be taken in the interim and the long term to ensure that the progress made to date does not wane. Recommendations for next steps include the following:

A. Immediate Next Steps

With the second symposium completed, there are some immediate next steps that can be undertaken to advance the efforts of the event and the research presented.

1. Webinars

To maintain interest in the results of C43 and the research that is coming out of them, webinars could be organized to allow presenters to engage a larger audience for their research, update their status from the symposium, and develop a wider range of interest in the field.

2. TRB Workshops

Further hands-on discussions on freight demand modeling and data improvement are a necessary step in maintaining research progress. These can be organized to further showcase the C43 participants and their research, focus on a specific topic (similar to the way the symposium was organized into groups), or develop into a format to educate new participants in the field to various approaches (such as agent-based versus tour-based, and so forth).

3. Recognition for Participation

Although there were only two winners of the competition at C43, it is important to recognize that there were 16 abstracts selected for presentation out of the 75 that were submitted to the call for papers. These 16 represent the best advances in innovative freight modeling since the first symposium. Recognizing all the presenters serves to encourage their continued efforts and challenge others in the field.

B. Moving Beyond Freight Modeling

The movement of goods on a transportation network is truly one leg of a larger system. To fully encompass the realities of freight transportation, research should incorporate other complexities.

1. Supply Chain

Most of the models presented in the first two symposia were narrowly focused. That may have been a focus on a single mode, a single commodity, or a single network. However, very rarely does freight move in such a manner. As freight data and models become more advanced, they must also evolve to better reflect the complexities of the supply chain moving between modes and networks, and incorporating multiple commodity inputs in the production of another commodity type.

2. Agriculture and Emerging Industries

Models have already begun to incorporate these important trends into current research. Agriculture is a driving force in many geographic locations, so understanding the complexity of the market associated with farming and food industries is important. Similarly, as certain industries (such as natural gas fracking) emerge, the unique nature of the operations should be considered separately from the general industrial code that encompasses it, in order to recognize the new challenges and realities that these industries place on the transportation network.

3. Ports

Typically, ports have been treated as a relatively static origin or destination, or even as an interim step, depending on the complexity of the model. But this does not recognize the elastic nature of supply-chain operations. Inputs such as costs, labor, and externalities can factor into a shipper's decision to move goods through one port or another. These factors should be examined within the transportation network, and models should be developed to better explain how these factors can influence the supply chain.

4. Risk-Based Modeling

Scenario modeling was not well represented in C43 and should be incorporated into further modeling efforts to help explain how events can influence goods movement. For example, the possible impact of the Panama Canal expansion project on how freight moves through an interior state—or the overall impact on how the transportation network is utilized—is potentially important research. It is appropriate and necessary to consider risk-based models to predict the potential impacts of such an event, as well as other high-impact possibilities, including disasters. This is especially critical as such events may drive greater demand for a certain type of commodity within a region or have other second-order effects that should be modeled.

C. New Sponsors

With SHRP 2 set to expire in the near future, it is important that the advances in research made between C20 and C43 are not lost. There are several candidates that could be considered to take up the role that TRB is currently occupying.

1. Academic Institutions

Academic institutions may be the most readily available and appropriate candidate to host further symposia and advance research in freight demand modeling and data improvement. Much of the research that is being conducted is through academic organizations that also have experience hosting events related to research. Academic research institutions do not always have the closest ties to private practitioners, potentially making further engagement with private industry a challenge.

2. Private Industry Groups

Research being conducted has the potential to greatly benefit the ability of private industry to operate efficiently on the transportation network. Typically, an industry may have connections to public entities and act as a liaison to the groups they represent. They also have experience holding events and could further engage their groups to the field. It should be recognized that research tends not be their main priority, so the ability to advance research may fall behind other industry priorities.

3. Metropolitan Planning Organizations (MPOs)

MPOs potentially represent a solid bridge between academic institutions and private industry groups. They typically have experience dealing with both and the ability to bring both together to address issues or for common interests. Furthermore, MPOs tend to be the federal funding mechanism for projects within their region and can direct money toward studies that enhance freight modeling. Not all MPOs are fully invested in the importance of freight demand modeling, so it will be important to identify and engage those organizations with the capability to take on such a role.

4. Other Governmental Agencies

In addition to MPOs, other governmental or quasi-governmental agencies could be considered to advance the practice of freight demand modeling. This could include state departments of transportation (DOTs) or a larger representative group such as American Association of State Highway and Transportation Officials (AASHTO) as well as federal agencies such as the Federal Highway Administration (FHWA).

D. Expanding Participation

C43 was a significant step from C20 in engaging other groups to provide abstracts to their research. The presenters represented a diverse group of geographic areas, the international freight modeling community, and private industry.

1. Private Industry

C43 was a step in expanding the community of freight modeling, which was primarily represented at the first symposium. At C43, representatives from two private businesses submitted abstracts that were chosen for presentation. As noted in the abstracts, their models and focus on improving their operations through modeling offered unique insights beyond what is typically understood by the public sector as to how freight moves through the network. There are several additional industry sectors that could be involved in future efforts, including shippers, carriers, and third- or fourth-party logistics companies; each has the ability to provide keen insight into supply-chain management that would provide significant benefit to modeling. Further engagement will only enhance the ability for practitioners to improve their own research.

2. Multi-modalism

As noted, the presentations tended to be primarily focused on the movement of freight via truck, and although some modelers did attempt to add multi-modal factors into their research, it was generally a secondary influence on their overall model. Participation should be expanded to engage other modes of transportation as well as the way a commodity may move across multiple modes in the supply chain.

3. International

While C43 was largely dominated by domestic freight models in diverse geographic areas, there were three presentations from the international community. One of these was chosen as demonstrating the greatest advancement of innovation in freight modeling. Exchange of methods and tools through the international community can improve the state of the practice in all areas.

4. Students

Students should be engaged to help build further interest in freight demand modeling at participating universities. In future symposia, greater outreach to local universities can be conducted or scholarships provided that allow for the attendance to a future symposium for a promising student or group of students. Furthermore, to help generate attention to freight demand modeling by students, a basic introductory course could be developed.

E. New Venues

Both the C20 and C43 were hosted in Herndon, Virginia, in the Washington, D.C., metropolitan region. Conference responses from both symposia indicated a desire to move the symposium locations around. This may help to improve the visibility of these freight modeling symposia and garner greater interest from those who might otherwise be restricted in travel. Additionally, as SHRP 2 ends, there is the possibility of linking the symposium to other events that might draw a similar attendance or even allow the event to expand.

1. Alternating Coasts or Interior of Country

As noted, both events were held in the Washington, D.C., area. Alternating venues to the west coast, the interior of the country, or various locations along the Atlantic seaboard could be combined with organizing tours for attendees with local freight transportation providers or industries to gain greater practical insight to their research.

2. Linking with Other Conferences and Events

Rather than hosting a separate symposium, this event could be combined with other conferences or workshops. This would allow for the practice to continue alongside an already commonly organized event. Further, this could also help to expand interest in the field and allow modelers to engage in new data exchange and ideas.

CHAPTER 5
Presentation Abstracts

The abstracts in this report are presented as they were submitted to the planning team during the call for papers, with the exception of any graphics and references to the graphics that may have been included. Some notes on the presentations from the symposium have been included ahead of their abstract content, and, where necessary, note when the presenter is different from the paper's author.

Day One Introductory Remarks

Rob Handfield, Ph.D.
Supply Chain Research Cooperative
North Carolina State University

North Carolina State University has established a supply chain cooperative, which puts students together with companies to deal with real-world problems. It is a multinational scholarly effort asking the question, "What are the big trends and issues shaping the global supply chain today?" We interviewed 60 supply-chain officers and sent surveys to 1,700 global professionals. The main takeaway is this: The world is becoming a much more complex place as it moves to a network economy. We are connected to the entire world.

For companies, the number one issue is an increase in customer expectations, but at the same time the lack of reliable infrastructure and increased regulation are growing concerns. They are using technology as an enabler, but the overall problem of infrastructure is pervasive.

Customers want customized solutions—packages a certain way, delivered in a certain way, at a certain time—and on-time delivery is a prerequisite for survival in this modern economy. These factors are dependent on infrastructure.

Everyone believes that the cost of logistics will increase. It may be through congestion, environmental regulations, or moving to same-day shipments. E-commerce has exploded the number of sales channels, and this has further led to smaller shipments.

More than half of manufacturing has moved off shore, but have the changes in the supply chain been addressed? This will require public-private sector joint products. The private sector is adjusting by improved cost estimation and network planning capacity. They are developing standardized processes than can still be flexible and investing in technology to track and trace shipments.

Industries are developing a global logistics governance playbook. This requires increased collaboration with the public sector and having a single voice. This means working with local governments. Top-level visits by a CEO can help address issues.

There is a growth in new technology and the sharing of data that comes along with it. From radio-frequency identification to inventory optimization software, this information is being integrated to be accessible for analytics on smartphones. The number one type of data that people want to share is transportation.

Creating a Supply-Chain Methodology for Freight Forecasting in Wisconsin

Jennifer Murray
Wisconsin Department of Transportation

Presentation Notes: Wisconsin Department of Transportation managed nine travel demand modelers, but there were few sketch-planning regional level successes. There was a need for a robust model that could meet day-to-day needs, so the fusion model was developed as a forecasting model but also to create a framework for performance measures and investment strategies. The model works to address three things: provide corridor commodity flows, visualize the data in one place, and align investment with needs across multiple modes. As first steps to developing the model, it was necessary to define the goals and agree on the level of detail and the last mile connections. The fusion model is based on the four-step model but factors in the economics of moving freight with business locations and product types. Further data improvement is needed, such as vehicle classification data, more commodity-specific information, modal shipment type, and commodity freights. There is a web-based mapping application being developed that includes locations, highway conditions, and annual average daily traffic (AADT).

Abstract

This presentation lays out a proposal for a new tool set that will forecast freight transportation in Wisconsin, called the Multimodal Freight Fusion Forecasting Model. Envisioned as a hybrid tool set, the Fusion Model will not function like a strict, traditional travel demand forecasting model based in time series, behavior, input-outputs, supply chain, or simulation. The Fusion Model will fully integrate the Wisconsin Department of Transportation (WisDOT) freight data with forecasting procedures to clarify current conditions, evaluate performance measures, and determine future alternatives. The Multimodal Freight Fusion Forecasting Model will link industry concepts with WisDOT long-range transportation planning goals, providing a context for discussion on freight movement in Wisconsin.

Currently, WisDOT and Wisconsin metropolitan planning organizations (MPOs) are examining freight data, creating tools, clarifying freight policies, and better collaborating with freight businesses. WisDOT manages specific freight functions, robust datasets, and reports. Current condition data summaries, combined with information collected during transportation projects and traffic forecast reports (future year truck AADT volume data) help long-range planners or transportation engineers determine future transportation needs.

In the last year, WisDOT has used the data to create a decision-support tool called the Multimodal Freight Network. The network data provides a scoring mechanism for WisDOT plans, programs and projects. As a data warehouse, proprietary data can be added to clarify

things like commodity flows and business point locations. The network has been translated into an interactive web mapping application. Freight forecasting information has not yet been updated for these efforts.

As part of the freight efforts, WisDOT has assessed its 2007 statewide travel demand model (with a truck freight component). The statewide model was not utilized for freight forecasting and had relatively few sketch-planning, regional freight flow level successes. Because it aggregates data, splits out modes by percentages, and tosses out long-haul, shorter-haul, and drayage freight data sensitivity, the model has not worked very well. To correct this, Wisconsin's freight forecasting tools should link these objectives with one another to solve mobility and preservation goals for long-haul and localized capacity, complete adequate roadway designs for heavy-weight vehicles, link areas (last mile connections), and increase the economic viability of private businesses.

Good data would help WisDOT. Data that could assist WisDOT in freight decision making is not limited to and includes

- Commodity information, including shipping costs, shipping value, commodity amounts, commodity weights, and the impacts to construction costs, depending on transportation mode;
- Freight or intermodal terminal and supply-chain data to better estimate travel times and trips made with empty containers;
- New business data affecting localized areas.

To promote data integrity, better understand data sources, and quickly respond to change, WisDOT is bringing multiple data components together. As WisDOT continues to develop the Multimodal Freight Network, freight forecasting tools will also need development. Tools will need flexibility and will need to be tailored to customer needs. The proposed Multimodal Freight Fusion Forecasting Model will serve as a set of plug-ins to the Multimodal Freight Network. As such, the Fusion Model should consider data quality improvement, data collection, data processing, and data analysis in a cyclical way to be responsive to ongoing freight activities and to increase WisDOT's ability to respond quickly to issues.

Possibilities for the Multimodal Freight Fusion Forecasting Model are endless. For example, indicators or indices outlining economic development potential could be created. WisDOT could partner with government and industry to better understand business location and site variability factors. To better understand supply chain activities, WisDOT could collect higher quality local commodity flows that include commodities hauled, shipment sizes, and trip end activity. Multimodal freight data could be gathered and warehoused together.

As the Fusion Model comes together, WisDOT could also develop new, standardized forecasting approaches. For example, freight business time frame forecasts (3–5 years) could be outlined on forecast reports relative to typical 20-year growth rates. WisDOT could develop forecast confidence scores based on the statistical significance of freight factors. Corridors could be evaluated based on mode, condition, and costs. Overall, the Multimodal Freight Fusion Forecasting Model should quantify future year transportation mode shifts and future year tonnage capacities on different corridors and link these with Wisconsin's economy. This information could be output as part of recognized business practices.

To develop the Fusion Model tool set, a schematic business plan approach is needed outlining long-range expectations, guidelines, stakeholder commitments, and technologies. Along with performance measures, WisDOT should create a solid data architecture framework. Data collection, data processing, data analysis, and data refinement must fit WisDOT, as a customer. The Multimodal Freight Fusion Forecasting Model will be unique and tailored to Wisconsin. It will be grounded in the principles of travel demand or statistical modeling and will act as a series of plug-in components to the already underway Multimodal Freight Network. The tool will be responsive to current freight issues between WisDOT and business and will be useful from an asset approach for long-range transportation planning, analysis, and forecasting.

Rail Freight Commodity Models: A First Generation Effort in Iowa

Phillip Mescher
Iowa Department of Transportation

Ronald Eash and Mary Lupa
Parsons Brinkerhoff

Presentation Notes: Presentation by Phillip Mescher, Iowa Department of Transportation (DOT). Iowa's first generation traffic model was developed in 2007 as a passenger car and truck model. This model is used by MPOs and regional planning affiliations (RPAs) for planning, engineering, and safety studies. The second-generation model, in progress, updates the base year of analysis to 2010 and represents a beginning of emphasis on freight and commodity movements. This model is being used to develop metrics, such as Iowa corn ton-miles by rail. The data sets being utilized are FAF3 data, disaggregated to county-level data and Federal Railroad Administration's (FRA) confidential rail waybill data. Major tasks remaining include developing mode choice, finalizing commodity tables, and identify emerging new markets. This model will assist in creating new metrics, developing scenarios for analysis, and tracking rail ownership changes.

Abstract

Public sector planners, at the rural RPA, MPO, and state levels have long had an interest in building and applying truck models. These truck models typically use zonal level employment data by category and integrate truck "special generators" that represent very large manufacturing, warehousing and intermodal facilities. Gravity models are used in most cases with two or three truck sizes and weights modeled. Truck commodity models have evolved greatly in recent decades, as planners and decision makers began to understand clearly the amount of highway capacity used by commercial vehicles as well as the disproportionate wear and tear on pavements when they carry trucks as opposed to cars. A small number of these truck models address the fact that the U.S. rail network delivers commodities to points, typically rail-truck transfer sites, where they may enter the truck "universe" and be added to the final truck trip tables in the travel model. What has generally been set aside in this effort is the development of a true rail freight commodity model.

In 2012, the Iowa DOT launched a statewide model update which includes the development of a first generation rail freight commodity module, scheduled for delivery in January 2014. This ambitious project fits three criteria noted under the topic "Modeling and Logistics Data Integration" in the "Call for Papers: Innovations in Freight Modeling & Data":

Modeling and Logistics Data Integration

- Integrating public and private data sources—new sources of data that can be merged to create improved opportunities for modeling.
- Freight demand modeling recommendations—new modeling technologies.
- Using private-sector data for public-sector models—types of data that can be integrated and used in the public sector.

The chief criterion for including the Iowa DOT rail freight commodity effort in the upcoming SHRP 2 freight symposium, however, is that it opens new ground in the arena of statewide planning and modeling. While rough and in progress, the Iowa DOT effort can provide to peers and interested parties:

- Model architecture, describing the statewide framework in which the rail models operate.
- Overview of the ongoing rail freight commodity model supply components
    - Assignable rail network (national),
    - Assignable rail network (Iowa),
    - Centroid or loading point strategy, and
    - Rail ownership link segment handling.
- Overview of the ongoing rail freight commodity model demand components
    - First step FAF-to-county disaggregation by freight mode by goods (FAF-to-county),
    - Discussion of disaggregation at a sub-county traffic analysis zone scale,
    - Truck-rail interface, and
    - Domestic and international commodity movements handling.
- Comprehensive public and private rail data review.

This presentation addresses three key topics related to the Iowa DOT rail freight commodity models: (1) model architecture, (2) rail freight model structures, and (3) applicability to states, MPOs, and decision makers in the planning and modeling community. This abstract will endeavor to communicate the importance of this emerging modeling tool.

Iowa DOT Model (iTRAM) Architecture

The Iowa DOT rail effort is in progress and is best explained in the context of the statewide travel demand model, known as the iTRAM, Iowa Traffic Analysis Model. This model, first launched in 2005, features state and national passenger car and truck models. References to both passenger rail and freight commodity rail have not been a priority until this most recent (2012) model enhancement phase.

Commodity Flow Processing

U.S. commodities are processed in a stand-alone model. The process follows these steps:

1. For 2007 and 2040, FAF3 data for four freight modes in Iowa are processed. The result is a master set of commodities for truck, rail, water, and intermodal modes for the base and future.

2. Disaggregation of the commodity flows will then be conducted. Three large sets of commodity flow tables are initially produced for domestic county-to-county, country-to-county import, and county-to-country export flows. Each of these three data sets contains a table for every mode-commodity combination in the FAF. The county flow tables are further disaggregated into project zones within the Iowa study area and combined into larger districts outside the study area. The disaggregation employment data sources vary from census and federal departmental offerings to private county level data and Iowa DOT public and private data holdings.

3. Intermodal commodity flows will be reallocated to the truck, rail, or water flows, using a freight mode choice approach.

4. The resulting commodity flow movements will be processed as follows:
    a. Truck movements will be routed to the main iTRAM model.
    b. Rail movements will be assigned to the rail network and the truck trips that serve these trips will be routed to the main iTRAM model.
    c. Truck trips that serve water freight movements will be routed to the main iTRAM model.

Rail Freight Model Structures

It is the rail freight commodity area that is the focus of this proposed presentation. A small number of rail freight commodity model efforts have been conducted as of the writing of this abstract. Even a cursory review will illuminate the challenges with respect to supply and demand data and approaches for rail commodity models. It is the intent of this abstract to present these challenges in an outline form.

SUPPLY SIDE–RAIL FREIGHT COMMODITY MODELS

- Networks: Iowa DOT staff members have taken a fundamental step with respect to rail models by developing the Iowa rail network. Class II railroads such as the Iowa Northern, the Appanoose County Community Railroad, and others will also be included in the rail freight model. Select Class I and II railroads outside of Iowa—particularly parallel to the rivers—will be reviewed for inclusion in the detailed Iowa rail network as well.

The Iowa rail network noted above is the first building block of the rail freight model. Once the network was built and reviewed, however, it became apparent that rail networks and freight rail models are very different from the corresponding highway-based network and models. Over the history of travel demand analysis, rail networks have received very little study compared to highway networks. The key rail network model components requiring study and integration are noted in the following.

- Zones: The traffic analysis zone (TAZ) structure established for the iTRAM will be active in the freight rail model as well. It will not, however, be the core zonal structure for rail freight. The rail zones will be a disaggregation of the FAF3 districts into counties and finally into points consistent with the observed data in Iowa. The points can be mapped to TAZs once the locations are established.
- Rail Segment Capacity: There must be a means of measuring rail capacity so that rail capacity deficiencies can be quantified. According to a rail study that has built assignable rail networks, the capacity of rail corridors is determined by a large number of factors, including the number of tracks, the frequency and length of sidings, the capacity of the yards and terminals along a corridor to receive the traffic, the type of control systems, the terrain, the mix of train types, the power of the locomotives, track speed, and individual railroad operating practices. Complete, consistent, and current information on all these factors is not always available so the capacity of the primary corridors can be estimated using only three dominant factors: number of tracks, type of signal system, and mix of train types. It is anticipated that rail segments in Iowa will start with these calculations and then evolve to use a customized combination of the available Iowa rail attributes to measure capacity. Train length will also figure into the capacity calculation.
- Rail Segment Modes: Just as highway segments can have modes such as “truck only” or “trucks prohibited,” the rail network will be designed so that only certain commodities and/or industries will be permitted to use any particular rail line segment, often keyed to the rail ownership. This customization will be Iowa-centered, will use the U.S. Surface Transportation Board’s rail waybill data and will be responsive to the origins and destinations of the freight commodity being transferred.
- Centroids: Rail freight originates in very different locations from persons traveling from households or from work. The iTRAM rail model has been conceptualized from the beginning to use the rail waybill data as the source of origin, destination, and commodity type; number of rail cars, tons, and revenue; length of haul; participating railroads; interchange locations; and Uniform Rail Costing System (URCS) shipment variable cost estimates.
- Centroid Connectors: Household-based travel models allow trips to enter the highway network from each zone evenly to any of the reasonable (and connected) road segments in the network. In the case of a rail centroid connector, commodities do not use the shortest rail path to exit the zone. Instead, the goods will seek the closest rail segment that

fulfills other criteria, such as a selected track owner, shipping cost, origin-destination efficiency, or other. The centroid connector approach will be similar to a transit park-and-ride model in which drivers find and use the most efficient station based on criteria other than distance.

- Daily/Annual Frame: Household-based travel demand models such as the iTRAM forecast an average weekday of travel during a representative year. Because freight flows are forecast through the FAF3, the starting point for the demand is a set of annual commodity flows. Rail freight capacity is likely to be calculated in units of trains per day. Hence the year-to-day assumptions become highly important.
- Rail Interface with Truck and Intermodal: Interviews with stakeholders in Iowa as well as a wide variety of data sources have demonstrated a strong connection in Iowa between trucks and rail. These important transfer points will be investigated via the numerous public and private point data sources.

While the rail network within Iowa is the main focus of the freight rail model, the model requires a national rail component in order to accurately capture Iowa rail flows. Outside the state, the Oak Ridge National Laboratory (ORNL) GIS and network products were downloaded and adapted for use as the national rail network. The total national network will be assembled from Iowa active rail and ORNL rail network components.

Demand Side—Rail Freight Commodity Models

The key to understanding the allocation of commodity flows to the rail network is the confidential Carload Waybill Sample collected and provided by the U.S. Surface Transportation Board (STB). The STB has statutory authority over the Carload Waybill Sample (49 CFR 1244). Railroads terminating over 4,500 cars per year are required to file a sample of waybills with the STB. The primary purpose of the Carload Waybill Sample (CWS) is regulatory oversight. The Iowa DOT has obtained this database for both 2009 and 2010. Rail movements are generally aggregated to the Bureau of Economic Analysis (BEA) region to BEA region level at the five-digit Standard Transportation Commodity Code level, and thus the BEA geography will provide a means for an intermediate disaggregation of rail flows.

Within Iowa, there are other potential sources of rail demand data in addition to the waybill. Because one primary goal of the update is to capture freight faithfully in Iowa, a library of freight special generator points for rail is under development. These points are derived from industry and DOT databases and include the following:

1. Raillinc: A comprehensive list of rail geography, including rail station name, location in latitude-longitude, standard point location code (SPLC), and track and junction information.

2. Iowa DOT Point Files: The Iowa DOT has researched and mapped a set of important point location maps relevant to freight, including
   a. Biodiesel and ethanol processing plants
   b. Grain facilities transfer points
   c. Wind turbine production sites
   d. Others, as identified

3. Caliper Corporation U.S. Point Files: the software vendor provides a starting point file for intermodals.

4. Other: As model development proceeds, data collection will proceed to deliver the most detailed state information to the rail model.

WHERE SUPPLY AND DEMAND MEET

The freight rail assignment is expected to consist of a simple all-or-nothing assignment with impedance equal to weighted travel time and interline transfer penalties. The steps are as follows:

- Allocate commodities to trains.
- Commodity to car type/capacity factors developed from the Carload Waybill Sample (CWS).
- Generalize train lengths based on observation.
- Adjust directional volumes by freight car type to account for backhauls.
- Factor to average weekday trains, understanding that discussions with the Iowa DOT will ascertain the most useful assumption to identify rail capacity needs in the state.
- Assign to the final Iowa and national rail network.

There are a great number of issues related to freight rail assignment. Specific business functions of rail freight, such as competition and cooperation between railroads, as well as the future rail regulatory environment, will be interpreted in a sketch fashion, integrating the basics, where possible. It is the goal of the rail freight assignment to take the first steps in rail freight modeling: getting the right goods in the right rail cars, modeling rail freight transfers accurately, and discovering relationships between make/use commodity relationships nationwide to construct a reasonable model. The rail model will be calibrated by adjusting the interline penalties to match Class I rail movements.

Applicability to States, MPOs, and Decision Makers in the Planning and Modeling Community

The Iowa DOT has gone out on a limb to add a first generation rail freight model to its suite of statewide modeling tools. It is well understood by state planners that private business owners, both on the truck and rail sides, do not share data freely and openly with the public or with public agencies. Hence, the ability to calibrate and validate rail freight models is very much limited and is a huge challenge. The first generation rail freight model is expected to answer DOT rail planning questions at the conceptual level including

- Summary statistics: Rail ton-miles by commodity within Iowa, base and future;
- What-if analysis:
    - Test placement of a new truck-rail intermodal or mega-warehouse or distribution center, and
    - Test the viability of a new short line railroad; and
- Rail ownership changes.

The specific capabilities envisioned for the iTRAM may not be readily transferable to smaller scale geographies, such as MPOs or corridors. The reason for this limit is the scale at which a tool such as rail freight can maintain accuracy, and the confidence we have in the disaggregation process when it must be conducted at a sub-county level. However, for state or regional studies, the iTRAM rail freight commodity model is expected to be transferable in its concept, given that local knowledge is used in the adapting process. While very much a work in progress, the iTRAM rail freight model is expected to advance the practice of freight modeling nationwide.

Innovative Tour-Based Truck Travel Model Using Truck GPS Data

Arun Kuppam, Jason Lemp, and Dan Beagan
Cambridge Systematics, Inc.

Vladimir Livshits, Lavanya Vallabhaneni, and Sreevatsa Nippani
Maricopa Association of Governments

Presentation Notes: Presented by Arun Kuppam, Cambridge Systematics, Inc. The tour-based truck travel model used non-inclusive data collection, relying on third-party data vendors for information. This included deploying Global Positioning System (GPS) units and collecting records from truck fleets. Commercial GPS data is widely available and common since companies use it for day-to-day logistics; however, privacy limitations require more data processing. The data set included 3.5 million GPS records from approximately 22,000 trucks, primarily heavy trucks. This represented about 60,000 truck tours. The GPS event is a signal that transmits the data back and forth, such as a signal stop, breakdown, or delivery. By collecting latitude and longitude data from American Transportation Research Institute (ATRI), it is possible to derive distance and speed. The origin lat/lon information was very similar to the final lat/lon. In this approach, parcel data were overlaid to identify land uses at these locations. This provides information as to the purpose of the truck trip and the associated land use. Stops were categorized into 10 stop types, with variables based on purpose type, derived from stop length, accessibility to employment, the number of stops on the tour, and the tour purpose. Next steps include further calibration and validation and determining the adequacy of GPS data to sample size and biases.

Abstract

The concept of truck travel demand forecasting, internal to a region, has always been built upon modeling discrete truck trip ends, distributing truck trip ends to various origins and destinations using travel time impedances and some land use characteristics, and allocating truck trip tables into distinct time periods, using factors derived from observed counts. An innovative enhancement to this approach is to apply activity-based modeling (ABM) principles to truck tour characteristics and develop a tour-based truck travel demand model.

In the recent past, Cambridge Systematics (CS) has successfully acquired, processed, and used truck GPS data to update urban truck models for MPOs. CS, through a contract with the Phoenix MPO, Maricopa Association of Governments (MAG), acquired and processed truck GPS data from the American Transportation Research Institute (ATRI) to develop an innovative framework that links trucks into trip chains in a tour-based model. These data had over 3 million GPS event records for the month of April 2011, which were reported by over 20,000 trucks. These trucks yielded about 20,000 truck tours comprising over 62,000 stops at various land uses. About 95% of truck tours are generated by retail establishments, farms, households, wholesale

trade, and manufacturing facilities in the region. This truck tour database formed a strong foundation to estimate robust tour-based models for various industry sectors.

GPS Devices in Trucks

GPS devices are widely deployed in cell phones, autos, and trucks. These devices can display information about the position of the vehicle, often on a map of the area, and the desired destination, based on signals received from GPS satellites. Sometimes these devices not only receive the GPS satellite signals or other information, such as traffic conditions, they also may wirelessly transmit that information back to a central location. The GPS event information is collected to serve the business purposes of the truck fleet operators. Those businesses are under no obligation to share this information with others. In fact, this information, since it contains sensitive information about the business practices of truck fleet operations, is contractually protected when it is collected as a part of a subscription but provided to third parties. However, information pertaining to the GPS locations (in the form of latitude and longitude) and the time stamp at which the transmission was sent is available. This information can be processed to derive a truck trip or tour database that can be used for model estimation.

ATRI GPS Data for Phoenix

CS processed the ATRI data for the MAG modeling area for the period from April 1, 2011, to April 30, 2011. The raw data delivery from ATRI contained 3,429,603 GPS event records. There are GPS event records reported for 22,657 trucks that indulge in 58,637 tours. At these GPS events, the vehicle may be stopped or moving. In principle, only certain stopped records can be grouped into tours or trips, but tours or trips cannot be precisely computed without further processing. A tour is defined as a sequence of GPS events for a given truck that is only intended for the initial filtering of the GPS records. Subsequent processing was done to determine truck tours consistent with its use in the development of touring models.

Truck Tour-Based Model

The objective of the truck tour model is to develop truck trip chains by industry sector. These truck trip chains can be grouped into the major linkages based on the land uses the trucks make stops at and the probability of making another stop based on the number of previous stops. For each truck tour, a series of choice models are employed in order to determine the time period of tour start times, propensity to make additional stops, next stop purpose, location of the stop, and stop duration.

The model generates the number of stops by industry sector (e.g., retail or manufacturing) and then strings the individual trips together into tours. The number of stops on a tour, the type of stops, and the location and time of day of stops are all estimated based on the type of truck making the tour, the activities conducted by the truck, the characteristics of the stops, and the traffic conditions in the network. All the tour model components were coded in Geographic Information System Developer’s Kit (GISDK) and implemented in TransCAD. Each component was individually assessed and calibrated. The reasonability of the explanatory variables was determined by their magnitude, *t*-statistic, and relation to the dependent variable. The individual model outputs were also compared with the truck GPS data to assess the model performance. These comparisons indicated that the model components are predicting very closely the observed data for the most part. There are some differences, which can be further improved upon with more rigorous calibration and validation of the model.

Design of an Agent-Based Computational Economics Approach to Forecasting Future Freight Flows for the Chicago Region

John Gliebe, Colin Smith, Kaveh Shabani, and Maren Outwater
RSG, Inc.

Kermit Wies
Chicago Metropolitan Agency for Planning

Presentation Notes: Presented by John Gliebe, RSG, Inc. The model was developed for the Chicago Metropolitan Agency for Planning (CMAP). While original models derived commodity flows from FAF3, the MPO wanted to model changes in macroeconomic conditions such as global supply chain shifts, advances in technology, and near-shoring, for example. The model accounted for the idea that companies have individuals who make decisions based on several drivers—imperfect information, cultural bias, personal affinity to service providers, a limited search effort—and decisions are not optimized. This model takes a bottom-up approach in which individual agents are simulated in a virtual world. This approach matches buyers and sellers and synthesizes firms or establishments outside of the region. It is inspired by the trade network game where buyers and sellers have attributes, some of which lead to buyer preferences for a seller's cost-service bundle.

Abstract

Transportation planners in the United States have benefited greatly by the development of the Freight Analysis Framework (FAF) set of data products, which have enabled analysis of not only recent (2007) but also future freight flows by commodity type across zone systems, permitting a useful level of spatial resolution between and within metropolitan regions. The most recent available version, FAF3, provides forecasts of future freight flows forecasts for the year 2040 based on a continuation of current trends, which is one possible depiction of the future.

For policy and planning sensitivity analysis, however, it is desirable to vary forecasts to reflect potential changes in macroeconomic conditions (e.g., foreign trade and oil prices), large-scale infrastructure changes (e.g., extra-regional port expansions as well as intra-regional infrastructure investments), technological shifts in logistics and supply chain practices (e.g., near-sourcing, outsourcing), and other assumptions related to regional economic competitiveness. The Chicago Metropolitan Agency for Planning (CMAP) has recently developed the first generation of a regional freight forecasting model that features two levels of resolution: mesoscale resolution, connecting Chicago to the rest of the nation and the world; and microscale resolution, a tour-based simulation model of freight movements within the region. To this already comprehensive set of tools, CMAP is now developing an extension to the mesoscale model to forecast future freight flows, independent of FAF, using a flexible agent-based computational economics approach for modeling the evolution of regional supply chains. This

represents the "macroscale" resolution. This paper will provide a brief overview of agent-based computational economics and discuss how it will be applied in the model.

Overview of Agent-Based Computational Economics

Agent-based computational economics (ACE) (e.g., Tesfatsion 2005) is an emerging, alternative approach to classical economic theory that is often applied to the study of market behavior. ACE methods utilize computer simulations of individual market actors, or agents, who follow relatively simple sets of rules in interacting with other agents. Through careful construction, it is possible for the analyst to specify a set of agents endowed with decision rules, outcome payoffs, and starting conditions, such that the simulated interactions played out over time will result in outcomes that resemble real market behavior. By modifying agent decision rules, payoffs, and starting conditions, it is possible to test a wide variety of potential markets and assumptions. Some of the most commonly studied applications of ACE include the formation of trading networks and production sourcing decisions.

At the core of ACE models are decision rules based on game theory. Perhaps the most well known is the prisoner's dilemma in which two apprehended agents independently decide whether to cooperate or defect in confessing to a crime, with their sentencing varying in severity depending on whether they both confess, both deny guilt, or one confesses while the other denies guilt. This fundamental cooperation-versus-defection paradigm with varying payoffs depending on the outcome is the basis for a wide variety of decision contexts in which agents act on privately held knowledge, while making assumptions about what other actors may or may not do. It forms the basis for many modern microeconomic models of bargaining and cooperation under varying assumptions of information provision and the evolution of market equilibrium conditions, weak stability, or structural change.

At a very practical level, game theoretic principles have been used in the global supply chain and logistics profession to develop more efficient practices, particularly for sourcing decisions and supply chain coordination more generally. Indeed, with the rise of Internet-based commerce, electronic procurement systems have emerged as a preferred means for producers of commodities to solicit bids and select suppliers for various input commodities and services. A chief reason for the popularity of "e-procurement" systems is the ability to control market outcomes through auction mechanism design. Mechanism design, a hot area of applied research in economics, finance, and operations studies, amounts to reverse engineering a market process by specifying a set of rules, payoffs, and initial conditions that will result in a preferred market outcome. Researchers in the field of algorithmic game theory have combined mechanism design with computer science to develop sophisticated algorithms to provide computationally efficient implementation solutions that can handle a wide variety of complex market situations in an automated fashion.

For example, one desirable outcome of a procurement situation, from the perspective of the buyer, is for suppliers to bid truthfully with respect to their actual costs, that is, to avoid strategic lying. An early solution to this problem, which seems to hold under many contexts, is the second-price sealed-bid auction in which the winning provider/seller was the submitter of the lowest bid (in the case of procurement); however, the price paid to the winner was that of the second-lowest bid. Thus, there is no incentive to bid higher than cost. Auction mechanisms vary in complexity and computational tractability, depending on starting conditions, such as whether there are multiple buyers as well as sellers (so-called double auction), or whether there is a single commodity up for bid or a multi-commodity bundle.

CMAP Freight Model Design

In the CMAP freight modeling system, firms are represented as commodity-producing agents, defined by firm size and by the 43 categories used by the Standard Classification of Transported Goods (SCTG) and FAF3. Firms are simulated based on data from County Business Patterns and Bureau of Economic Analysis's (BEA) Input-Output (IO) Accounts and are located either in traffic analysis zones within the Chicago region, or in FAF zones representing other regions of the United States and foreign countries.

The design for the future freight forecasting element utilizes the relationships found in the IO data as the foundation for supply chain network formation. For each output commodity produced by a firm, the IO use tables provide a recipe for the producer value of input commodities. To forecast future freight flows, the modeling system will allocate total commodity production to producer agents, based on firm size and SCTG code. For each input commodity specified by the IO tables, the producing firm will choose one or more suppliers from a pool of agents in the simulation who produce that commodity. The supplier pool may include intra-firm establishments, other regional suppliers, and supplier agents from other U.S. states and other countries. Costs of production will vary by each potential supplier's attributes, taking into account regional differences in both transport and non-transport costs. Transport costs will be derived from multi-modal network path values, considering truck, rail, water, and air modes.

An ACE approach will be used to select suppliers for each commodity to be sourced under a variety of commodity markets and firm typology assumptions. Of central importance to the model design is the ability to reflect the degree of vertical integration in firms' procurement practices as well as propensities to outsource to foreign countries and so-called near-sourcing. Thus, the utility of choosing a firm as the source for a particular commodity will depend on the commodity itself (e.g., bulk versus specialty goods). This will result in varying weights assigned to cost vis-à-vis quality considerations, such as timeliness of delivery and the need to maintain quality control over the product. To remain flexible with respect to ACE methods, consider a couple of flexible mechanism design strategies such as bilateral trading scenarios and double auctions.

To facilitate scenario testing, the model design calls for the ability to vary assumptions on

- total levels of production;
- technical coefficients of production found in the IO tables;
- transport and non-transport unit costs, including foreign trade tariffs; and

- the ability to code network infrastructure changes, such as port capacity expansions, intermodal terminal capacities, and similar infrastructure changes.

Testing

Once the model is implemented, the researchers plan to conduct several tests of the model performance for the purposes of fine tuning as well as demonstrating its capabilities. An initial test will be a comparison with FAF3 baseline and future freight flows. In addition, the team plans to conduct a series of sensitivity tests. Preliminarily, these include

- Completion of the Chicago Region Environmental and Transportation Efficiency Program (CREATE), a multi-billion dollar program to improve rail infrastructure to ease congestion and minimize impacts on non-rail traffic;
- Introduction of a dedicated truck network in Chicago;
- Introduction of a large intermodal facility in Iowa;
- Expansion of the Port of Prince Rupert, British Columbia; and
- Changes in the volume of international trade with China.

Reference

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Florida Multimodal Statewide Freight Model: A Model Incorporating Supply-Chain Methods and Providing Linkages to Regional Tour-Based Truck Models

Colin Smith, Kaveh Shabani, and Maren Outwater
RSG, Inc.

Vidya Mysore
FHWA Resource Center

S. Frank Tabatabee
Florida Department of Transportation

Presentation Notes: Presented by Colin Smith, RSG, Inc. The purpose of the model is to enhance modeling capacities. This led to replacing the state's freight model with a national supply-chain model, while the passenger model was left untouched. The model looks at the way freight moves to individual locations and assigns mode and transfer locations. Additionally, it creates a set of agents that represent firms, similar to population synthesis used in activity-based models. The commodity data are based on FAF3, 2007 benchmark input-output account, to determine type and percentage of commodities used by each industry. The model visualizes trading partners and shows characteristics of commodity and type. The statewide model is designed to be integrated with the regional model where both can run simultaneously.

Abstract

In recent years, freight forecasting has been identified as a way to understand the patterns of interstate and international trade, economic growth, and the impacts created by the use of the transportation system for the movement of freight. These impacts can include congestion and delay, potential exposure to hazardous materials and other safety concerns, and economic impacts, as well as energy use and environmental consequences. The fact that more and more freight today is moved by heavy trucks on the interstate highway system has become an area of particular concern to planners.

Despite recent advances in freight forecasting, the current methods are not adequate to address the increasingly complex issues related to freight demand. Current models are mostly based on methods that were developed for personal passenger travel. Freight is obviously different from personal vehicle travel and requires a different technical approach. Given the transition that is currently underway to implement disaggregate modeling techniques, it is only logical to apply disaggregate techniques for modeling the movement of freight as well.

Tour-based and economic methods have become the state of the art in household travel modeling. This new approach offers a myriad of benefits that include the ability to model various aspects of choice behavior explicitly. These factors are relevant in personal travel but are also

important in freight modeling as well. In research funded by the Federal Highway Administration (FHWA), the authors have implemented a freight demand forecasting framework in the Chicago region, based on existing research on tour-based and logistics supply chain models for commercial movements that demonstrates the potential of these new methods as a basis for new freight demand forecasting models.

The authors have now transferred this freight demand forecasting model to Florida in a project funded by the Florida Department of Transportation. In this work, the researchers have implemented the national level supply-chain model that micro-simulates shipments of commodities between businesses and produces truck, rail, air freight, and water-borne freight volumes. The model is called the Florida Multimodal Statewide Freight Model. The model is designed to link with the regional portion of the freight demand forecasting framework, which is a regional tour-based truck model that micro-simulates the pickup and delivery of each shipment in a metropolitan region.

The Florida Multimodal Statewide Freight Model is described in this paper, with particular emphasis on the implementation of the national supply-chain model to support statewide freight modeling in Florida. An overview of the regional tour-based truck model, which is planned to be implemented in one or more metropolitan areas in Florida and was implemented in Chicago, is also included.

Description of the Florida Multimodal Statewide Freight Model

The Florida Multimodal Statewide Freight Model is comprised of several steps that simulate the transport of freight between each supplier and buyer business in the United States. This modeling system includes selection of business locations, trading relationships between businesses, and the resulting commodity flows, distribution channel, shipment size, mode, and path choices for each shipment made annually.

Firm Synthesis

The initial element of the model synthesizes all firms in the United States and a sample of international firms. The geographic detail within Florida, Alabama, and Georgia is traffic analysis zones, while outside those three states the geographic detail is defined by Freight Analysis Framework zones. This model synthesizes firms by industry category and by size category to capture the primary drivers of commercial vehicle travel.

Supplier Selection and Goods Demand

The next element of the model predicts the annual demand in tonnage for shipments of each commodity type between each firm in the synthetic population. The demand represents the goods produced by each firm and the goods consumed by each firm. The model is applied in two steps. In the first step, buyers who have a demand for goods are paired with suppliers who sell those goods using a probabilistic model. The connections between industry types for each commodity are based on input-output tables. Once the buyer-supplier relationships are established, the amount of commodity shipped on an annual basis between each pair of firms is apportioned based on the number of employees at the buyer and their industry, so that observed commodity flows are matched.

Distribution Channels

Using a multinomial logit model, each shipment between each buyer-supplier pair is assigned a probability of choosing a specific distribution channel to represent the supply chain it follows from the supplier to the consumer. The model predicts the level of complexity of the supply chain, for example whether it is shipped directly, or whether it passes through one or more warehouses, intermodal centers, distribution centers, or consolidation centers. This is a simple representation of supply chains, limited by the available data to estimate distribution channels by industry.

Shipment Size

Shipment size is estimated using a discrete-choice model based on a variety of firm, commodity, and travel characteristics. It is as this point in the model that the units of analysis change from annual commodity flows between pairs of firms to discrete shipments that are individually accounted for and delivered from the supplier to the buyer.

Modes and Transfers

There are four primary modes (road, rail, air, and water) that are modeled. Detailed networks of road and rail for the United States are used, with simpler functions of distance and the value of goods being transported to represent the air and water modes. The modes and transfer locations on the shipment paths are determined based on the travel time, cost, characteristics of the shipment (perishable, expedited, containerized), and characteristics of the distribution channel (whether the shipment is routed via a warehouse, consolidation or distribution center, and whether the shipment includes an intermodal transfer, e.g. truck-rail-truck).

Daily Shipments and Warehouse Selection

Once the modes and intermodal transfers have been assigned, the shipment list is converted from all annual shipments to a daily sample to represent the day being modeled. This component of the model can be adjusted to allow for seasonal variations in commodity flows. This component of the model also assigns shipments to specific warehouse, distribution, and consolidation centers if the shipment passes through one of those locations.

The model also incorporates a multimodal transportation network that provides supply-side information to the model including costs for different paths by different modes (or combinations of modes), and to which freight vehicle flows are assigned. While the model is focused on Florida, it encompasses freight flows between Florida and the rest of the world.

Overview of the Regional Tour-Based Truck Model

The Florida Multimodal Statewide Freight Model is designed to be integrated with a regional truck-touring model, which is a sequence of models that takes shipments from their final transfer point to their final delivery point. The final transfer point is the last point at which the shipment is handled before delivery, i.e. a warehouse, distribution center, or consolidation center for shipments with a more complex supply chain or the supplier for a direct shipment. It does the same in reverse for shipments at the pickup end, where shipments are taken from the supplier and taken as far the first transfer point. For shipments that include transfers, the tour-based truck model accounts for the arrangement of delivery and pickup activity of shipments into truck tours. The model produces trip lists for all of the freight delivery trucks in the region that can be assigned to a transportation network. The truck-touring model predicts the elements of the pickup and delivery system within a region through several modeling components:

Vehicle and Tour Pattern Choice

This multinomial logit model predicts the joint choice of whether a shipment will be delivered on a direct tour from transfer to delivery (i.e., where a truck departs the transfer location, delivers the shipment, and returns to the transfer location) or a peddling tour where the truck makes multiple deliveries or pickups, and the size of the vehicle that will make the delivery.

Number of Tours Choice

This multinomial logit model predicts the complexity of the peddling tour in which a shipment is contained: for example, a truck might return to the transfer point after one large loop or might break the delivery schedule into two, three, or more tours.

Number of Stops

This model uses hierarchical clustering to divide the shipments into spatially collocated groups that can be reasonably delivered by the same truck.

Stop Sequence

This model uses a greedy algorithm to sequence the stops in a reasonably efficient sequence but not necessarily a shortest path (our research shows that touring trucks only sometimes deliver in a sequence that is efficient in shortest path terms).

Stop Duration

This multinomial logit model predicts the amount of time taken at each stop based on the size and commodity of the shipment.

Delivery Time of Day

This multinomial logit model predicts the departure time of the truck at the beginning of the tours. Based on this, the travel time of each trip, and the stop duration of each delivery, all of the trips on the tour can be associated with a time period for assignment purposes.

Model Implementation

The Florida Multimodal Statewide Freight Model is currently being calibrated and validated to a series of modal data sources in the state. Commodity flows by mode will be validated against Transearch data within the state, truck origin-destination patterns will be validated against ATRI data, and modal volumes will be validated to truck counts, Waybill data, Piers data, and T-100 data for highway, rail, water and air modes, respectively.

Logistics in Freight Modeling—A Report from the Delft Group

Lóri Tavasszy
Delft University of Technology and TNO

Presentation Notes: The focus of this effort was using freight modeling to disentangle freight data, distribution centers, and moving freight to rail and waterways. There was significant distribution center and logistics sprawl, and there was a question on whether the location of distribution centers within the region could be predicted. The model uses big data for inputs, with 30 to 40 intermodal terminals that ship 10 to 12 million 20-foot equivalent units (TEUs) through Rotterdam. It was determined that trucks will not have greater than a 35% share in new container terminals. The model was also developed to understand how the network is influenced by carbon dioxide (CO_2) pricing. Results show that waterways are the dominant mode of travel over rail. This model is an agent-based model that is validated through gaming. Shippers and carriers can be a shopkeeper, a freight forwarder, a service provider, or a manufacturer.

Abstract

In 2013, the research programs on innovative freight transport models (supported by a 4-year national grant) will be completed. The results that seem interesting to report are the following:

- Developing empirical models of freight flows through distribution centers. Change in spatial patterns of freight flows is partly due to the creation or removal of distribution centers (nowadays visible as logistics sprawl, when focusing at major, heavily industrialized cities). Although the first models date from the ’90s there has been little empirical research. Delft Ph.D. candidate Igor Davydenko has developed these models for the Netherlands, Germany, Japan, France, and Europe. The Dutch model was built on the trip surveys of Statistics Netherlands.
- Optimization of multimodal networks for hinterland container operations. Ph.D. candidate Mo Zhang developed an optimization approach that takes into account cooperative service networks and allows the research team to study the effects of a strong internalization of external costs. The model was used as a basis for a game in which inland waterways service providers were asked to consider joint services and joint investments in terminals.
- Multi-stakeholder ontologies as a basis for data and model architecture. An important reason for the short lifetime of many city logistics concepts is the failure to take into account the business models and perceptions of the different stakeholders. In the Ph.D. project of Nilesh Anand, a new design approach for a multi-stakeholder agent-based modeling (ABM) is created by building upon a multi-stakeholder ontology. This serves as the basis for the architecture for data acquisition, creation of the ABM, perception alignment through gaming, and evaluation of alternatives.

A new dataset on global multimodal transport chains was created by Statistics Netherlands, in partnership with Amsterdam University. Typically, statistics only measure one leg in a transport chain, and do not connect these legs. This gives problems in transport modeling and in economic analyses where the true origins and destinations of freight should be known and where flows in transit should be separated from flows originating from local industries. The problem was solved with the help of a detailed input-output (IO) model.

Discrete Model of Freight Mode and Shipment Size Choice

Megersa Abate and Inge Verth
Swedish National Road and Transport Research Institute

Gerard de Jong
University of Leeds

Presentation Notes: Presented by Megersa Abate, Swedish National Road and Transport Research Institute. The model is based on a deterministic cost model, with the minimization of total annual logistics costs. The current model lacks two main elements: it does not account for other determinants of shipment size and chain choices and it lacks a stochastic component. The data source was the national commodity data flow of about 2.8 million shipments. This model includes information for supply chain, weight, and infrastructure variables. Initial results show a low elasticity for transport costs for most modes.

Abstract

The main feature of the current Swedish national freight model system (SAMGODS model) is incorporation of a logistic component in the traditional freight demand modeling. The logistics module of the SAMGODS model estimates frequency/shipment size choice and transport chain choice (transport chain and mode choices and use of transshipment). Logistical decisions of firms are incorporated in the modeling process based on the shipment size optimization theory. According to this theory, firms are assumed to minimize total logistics costs by trading off inventory holding costs and transport costs.

Judged by international standards in freight transport modeling, the SAMGODS model is relatively modern. Its logistic module, however, lacks two main elements. First, it does not account for main determinants of shipment size and transport chain choices other than cost, that is, decisions are solely based on cost consideration. Second, the model is deterministic and lacks a stochastic component. In order to improve the prediction of the model, logistical decisions should be modeled taking into account these two elements. A full random utility logistic model which accounts for this was planned but has not yet been estimated on disaggregated data (de Jong and Ben-Akiva 2007).

This project is a first step toward estimating a full random utility logistic model. The researchers will formulate a model of transport chain and shipment size choice using the 2004–2005 Swedish Commodity Flow Survey. The main econometric work in this project involves modeling the interdependence between shipment size and transport chain choices using a joint (e.g., discrete-continuous) econometric model. Parameter estimates from this model will later be used for estimation of a full random utility logistic model. They will also be used to estimate transport time and cost elasticities to analyze policy outcomes.

Reference

de Jong, G., and M. Ben-Akiva. A Micro-Simulation Model of Shipment Size and Transport Chain Choice. *Transportation Research Part B*, Vol. 41, Issue 9, 2007, pp. 950–965.

Freight Models, Constrained Economic Models, and Natural Resource Data

Ming Chen and Olga Ivanova
TNO

Presentation Notes: Presented by Ming Chen, TNO. The model was designed to understand the implications of scarcity of non-renewable natural resources on the supply chain. Further, a shifting of economic strengths worldwide is having an effect on resource utilization. An increase in price led to production at higher costs, which resulted in more supply. There is a need for restricted economic growth in some resources and the application of a world economic model to nations for freight movements.

Abstract

This abstract describes the connection of a freight model to a restricted economic growth model that takes into account production capacity and substitution data of natural resources. The database on production capacity of natural resources and the substitution possibilities is unique and therefore also the economic model that takes this into account. The restricted growth has major impacts on freight transport forecasting and analysis.

Restricted Growth

We are living in interesting times full of major trend breaks and innovation. The world is facing large challenges in the coming decennia and further, such as climate change and scarcity of important natural resources, and at the same time large-scale solutions are being set in place. These solutions are in some cases changing old paradigms, leading to new insights and a changing way of approaching challenges. These changes in turn require different products, which in many cases result in a changed use of natural resources. This is obviously the case for energy, but it can also involve other natural resources, including labor.

Scarcity of natural resources is generally expected to be solved by the laws of economics; a too high demand leads to higher prices, which will reduce the demand for the specific commodity. Assuming that there are substitutes for the scarce products, a shift of demand will take place, and assuming that production of the scarce commodity will increase, eventually it will lower its price again. There is no reason to assume that this process will hinder economic growth. However, for some natural resources, increase of production can only be done at a higher price level. The substitutes generally also are only used at higher price levels. Therefore, the overall price level of any commodity using the scarce natural resource should be expected to increase. This has a negative effect on the potential for economic growth. An innovation that can replace the use of the scarce natural resource for another natural resource at lower costs will therefore boost economic growth.

Freight transport is derived from physical trade activities. Modeling freight transport requires proper economic models. Traditional economic models have been developed in times of unrestricted growth. The resulting trade patterns are represented by exponential growth, which obviously will not work anymore in times of scarcity, which can be expected in the coming decades, especially given the growing world population and the upcoming BRIC countries, Brazil, Russia, India, and China.

Natural Resource Database

The database that connects economic and physical dimensions (including the use and stock of natural resources and emissions) has been developed by TNO in a series of projects for the European Commission. The project EXIOPOL (A New Environmental Accounting Framework using Externality Data and Input-Output Tools for Policy Analysis) had as a key goal to produce a Multi-Regional Environmentally Extended Supply and Use Table (MREESUT) for the whole world. The EXIOPOL database (EXIOBASE) has a unique detail and covers 30 emissions, around resource extractions, given specifically for 130 sectors and products by 43 countries making up 95% of global GDP, plus the rest of world. A follow-up project of 3.5 million euro under the EU’s FP7 program, called Compiling and Refining Environmental and Economic Accounts (CREEA), has expanded this database with improved extensions for water, land use, and other resources, but above all it has created an additional layer with physical information in the (economic) SUT in the EXIOPOL database (in short: EXIOBASE). For the first time the researchers have produced a global, integrated Multi Regional Environmentally Extended Economic and Physical Supply and Use Table (MREEE & PSUT).

This worldwide database incorporates the latest available transport statistics from an ETISplus project in the form of physical trade flows and the split of trade flows between various modes of transportation. The international transport services are further produced by various countries and are a part of the supply and demand relationships of the database.

Restricted Economic Model

The restricted economic model EXIOMOD has been developed by TNO with own resources; it was applied and further extended in a number of recent and ongoing European Commission projects.

EXIOMOD combines the main structure of traditional computable general equilibrium (CGE) analysis with the innovative elements of semi-endogenous growth and adaptive expectations under the framework of dynamic general equilibrium. All main behavioral parameters of the model have been estimated econometrically based on the available data.

The model incorporates the representation of 43 main countries of the world. It includes an individual representation of all EU-27 countries and candidate member states. It also includes the largest emitters, such as the United States, Japan, Russia, Brazil, India, and China. The EXIOMOD model is dynamic and recursive over time, involving dynamics of capital accumulation and technology progress, stock and flow relationships, and adaptive expectations.

EXIOMOD combines economic, environmental, and social domains in an efficient and flexible way:

1. Social effects: includes the representation of three education levels, 10 occupation types, and households grouped into five income classes. One can trace the effects of specific policy on income redistribution and unemployment.
2. Economic effects: the model captures both direct and indirect (wide-economic and rebound) effects of policy measures. EXIOMOD allows for calculation of detailed sectoral impacts at the level of 163 economic sectors and 200 commodities.
3. Environmental effects: the model includes representation of 28 types of greenhouse gas (GHG) and non-GHG emissions, different types of waste, land use (15 types), and use of material resources (171 types).

Integration of physical and monetary data allows one to take proper account of the physical restrictions on consumption and production activities as well as to provide a full analysis of sustainability issues. The EXIOMOD database includes both monetary and physical units in a consistent way and allows for their integration in a unified modeling framework. The physical dimension provides the representation of all main resource constraints in the global economy.

Connecting to Freight Models

The restricted economic model has been connected to the TNO freight transport models. The TNO freight models are based on the first TRANS-TOOLS (Tools for Transport Forecasting and Scenario Testing) model, which has been developed under coordination of TNO for the European Commission to serve as a reference model for their policy studies. Up to now, the connection has been done in one direction; i.e., the predictions of future trade flows in physical units serve as input to the freight data model. In future, the aim is to feed the results from the freight models back into the economic model. The second link will allow TNO to assess the impacts of the changes in transport infrastructure and logistics system on the worldwide distribution of economic activities, economic growth, availability and use of natural resources, and various external effects.

The TNO freight models cover the entire European Union at regional detail (Nomenclature of Territorial Units for Statistics [NUTS 2]) with country detail and some country groupings for the rest of the world. Since EXIOMOD operates at a country level, the step to take is to disaggregate the country results to a regional level. This is done by partner relation and commodity group (NSTR chapters) so it can be differentiated where possible. The next steps operate with the results of this trade connection module as normally would be done. A modal split model determines shifts in the modal split due to changes in cost structures and commodities to be transported. The assignment is done with Omnitrans with the TRANS-TOOLS network.

Advantages

Having the connection between the natural resource data with the freight transport models through the restricted economic model has some clear advantages. Some advantages are the following:

- Improved prediction of economic development for all commodities;
- Improved prediction of bulk flows; and
- Improved assessment of external impacts.

These will impact the assessments of infrastructure needs for ports and the inland modes and policies at each level (national, regional).

DAY 2 Introductory Remarks

Anne Strauss-Wieder
A. Strauss-Wieder (ASW), Inc.

Engaging Freight and Supply-Chain Representatives in Public Sector Projects

MAP-21 encourages each state to establish a freight advisory committee, which must consist of public- and private-sector stakeholders. However, from these meetings, the private sector must be able to obtain value that will be meaningful to them. These private-sector players can be shippers and receivers, carriers, service providers, terminal facility providers, and warehouse and industrial developers.

Personnel from the public sector must ask themselves before they engage the private sector, what do we really need to know from them? Are they directly affected by a project or study? It's important to keep in mind that the private-sector planning timeline is much shorter than the public sector's, typically three to five years. They are also more responsive to supply chain drivers and considerations, which include

- The bottom line
- Market pressures
- Globalization and localization of the supply chain
- Shocks to the system (e.g., disasters, labor issues)
- Product proliferation
- Sustainability and profitability
- Governmental policy

There are several ways to engage the private sector—networking, educational seminars, regional business coalitions, and roundtables—but public-sector planners must get out into the field. When planners do engage, keep it project-specific and see if others are doing the same data collection first, so more time is not utilized sharing data already readily available.

Perform outreach with outcome: understand the objectives, their priorities and motivations; consider when to involve the private sector, when to inform them, or when to involve them; and allow opportunity for feedback.

Lastly, it is important to understand the current freight context. Is it peak holiday shipping season, which is earlier than the shopping season, is there a strike, or are toll increases being considered? These may significantly impact the availability for the private sector, so timing is important as well.

Exploratory Use of Raster Images for Freight Modeling

Pedro Camargo, Michael McNally, and Stephen Ritchie
University of California, Irvine

Presentation Notes: Presented by Pedro Camargo, University of California, Irvine. The California model is a commodity-based model, aggregated to 15 commodities. This model breaks five FAF zone into 97 zones and is integrated with the statewide travel demand model. CropScape is a U.S. Department of Agriculture project that takes raster images for 48 states from 2008 to the present, using remote sensing technology. In larger area row crops, the information is 85–90% accurate. There were 105 different crops identified. These areas are viewed by remote sensing every five days, and then the areas are checked to validate classes to actual use. CropScape allows for the estimation of current unused land and provides the upper limit of planted areas, which is tied to estimates of future yields. The expansion of planted areas can also be tracked. The model approach provides temporal analysis seasonally, as opposed to FAF data, which is provided annually. Furthermore, VegScape was launched in 2013 and could be used to analyze when planting periods and harvesting occurred, to better measure the timing of freight shipments from agriculture.

Abstract

When working with freight planning, particularly commodity modeling, it is frequently a daunting task to find data sources, especially data disaggregated to county or less than county levels. In the case of agricultural commodities, information availability is further reduced, since agricultural census data collection is infrequent and is not completed in terms of crops covered, nor does data exist below the county level in terms of geographical aggregation. Data sources such as the Freight Analysis Framework (FAF) often present annual data. Since transportation models are usually developed for peak periods and/or typical days, the traditional assumption of flat peak factors is not consistent with the facts that agricultural commodities are seasonal and that seasonal patterns vary geographically.

It is in this setting that we tested the use of raster images provided by the U.S. Department of Agriculture (USDA) in two different analyses: FAF disaggregation and seasonality analysis. We present results that include models for FAF disaggregation that outperform the best models currently available in the literature and a full procedure for computing agricultural seasonality for any geographical aggregation.

The Data Source: Cropscape

CropScape is a website/tool maintained by the National Agricultural Statistics Service (NASS), which is a branch of the USDA. This tool provides what is called Cropland Data Layers (CDL), which provide information on crops for all 48 contiguous states.

These data layers are geographical raster layers created using remote sensing technology and an automated classification software that, every five days, classifies each pixel of an image (translating to approximately 0.77 acre) into several categories which define different crops, urbanized areas, open water, etc. The classification software is calibrated using ground truth reported by researchers who visit different parts of the country (randomly generated), registering the coordinates of some points and the actual crop/use of such points.

Although the program has been in existence since 1997, only since 2008 are all contiguous states being covered. In 2010, a new generation of satellites was deployed. Although no major changes should be expected over the next few years in this database in terms of satellite system used or geographic coverage, new functionality is continually being added to the website hosting the images.

One of the greatest advantages of CropScape data is that they are available for all 48 contiguous states at any geographical aggregation level larger than the image's pixel size, with the reliability intrinsic to the procedure of automatic classification used to generate these images. Although not very accurate in small distinct areas (such as a small crop within an urban area), classification for large area row crops, NASS claims, has produced accuracies ranging from "mid 80% to mid 90%." In terms of geopositional errors, the 90% confidence interval computed is a 60 meters error to any direction.

CropScape images have been available for free for all 48 contiguous states since 2008, and for at least one state since 1997, which allows for the analysis of tendencies as well as having the appropriate year data for developing any model using this dataset.

FAF Disaggregation and Freight Generation Models

FAF is perhaps the most widely used data source for regional freight modeling, but its use is almost always dependent on its regional disaggregation, since geographically it is very aggregate. Several reports and papers in the literature present disaggregation procedures based on tools that vary from linear regressions to structural equation modeling; the results have been invariably poor. Further, most of such efforts have used explanatory variables originated in the economic census and the agricultural census (in the case of agricultural products), which are available at the county level at best (a good portion of the results are flagged due to privacy concerns).

Therefore, the researchers proceeded with an evaluation effort of suitability of CropScape as a source of explanatory variables for FAF disaggregation and possibly generation models estimation. To better evaluate the explanatory power of the variables extracted from CropScape, all models estimated in this exercise use solely variables obtained by processing CropScape and thus should not be considered as the best models one could obtain with the use of CropScape. One important feature of the data extracted from CropScape is the possibility of considering specific crops, such as grains, animal feed, and other crops, and using each one of these groups to disaggregate or model the commodity groups corresponding to such crops.

Preliminary Results

Some preliminary models for disaggregating agricultural commodities were estimated using standard ordinary least squares (OLS) estimation procedures and their results are presented in Table 5.1. All production values are measured in tons and crop areas in 1.000 acres.

Table 5.1. Models Estimated Using CropScape Data Versus Models from the Literature

MODELS	Variable 1		Variable 2		R^2
	Description	Coefficient (t-test)	Description	Coefficient (t-test)	
FAF group 1 Live animals & Fish	Pasture land	0.0864 (8.17)	Crops related to animal feed (hay, haylage)	0.2367 (5.87)	0.49
FAF group 2 grains	All grains crop area	1.511 (37.87)	-	-	0.92
FAF group 3 Other crops	Other crops (non pasture, grains or animal feed)	0.7368 (14.17)	-	-	0.62
FAF Group 4 Animal Feed	Crops related to animal feed (hay, haylage)	2.68E-07 (1.99)	Other crops (non pasture, grains or animal feed)	4.14E-07 (7.38)	0.51
FAF groups 1-4	All grains crop area	1.7524 (21.16	Other crops (non pasture, grains or animal feed)	0.9754 (4.51)	**0.90**

Some of these preliminary results need to be highlighted: the model for the all agricultural commodities combined resulted in an R^2 of 0.90, much higher than any other value found in the literature. The second important result is the R^2 of 0.92 for grains, which represent 63% of all agricultural commodities.

Seasonality Analysis

An interesting attribute of agricultural production is seasonality, not only because agricultural commodities are indeed very seasonal but also because harvest periods vary between agricultural products.

The caveat in seasonality analysis, however, is that seasonality in production does not necessarily translate into seasonality in transport, which can be a factor of major importance if much of the harvest is stored within the production regions and also shipped out after the harvesting period is over. Since the consideration of storage and its impact on transportation seasonality demanded information on storage facilities and policies, the researchers carried out an analysis of production seasonality and, in the development of the California Statewide Freight Forecasting Model (CSFFM), applied the results to the annual flows.

Results

By computing the production of all products for all FAZs in each season, it was possible to compute a distribution of production in each one of these areas. For example, a group of zones north of San Francisco, specifically Marin County, has a very concentrated production, with more than 75% of the annual total being produced in a single season.

Both results, although preliminary, demonstrate a great potential for using CropScape as an important data source for modeling agricultural commodities. Further, CropScape allows for a spatial disaggregation to a very fine level not allowed by any other public data source.

Disaggregate State Level Freight Data to County Level

Shih Mao Chin, Ho-Ling Hwang, and Francisco Moraes Oliveira-Neto
Oak Ridge National Laboratory

Presentation Notes: Presented by Ho-Ling Hwang, Oak Ridge National Laboratory. FAF2 provides comprehensive movement of freight among states and metropolitan areas by all modes. There are 123 domestic regions and eight foreign regions. To disaggregate the data, the commodity flow survey, county business patterns, and industry input-output accounts were used. The model was used to estimate ton-miles, as tonnage and the value of goods are important measures of freight activity. This also helps measure environmental impact and the revenue of transportation firms relative to the accounting of freight in tons transported by mile. The main disaggregation steps for the model were linking freight activities to economic activity, disaggregating the FAF3 data to the county level, and estimating the average shipment distance by mode based on multimodal network systems. The information was compared to other data sets for calibration based on ton-miles.

Abstract

As part of efforts to support Federal Highway Administration (FHWA) in its development of comprehensive national and regional freight databases and network flow models, researchers in the Center for Transportation Analysis (CTA) in the Oak Ridge National Laboratory (ORNL) constructed the Freight Analysis Framework (FAF) database. FAF data include freight flows for U.S. domestic and international (imports and exports). The main source of FAF is the Commodity Flow Survey (CFS), which is a shipper-based survey carried out every 5 years as part of the U.S. Economic Census. Given that the CFS does not contemplate all industry sectors and that a considerable portion of more detailed level data is undisclosed, FAF complements the CFS by estimating missing cells as well as by integrating other data sources for sectors not covered by the CFS scope. FAF products provide estimates of U.S. freight flows by aggregated levels of geographic detail, that is, as defined by the CFS with flows between states, major metropolitan areas, and the remainder of the states.

This paper describes a disaggregation methodology that the CTA research team developed to transfer FAF zone-level freight estimates to the county level. This method relies on estimating disaggregation factors that are related to measures of production, attraction, and average shipment distances by mode. Production and attraction in counties are captured by their total employment payrolls. Travel distances of shipments between counties are calculated by using the CTA multimodal network system. Results from validation experiments have demonstrated the validity of this method. Moreover, this method was used in estimating the ton-miles for FAF, and comparisons with major freight data programs, specifically for rail and water movements, showed consistencies in results.

Freight Data

The CFS is the most comprehensive survey of freight activities in the United States. The survey is conducted by the U.S. Census Bureau, in partnership with Bureau of Transportation Statistics (BTS) within the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation (DOT). The latest survey was conducted in 2012, with previous years of study including 1992, 1997, 2002, and 2007.

Data from the 2012 CFS will not be released until late 2014; thus, the latest available data are for 2007. The survey includes freight activities that originated in the United States; thus, it does not include the movement of imports. The sample survey of 2007 covered business establishments with paid employees located in the United States and classified according to the 2002 North American Industry Classification System (NAICS) industry codes in mining, manufacturing, wholesale trade, and select retail trade industries (e.g. electronic, stores, and mail-order houses). In addition, it also covered auxiliary establishments (e.g., warehouses and managing offices) of multi-establishment companies with shipping activity.

FAF integrates CFS data with a variety of supplemental sources for industry sectors and movements not covered in the CFS (out-scope of the CFS) to create a comprehensive picture of freight movements among states, major metropolitan areas, and the remainder of states by all modes of transportation. FAF also provides forecasts on freight flows up to 30 years in the future, as well as annual provisional updates for the current year and truck flow assignments for the base year and outlying future year. The current release of FAF3 is the third database of its kind, with FAF1 providing similar freight data products for calendar year 1997, and FAF2 providing freight data products for calendar year 2002. Under the FAF3 process, the CTA team provided estimates of ton-miles for freight flows using network system and freight flow models, including the detailed multimodal and intermodal freight network databases. Specifically, these databases include transportation network systems (highways, railroads, waterways, airways, and pipelines) and their associated infrastructure (e.g., intermodal terminals, transfer points, seaports, and airports).

Disaggregation Method

Fundamentally, to disaggregate FAF freight flows from FAF zones to more detailed geography, one needs to estimate the relationship between freight generation and industry activities within zones; this is done through freight modeling. As suggested in Oliveira-Neto et al. (2012), aggregate generation (production and attraction) models were estimated using available data from CFS at the state level. These generation models also considered the association between industry producers and consumers of commodities, as observed in the 2007 Input-Output Accounts, and were applied to estimate freight shipped/received by county.

Likely shipment distances by mode between counties were estimated by using routing routines with the CTA intermodal network system. The routing algorithm used impedance functions to route shipments onto the network system. The impedance functions considered functional categories (e.g., major and local roads) of the link, the interactions between different companies (i.e., railroad companies) or vehicles (e.g., different vessel categories), as well as intermodal and multimodal operations in transfer points and terminals. A route for a single mode was generated using a shortest path algorithm that finds the minimum impedance between county centroids. If multiple modes or vehicles were used, the algorithm would find minimum routes connecting different sub-networks through terminal and transfer points. County distance matrices were used not only to calculate ton-miles; they were also applied to find the spatial distribution of freight generated. In this case, a gravity model was applied to generate freight flows between counties.

In sum, the disaggregation process of FAF database includes

1. Estimate total freight shipped and received by county. For a given FAF origin–destination (O-D) pair, production and attraction shares for tons are estimated for the set of counties within the FAF zones O and D, respectively.

2. Distribute the total freight shipped/received between counties. The technique for freight distribution relies on matrix balancing procedures, or a doubly constrained gravity model.

Two methods were deployed to obtain the disaggregation coefficients for the models. The first one was based on traditional two-step modeling, which aimed to estimate descriptive freight generation models and distribution models separately. The second approach for estimating the parameters was to combine the data into a pooled cross-section structure, from which a combined generation-distribution model was estimated.

Final Remarks

In this paper, a disaggregation methodology used for the FAF3 data processing is discussed. This method was applied to disaggregate data from FAF-zone level to associated county-level geography. This method was developed as a part of the FAF ton-mile estimation effort. As an added value, the team considered the method developed could be applied to generate information that supports transportation freight analysis and planning at a more reasonable level of detail than FAF zones. Validation results of these models suggested that techniques presented in this paper provided consistent results for macroanalysis in transportation planning.

In summary, the framework for national freight data (i.e., the FAF database) as well as the analytical and geographic tools (CTA’s network system and the freight flow models) presented in this paper can be used for estimating the generation and spatial distribution of goods in the United States at the county level of geography. The estimation of freight ton-miles is an import application of such tools to gauge the freight system usage and provide insightful information for national policy decisions.

Reference

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Statewide Freight Demand Modeling to Support Long-Range Transportation Planning in North Dakota

EunSu Lee, North Dakota State University; Alan Dybing, North Dakota State University; Denver Tolliver, North Dakota State University

Presentation Notes: Presented by EunSu Lee, North Dakota State University. The model is the third generation of the state model. In 2011, the state began an integrated system modeling for the DOTs and MPOs. It combines economic and social activities into transportation planning. In addition to the state's oil production, agriculture is a major producer for the state and, as land use has changed, there has been a change in crop mixture and growth in grain elevators. The amount of grain, by tons, shipped by elevators has increased dramatically. It is recognized that the growth of these industries has effects on the state's economy, safety, and the environment. There is a need for spatial analysis and freight demand modeling to develop an integrated model. The model uses trip generation and crop yields for agricultural trip generation. This was validated through a traffic county program. Further, pavement information was collected for a lifecycle cost analysis. This is to be applied for decision making for state and county transportation planning. The model also supports energy and agricultural logistics, analyzes bridge needs, and provides transferability and a manner of integration to other models.

Abstract

North Dakota has experienced significant traffic increases during the last 10 years because of growth in oil production and changes in agricultural production and marketing patterns. As of November 2010, the number of oil wells in the state had risen to 5,200 (Tolliver and Dybing 2010). The total number of truck movements is estimated to be 2,300 per well, with approximately half of them representing loaded trips. In addition to the oil-related activities, the importance of agriculture of North Dakota's economy is significant. In 2009, the total market value of agricultural goods produced in the state exceeded $5.5 billon (Tolliver et al. 2011).

This study combines the effects of agricultural and oil-related traffic and other economic activities on county and local roads and major highways in North Dakota. This study focuses on the prediction of agricultural traffic flows, oil-related traffic flows, and passenger travel across the state. The study predicts traffic flows for the next 20 years and projects infrastructure investment needs of the state to support long-range transportation planning.

Model Development and Data Sources

Large-scale freight modeling is complex because of the variety of factors involved, difficulty in obtaining data, and dynamic changes in facilities and logistics behavior. As much as possible, this study utilizes private and public data sources to consider several major transportation activities in the state for freight demand modeling. Base networks are downloaded from the National Transportation Atlas Databases (NTAD), including national highway performance networks, the Freight Analysis Framework (FAF3) network, railroads, waterways, intermodal facilities, and geographical boundaries. State highways and county and urban roads are collected from the North Dakota GIS Hub, which provides surface types and local route names.

Trip Generation and Location Model

Estimating agricultural tonnage and investment needs for individual road segments requires facility locations, crop production, and a crop distribution mode in which movements or flows are predicted from crop-producing zones to elevators and processing plants. The county-level crop production survey is available from the National Agricultural Statistics Service (NASS). In the analysis process, the land area devoted to the production of each crop in each county subdivision is estimated using GIS procedures that allow the extraction of vector data that are geometrically and mathematically associated with satellite raster images and geographically calculated cropland area.

To facilitate the development of these estimates, the predicted areas devoted to crop production in each subdivision are adjusted based on the 2009 county production values (Tolliver et al. 2011). In the study, the final or interim destinations for crops are in-state processing plants or elevators that ship crops out of state to various domestic and export locations. The throughput at elevators is computed from monthly reports submitted to the North Dakota Public Service Commission by outbound mode and destination.

Forecasts of future oil development were obtained from the North Dakota Oil and Gas Division. Over the long term, the total number of wells is expected to grow. However, the forecasts do not include future oil well locations. Instead, mineral spacing units (1 by 2 miles) were utilized for locating drilling locations and future wells. To forecast future well locations, a probabilistic maximum likelihood algorithm was developed. The spacing units are available from the Oil and Gas Division, and fresh water sources are available from the North Dakota Department of Natural Resources and private companies that drill water wells. Rail transloading centers are available from railroad companies and the North Dakota Pipeline Authority. However, the precise pipe loading sites are not available to the public, so this study collected the pipe transloading facilities from the public sources on the web.

Route Generation and Trip Distribution

Route generation provides the links between all possible origins and all possible destinations. Each spacing unit and crop field is connected to the area's origin and destination locations in the network optimization model while considering maximum distance and capacity limitation (Tolliver and Dybing 2010). For the agricultural model, the study used the fastest paths to match origin of crop fields to the nearest elevators or elevators to the closest shuttle elevators or processing centers using PROC NETFLOW in SAS statistical software. Because trucking cost is measured on a per-mile basis, minimizing the travel time of agricultural goods movements to elevators and plants minimizes farm-to-market trucking cost on a system-wide basis. For the oil transportation model, the study finds the fastest paths to deliver materials and products through higher classification and a higher speed limit, because the truck drivers are time-sensitive and congestion is an issue in the rural area, due to heavy oil development activity.

Trip Assignment and Visualization

During the process of the route generation, the researchers collected the road segments using Network Analyst in GIS. Thus, the assigned trips on a route can be converted to traffic on the segments that belong to the route. By adding up the traffic for all origin-destination pairs, the study can visualize the total traffic on a segment.

Traffic Analysis (Traffic Data Survey and Traffic Counts)

Traffic counters were deployed at 100 locations in 15 of the 17 oil and gas producing counties (Tolliver and Dybing 2010). At each of the selected sites, a count of no less than 24 hours was taken and adjusted to present the traffic over a 24-hour period. These raw counts were adjusted for monthly variation in the traffic to estimate the average daily trips (ADT) from each segment. The traffic counters were utilized to calibrate and validate the model for the base scenario.

To classify road segments by traffic volume, the segments were classified by county road managers using maps obtained from the North Dakota Department of Transportation. The process is essentially to send a survey to county managers that includes detailed maps of each county with instructions to classify road sections by traffic volume (high, medium, and low). The secondary survey to the county contact persons included another set of county maps with instruction to classify the paved and gravel sections by road condition. A two-page questionnaire included in the condition survey identified component costs and existing maintenance and improvement practices.

In addition to miles of road and forecasted traffic levels, the key factors that influence paved road investments are the number of trucks that travel the road, the types of trucks and axle configurations used to haul inputs and products, the structural characteristics of the road, the width of the road, and the current surface condition. The primary indicator of a truck's impact is its composite axle load—which, in turn, is a function of the number of axles, the type of axle (e.g., single, double, or triple), and the weight distribution to the axle units. The pavement design equations of the American Association of State Highway and Transportation Officials (AASHTO) are used to analyze paved road impacts.

Conclusions and Limitations

More than 5,600 miles of paved county and local roads (exclusive of city streets) are traveled by agricultural and oil-related traffic and other highway uses. Some of these roads are under the jurisdiction of governments or agencies other than counties, such as townships, municipal governments, the Bureau of Indian Affairs (BIA), and the U.S. Forest Service. BIA and tribal roads are included, but the city streets and Forest Service roads are excluded from the study. To support energy and agricultural logistics, this study identified road segments to be improved and in need of investment for the next 20 years.

This study could be improved by including oil collection points along pipelines and by including urban traffic models. Smaller units of TAZs such as census blocks or 2-mile-by-2-mile polygons would provide better analysis for rural county roads than using 6-mile-by-6-mile township boundaries.

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On the Evaluation of Incentive Structures Fostering Off-Hour Deliveries

Felipe Aros-Vera and José Holguín-Vera
Rensselaer Polytechnic Institute

Presentation Notes: Presented by Felipe Aros-Vera, Rensselaer Polytechnic Institute. The model identifies the potential for off-peak deliveries to businesses in New York City, driven by congestion and a supply perspective. The question of how incentives can be used to encourage change in behavior for those producing externalities was analyzed. An important measure of transportation demand management (TDM) involves using public-sector incentives to include a change of delivery times from regular hours to off-hours. Typically, the truck is not making the decision of delivery time even as tolls were increased for truckers; rather, it is client demand that requires behavior change. The objective was to simulate the carriers' and receivers' joint decision process to evaluate TDM policies and determine whether receivers will accept incentives to move delivery times. There were three types of incentives analyzed: business support, public recognition, and one-time incentives. Data were taken from the New York Metropolitan Transportation Council (NYMTC) regional transportation model.

Abstract

This paper develops a methodology to evaluate incentive structures for implementing off-hour deliveries (OHD) programs. Using a behavioral microsimulation (BMS) to reproduce the joint decision of carriers and receivers toward OHD, the methodology determines the percentage of trucks and deliveries that would switch to the off-hours and the budget required for the implementation. The behavior of receivers is modeled using discrete choice models, and the behavior of carriers depends on the cost comparison between the base case scenario and the new delivery network that emerged after the receivers' decisions. The results are analyzed in conjunction with previous theoretical research regarding the benefits of providing different combinations of incentives and a targeted set of receivers according to geographic location or industry segment. The methodology is applied to the freight industry in Manhattan. The paper delivers policy recommendations that shed light into the implementations of OHD programs.

Introduction

Congestion has serious economic implications in terms of productivity losses and pollution. So far, congestion has been tackled mostly from the supply perspective by enhancing infrastructure or operations. However, as it has been widely documented, in the long term, such an approach increases demand for transportation that brings the situation to the same place where it started. An alternative is to use transportation demand management (TDM) initiatives, which influence users' behavior to bring the demand to the level that infrastructure can optimally accommodate. Examples of car TDM include congestion pricing, carpooling programs, and high occupancy lanes. Despite the relatively long tradition of car TDM, similar measures for urban freight are very rare.

The heart of the issue when implementing freight TDM is that the generation of freight demand is largely the work of shippers, producers, and receivers, as the carriers are primarily a conduit between the supply and the demand for freight. In this context, freight TDM entails inducing behavior changes on the receivers of the supplies, who are the ones who need the supply as input for their economic activities.

Only recently, however, the research community has realized the important role that receivers play. For the most part, transportation policy has focused on the carriers, overlooking the fact that, though freight traffic is what materially produces the externalities, it is the demand for freight at the receiver sites that creates the freight traffic. As a result, policy initiatives that target the receivers, who are the actual decision makers, are more effective than policies that focus on the carriers, who play a secondary role. The challenge is, however, that estimating how receivers and carriers would react to such incentives is a complex endeavor. While modeling the behavior of receivers could seamlessly be done with discrete choice models, modeling how the carriers would react to the receivers' response to the incentives is significantly more complicated. In fact, the carrier's response depends on the structure of the delivery network that would arise, the number of receivers switching to OHD, and the unit transportation costs, among many other variables. Another important aspect is the structure of the incentives to be provided. The incentives could target receivers in all or some specific industry sectors, or receivers located in a congested area. Moreover, the incentive amount could be the same to all receivers or could be different depending, for instance, on the number of deliveries switched to the OHD.

The main objective of this paper is to use a behavioral microsimulation (BMS) to (1) assess the different combination of incentives and (2) analyze the effectiveness of targeted monetary incentives for receivers in specific geographic locations and industry segments. The paper briefly reviews the literature on OHD; describes the methodology and its application to the case of New York City; and delivers conclusions and policy recommendations to shed light on the implementation of OHD programs.

Methodology

The methodology developed in this paper is based on a behavioral microsimulation (BMS). The BMS generates the carrier and the set of receivers on the Carrier/Receiver Synthetic Generation. This module selects an industry segment and, according to its characteristics, determines the number of receivers and their locations so that the entire simulation reproduces the geographic distribution of businesses in the area under analysis. The receiver behavioral simulation determines the decision of the receivers in response to incentives using discrete choice models. Finally, the BMS models the decision of the carrier, using the receivers' choices and the cost of delivering as inputs. This process is repeated for a large number of carrier-receivers combinations.

The root of the complexity is that, in response to an incentive, the receivers in a delivery tour react differently: some receivers will accept OHD, and others will reject the idea. Once the receivers decide how they would react to an incentive, the carrier decides what to do. From the carrier's perspective, two delivery networks arise: one for the base case, where all receivers are in the regular hours, and another one with a mixed operation. The carrier will do OHD only if the mixed operation has a lower cost than the base case. In general, if only a handful of receivers want OHD, the additional delivery tour required in the mixed operation is likely to produce an increase in costs leading the carrier to reject OHD. Conversely, if a large number of receivers accept OHD, the carrier is likely to go along with their request, as it will lead to cost savings.

The BMS considers three incentives: one-time incentive (OTI), business support (BS), and public recognition (PR). These incentives can be handed out to all receivers in Manhattan or some receivers according to industry segment or geographic location. The combination of type of incentive and how the incentives are handed out is denominated a structure of incentives. Each of these structures is analyzed according to three performance measurements: (1) the percentage of trucks switching to OHD, denominated joint market share (JMS) since it is the result of the joint decision of carriers and receivers; (2) the percentage of deliveries switching to OHD, denominated receivers market share (RMS); and (3) the budget required to provide the incentives to receivers, which is determined based on the RMS.

Results for Manhattan and Policy Recommendations

A monetary incentive of $1,000, in combination with business support and public recognition to receivers in Manhattan, could move more than 2,300 deliveries to the night hours; this corresponds to a reduction of 2% of deliveries. The budget required for the incentives is about $2.4 million. Therefore, the cost of the program has to be compared with the social and economic benefits of moving these deliveries to the off-hours. In the case of Manhattan, each delivery is estimated to take between 45 and 90 minutes during day hours. If the incentive reaches $10,000, more than 8,000 deliveries could be moved to the night. Consequently, the benefits must be compared with the $70 million of the program.

The analysis of industry-oriented incentives reveals the benefits of giving incentives to retail, which produces almost 60% of freight trips in Manhattan. However, the most remarkable results come from geographically oriented incentives. In this case, incentives to receivers located in the most congested parts of the city—lower and midtown Manhattan—have the largest economic and social benefits. For instance, an incentive of $10,000, requiring $36 million, could move around 4,100 deliveries, similar numbers to giving incentives to the entire city, with the exception that these deliveries are made in the most congested part of the city. The effectiveness of the investment can be confirmed using a simple measure, the ratio between the percentage of carriers moving to OHD and the budget. The ratio shows that giving incentives to the most congested part of the city is, on average, 30% more effective. These results are aligned with previous theoretical research that encourages the application of geographically focused incentives to foster off-hour deliveries.

The analyses produced in this paper are very important and encouraging. To start with, they show the potential impact of providing incentives to receivers as a way to implementing OHD programs and the importance of giving monetary incentives in conjunction with other types of incentives that recognize the good practice in the industry. Second, they confirm that geographically focused incentives are more effective than other policies. In addition, these findings suggest that multi-year policies aimed at fostering unassisted OHD could gradually achieve major reductions in truck traffic in the regular hours. The reason is that, according to the experience in New York City, the receivers that try unassisted OHD tend to stay in the program after the termination of the incentive. If this trend continues, it could mean that multi-year incentives programs would be able to keep increasing the market share of OHD, though a point could be reached where no more increases are possible. These are, nevertheless, promising developments that highlight the potential of freight TDM.

Analyzing Future Freight Challenges in Maryland Using Freight Data Sources and the Maryland Statewide Transportation Model (MSTM)

Subrat Mahapatra
Maryland Department of Transportation

Mark Radovic
Gannett Fleming, Inc.

Sabyasachee Mishra
University of Memphis

Presentation Notes: Presented by Subrat Mahapatra, Maryland Department of Transportation. Maryland estimates that freight transportation is expected to more than double by 2025 to an estimated 1.4 billion tons of freight. This leads to several policy questions as to what is the projected increase in demand and how to develop multiple modes to offer choices. The model ran two scenarios: a limited funding scenario and a high funding scenario that assumed a system expansion. Operationally, the model was used to identify hotspots for mobility, reliability, bottlenecks, and safety. Truck trips were generated by industrial, retail, and office employment. The model can be applied to study a variety of scenarios, such as effects from pricing, zoning, infrastructure improvements, changes in the economy, and other external variables.

Abstract
The state of Maryland is strategically located in the middle of the eastern seaboard and accommodates many major population and manufacturing centers, especially along the I-95 corridor. With numerous major transportation facilities and freight terminals within the state (highway, rail, water, and air), the state's own existing manufacturing sector, and the need to get goods to consumers in the state, freight movement is known to be a major and growing component of the trip generation within and through the state. Truck traffic is projected to grow by 61%, and traffic moving through the state is estimated to grow by 52%, by the year 2030. Additionally, an expansion of the Panama Canal would have significant impacts on every major metropolitan region along the East Coast. This has special significance in the state of Maryland, as I-95 is a major backbone for economic growth as well as major commuter route in the Baltimore-Washington region, and the Port of Baltimore is a major freight hub. The corridor is already one of the heaviest traveled corridors in the country, accommodating more than 250,000 vehicles daily and about 15% trucks on many segments.

Background
The Maryland Statewide Travel Model (MSTM) was developed as a multi-layer model that operates at a national, statewide and urban level. The national model covers North America, the

statewide model includes Maryland, Washington DC, Delaware, and selected areas in Pennsylvania, Virginia, and West Virginia, and the urban model serves as a linkage to the existing urban models and is primarily used for comparison purposes. The MSTM includes two truck types: medium trucks and heavy trucks, in addition to commercial vehicles. Long-distance trips from, to, and through Maryland are captured in the national model, whereas short-haul trips are captured in the statewide layer.

The MSTM utilizes the third generation of FHWA's Freight Analysis Framework data (FAF3). This dataset summarizes existing and forecast commodity flows (in tonnage and in dollars) by FAF3 zones. The challenge lies in the coarse resolution of this dataset; some entire states (such as New Mexico, Mississippi, or Idaho) comprise a single FAF3 region. Flows to and from these large regions would appear as if all commodities were produced and consumed in one location in the center of the region. To achieve a finer spatial resolution, truck trips were disaggregated from regional FAF3 zones to flows between counties (based on employment distributions) throughout the entire United States. Subsequently, trips are further disaggregated to the statewide model zone (SMZ) structure in the MSTM model area. The FAF3 data also contain different modes and mode combinations. Additional data are required for the truck model, including the Vehicle Inventory and Use Survey (VIUS). The U.S. Census Bureau publishes the data with survey records of trucks and their usage. County employment by 10 employment types was collected from the Bureau of Labor Statistics, and county-level employment for agriculture was collected from the U.S. Department of Agriculture. The input and output coefficients that were used for flow disaggregation were provided by the Bureau of Economic Analysis. Finally, commodity flows in tons were converted into truck trips using average payload factors, and these truck trips were assigned to traffic network using multi-class time of day assignment and ultimately were validated against truck counts for both medium trucks and heavy trucks.

Current Applications

The MSTM continues to prove itself as a valuable tool in providing a foundation for data-driven decision making. At the policy level, the MSTM is providing insight to the Governor's Smart Growth Initiatives, the state's Freight Implementation Plan, and the statewide Maryland Transportation Plan. The MSTM has also provided insight regarding evacuation planning and emergency preparedness concerns along major corridors such as the I-95 corridor. The ability to assess truck traffic going through the state on major corridors and how the characteristics of these trips change over time has been invaluable in regards to both short-term and long-range planning.

In addition to providing data that support various statewide policies, the MSTM has also been utilized for project-level analysis. An example of this was the evaluation of the CSX Intermodal Container Transfer Facility (ICTF). This facility transfers containers from railcars to trucks and vice-versa. To accommodate the expected growth in freight, a site assessment was performed to evaluate potential locations that would allow accommodations that meet the increased freight demands. Additionally, there are structural limitations on several bridges within Baltimore City that prohibit double-stacked rail cars. Relocating this facility outside of the city would allow double-stacked rail cars to travel along the corridor where the containers would then be transferred to trucks. This would reduce truck traffic on a heavily travelled I-95 corridor and results in creating much needed capacity. The MSTM has also been able to provide insight into characteristics of through truck trips along the I-95 corridor and the anticipated growth in through truck trips along selected corridors over time.

SCENARIO ANALYSIS

The MSTM design allows truck flows to be assigned to the network jointly with autos in a multi-class assignment. Validation results show a close match with observed travel patterns. MSTM was used to analyze a series of planning scenarios, covering the following two options: (1) Economic growth: Test alternative growth and decline assumptions of the overall economy by 2030. (2) Port growth: Check the impact if there is a capacity increase at the marine port in Baltimore. The model appears to provide reasonable results, as much of the future demand is concentrated on major corridors like I-95, I-270, I-70, I-495, and I-695.

Conclusions

Although truck trips comprise approximately 2% of total trips in Maryland, they account for 15% of all vehicle miles travelled (VMT). As truck volumes increase, maintaining a safe, efficient, and reliable transportation infrastructure will be critical in sustaining economic growth throughout the region. Developing more advanced tools and forecasting capabilities will help ensure the mobility needs for all users of the system. Accommodating the increased freight movement within and through Maryland is vital to continued economic growth. Developing reliable forecasts will assist in managing this growth—but these tools can also enable the evaluation of short-term improvements. Having the ability to monitor system performance specifically pertaining to truck traffic will play a critical role in ensuring safe and efficient mobility of goods to, from within, and through the state of Maryland. A tool like the statewide model provides an analysis engine to evaluate and quantify the implications of freight policies, the impact of external variables on the freight industry, and overall transportation system performance. Lack of disaggregate freight flow data and datasets showing the truck tours by commodity classes makes it extremely challenging to model freight from a supply-chain perspective. Nevertheless, using existing datasets to build freight models has provided state DOTs the analysis capabilities to undertake more data- and performance-driven freight planning.

Examining Carrier Transportation Characteristics Along the Supply Chain

Anne Goodchild, Maura Rowell, and Andrea Gagliano
University of Washington

Presentation Notes: Presented by Anne Goodchild, University of Washington. This model examines carriers and characterizes statistically significant and predictable transportation patterns at the regional and statewide levels. The data were applied to existing statewide transportation models and the goal was to improve the state of the practice, not to try to capture all the complexities of the world. The model represented carriers and recognizes that carriers have different behaviors based on their category. Data collection included short survey phone interviews and received 522 responses from Washington and Oregon. Responses to one question on whether the respondents owned or operated facilities were used to classify carriers into node carriers or link carriers. The model identifies significant transportation characteristics and determines clusters of behavior. Differences related to time-of-day operations, length of trips, and scheduling were modeled. Current models are trip-based, and the percentage of truck trips is based on spatial and industrial classifications, while this model modifies assumptions based on link and node classifications. As a result, time-of-day distribution, frequency, and intermediate facilities serve as the fifth step to the model.

Abstract

Transportation decisions in the private sector are made within a supply chain framework. Decisions made in the public sector, however, are based on models with limited supply chain considerations (Tatineni and Demetsky 2005). If policies are to effectively manage congestion, they must be informed by models that reflect at least those most fundamental of industry's supply-chain practices. Carriers are expected to respond differently to policy changes depending on variables such as type of cargo, trip distance, and fleet size. The investigation of this hypothesis requires data on carrier demographics and transportation characteristics.

In this paper, through an evaluation of survey data, the statistical validity of classifying carriers based on their role within the supply chain is demonstrated. Carriers associated with firms that own or operate a supply-chain node (raw production facility, manufacturing facility, storage center, distribution center, and/or retail facility) are termed supply-chain node carriers; those carriers that are associated with firms that do not own or operate a supply-chain node are termed supply-chain link carriers. Node carriers can be broken down further, depending on which nodes they are associated with. Transportation characteristics such as shipment size, pickup/delivery time of day, delivery time windows, and locations served vary, depending on the type of carrier.

Existing freight models are typically limited to characteristics such as vehicle classification or a small set of commodity codes. Commodity flow data used for these

classifications, however, lack the important operational detail that is necessary to understand the implications of policy changes. Modeling the effects of disruptions will require additional knowledge of logistical practices (Goodchild et al. 2013). Without this data, models used to evaluate policies cannot capture the varying uses of the network. This research is intended to help address this gap by developing a categorization of motor carriers based on their supply-chain and transportation characteristics. The goal is not to capture all of the complexity of supply-chain logistics but to identify discriminating categories from a transportation perspective.

Literature Review of Modeling Frameworks

Modeling freight proves to be more complex than modeling passenger vehicles, due to the number of stakeholders influencing decisions and the physical limitations on trucks. For instance, truck trips are influenced not only by the road network and time of day but also by the physical qualities of the commodities being carried (e.g., perishable, hazardous, or bulk), the value of the shipments, and the availability of intermodal facilities (de Jong et al. 2004). As a result, many modeling techniques are being explored to capture the complexity of freight flows.

In an attempt to address the limitations of both trip-based and commodity-based modeling approaches, Holguin-Veras suggested modeling empty truck trips on the basis of commodity (2000). In 2005, Cheng suggested using logistics-based modeling for agriculture, petroleum, forestry, and mining industries (i.e., bulk goods) while using tour-based modeling for textiles, apparel, electronics, furniture, and services (i.e., packaged goods). Logistics-based modeling focuses on how shipments move from the producer to the consumer, while tour-based modeling focuses on forming a single tour from a series of legs.

Tatineni and Demetsky (2005) stress the integration of supply chain considerations into truck models. They surveyed manufacturing companies and split freight traffic into business-to-business links and business-to-customer links of the supply chain. Business-to-business links are less time sensitive and have larger shipments than business-to-customer links. They found that road pricing needs to incorporate commodity because different industries travel at different times and are dependent on customer service requirements and production schedules.

While these studies have addressed components of supply chain decision making, these have been hampered by limited data and have often only considered modifications to existing freight modeling frameworks (de Jong et al. 2004). More detailed data are required to build an understanding of transportation characteristics. This paper contributes to closing this gap.

Survey

The survey designed for this research asks general business demographic questions and freight-related questions aimed at capturing how the respondent moves freight. The survey ends with questions concerning number of vehicles, travel locations, travel distances, delivery/pickup types, vehicle types, time windows, travel times, delivery/pickup locations, facility locations, facility size, and company revenue.

The principal question asked if the respondent owns or operates a facility that produces raw materials, a facility that manufactures goods, a storage center, a distribution center, and/or a retail store. Respondents who responded “no” to all the facility types were classified as link carriers. Those who responded “yes” to at least one of the facility types were classified as node carriers. Node carriers were then further classified to create four subcategories: raw and/or manufacturing, distribution and/or storage centers, retail facilities, and multi-node. This paper addresses the hypothesis that link and node carriers demonstrate substantially different transportation characteristics.

Results

This section describes the transportation differences between link and node carriers. Conclusive differences are drawn among factors that are statistically significant as determined by a Welsh two-sample *t*-test for continuous data or the Fisher comparison of proportions test for categorical data. The transportation characteristics investigated include delivery/pickup type, frequency, location, style, time of day, and time windows.

- Both less than truckload (LTL) and full truckload deliveries/pickups had a significant difference between all subgroups except when comparing retail and multi-node carriers.
- Link carriers and node carriers had significantly different results for the range of delivery frequencies (multiple times a day, daily, weekly, monthly, and less than monthly) to a single facility.
- Raw/manufacturing had a much lower percentage of activity in urban areas. Retail carriers had much lower percentages of activity in suburban and rural areas. The majority of all deliveries/pickups were to businesses, regardless of carrier type.
- Except for link carriers, manufacturing facilities were the most visited and intermodal facilities the least. Link carriers most often visited distribution centers.
- On average, 75% of pickups/deliveries by link carriers are scheduled and 15% are made on a first-come-first-served basis. In comparison, node carriers average 55% scheduled and 37% first-come-first-served. The *p*-values for these results indicate that both delivery styles differentiate link and node carriers. Within the node carrier breakdown, retail and multi-node are the two extremes, with retail carriers having 58% first-come-first-served and 23% scheduled deliveries and multi-node carriers having 28% first-come-first-served and 68% scheduled deliveries.
- Between link and node carriers, all times of day (morning, daytime, evening, and overnight) were significantly different, except the daytime period. Within the node carrier breakdown, all comparisons yielded significant results. The morning and daytime periods were the most active periods for all carrier types. Link carriers had the highest morning and lowest overnight activity.

- All time windows (less than 30 minutes, one to two hours, half day, and all day) were significantly different between link and node carriers. Although the percentages of carriers that use other time windows differ greatly, they are not found to be statistically significant. The significance of the differences between subgroups of node carriers varied. The majority of carriers use time windows of less than 30 minutes or one to two hours. Retail carriers had the highest percentage of one-to-two-hour time windows.

Conclusions

This paper presents travel behavior trends in the classification of link carriers and node carriers as well as the further breakdown of node carriers into raw/manufacturing, storage/distribution center, retail, and multi-node carriers. Through the analysis, it is evident that there are travel behavior differences among these classifications and that the classifications provide a useful framework for truck modeling.

The research team proposes a modeling methodology that classifies carriers by their place along the supply chain. Carriers would be classified based on the types of facilities they own or operate within a supply chain. Using different modeling parameters according to the results presented here will provide a freight model that connects the industries' supply-chain practices with government policy plans.

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Appendix A

SHRP 2 Second Symposium: Innovations in Freight Demand Modeling and Data Improvement

Agenda and List of Presentations

TRB SHRP2 Second Symposium: Innovations in Freight Demand Modeling and Data Improvement • Final Program

Day 1
Monday, October 21, 2013

7:00 – 8:00 am	Symposium Packet Pick-Up and Deluxe Continental Breakfast
8:00 – 8:10 am	Welcoming Remarks: Richard Easley, E-Squared Engineering
8:10 – 8:35 am	Introductory Remarks: Rob Handfield, Ph.D., Director, Supply Chain Research Cooperative, NC State, **Trends in Logistics and Supply Chain Management - Embracing Global Logistics Complexity to Drive Market Advantage**
SESSION 1: State DOT Freight Modeling	
8:35 – 9:10 am	**Creating a Supply-Chain Methodology for Freight Forecasting in Wisconsin** Presenter: Jennifer Murray, Wisconsin Department of Transportation
9:10 – 9:45 am	**Rail Freight Commodity Models: A First Generation Effort in Iowa** Presenter: Phillip Mescher, Iowa State Department of Transportation
9:45 – 9:55 am	Break: Refreshments Provided
SESSION 2: Regional/Urban Tour Modeling	
9:55 – 10:30 am	**Innovative Tour-Based Truck Travel Model using Truck GPS Data** Presenter: Arun Kuppam, Cambridge Systematics Inc.
10:30 – 11:05 am	**Design of an Agent-Based Computational Economies Approach to Forecasting Future Freight Flows for the Chicago Region** Presenter: John Gliebe, Resource Systems Group Inc.
11:05 – 11:40 pm	Florida Multimodal Statewide **Freight Model: A Model Incorporating Supply Chain Methods and Providing Linkages to Regional Tour-based Truck Models** Presenter: Colin Smith, Resource Systems Group Inc.
11:40 – 12:40 pm	Lunch Provided
SESSION 3: International Models	
12:40 – 1:15 pm	**Logistics in Freight Modeling – A Report from the Delft Group** Presenter: Lori Tavasszy, Delft University of Technology and TNO
1:15 – 1:50 pm	**Discrete Model of Freight Mode and Shipment Size Choice** Presenter: Magersa Abate, VTI
1:50 – 2:25 pm	**Freight Models, Constrained Economic Models and Natural Resource Data** Presenter: Ming Chen, TNO
2:25 – 2:35 pm	Break: Refreshments Provided
SESSION 4: Private-Sector Supply-Chain Decision Making	
2:35 – 3:10 pm	**NMHG Shipment Modeling** Andy Street, NACCO Materials Handling, Inc.
3:10 – 3:45 pm	**The Caterpillar BCP Transportation Strategy: Thinking Outside AND Inside the Box** William Lucas, Caterpillar, Inc. and Matthew Drown, Caterpillar, Inc.
3:45 – 4:35 pm	**Panel Discussion – Bridging the Gap between the Public Sector and Private Sector – Is it Possible?**
4:35 – 4:45 pm	Parting Remarks and Adjourn

Day 2
Tuesday, October 22, 2013

7:00 – 8:00 am	Deluxe Continental Breakfast
8:00 – 8:20 am	Introductory Remarks: Anne Strauss-Wieder, **Engaging Freight and Supply Chain Representatives in Public Sector Projects**
SESSION 5: Freight Data Innovations	
8:20 – 8:55 am	**Exploratory Use of Raster Images for Freight Modeling** Presenter: Pedro Camargo, University of California, Irvine
8:55 – 9:30 am	**Disaggregate State Level Freight Data to County Level** Presenter: Ho-Ling Hwang, Oak Ridge National Laboratory
9:30 – 10:05 am	**State-wide Freight Demand Modeling to Support Long-Range Transportation Planning in North Dakota** Presenter: EunSu Lee, North Dakota State University
10:05 – 10:15 am	Break: Refreshments Provided
SESSION 6: Business Implications	
10:15 – 10:50 am	**On the Evaluation of Incentive Structures Fostering Off Hour Deliveries** Presenter: Felipe Aros-Vera, Rensselaer Polytechnic Institute
10:50 – 11:25 am	**Analyzing Future Freight Challenges in Maryland Using Freight Data Sources and the Maryland Statewide Transportation Model (MSTM)** Presenter: Subrat Mahapatra, Maryland Department of Transportation
11:25 – 12:00 pm	**Examining Carrier Transportation Characteristics Along the Supply Chain** Presenter: Anne Goodchild, University of Washington
12:00 - 12:15 pm	Closing Discussion – Feedback on Symposium and Its Future
12:15 – 1:15 pm	Award Presentation: Lunch Provided

Symposium Planning Team

Jim Brock, Avant IMC, LLC, Chair
David Plazak, Transportation Research Board/SHRP 2
Patrick Anater, Gannett Fleming, Inc.
Richard Easley, E-Squared Engineering
Sharon Easley, E-Squared Engineering
Wade White, Whitehouse Group
Tom Phelan, VHB Inc.
Erik DeLine, VHB Inc.
Rob Handfield, Ph.D., North Carolina State University
George List, Ph.D., North Carolina State University
Ram Pendyala, Ph.D., Arizona State University
Arnie Maltz, Ph.D., Arizona State University

Technical Expert Task Group

Susie Lahsene, Port of Portland
Alison Conway, City College of New York
Jose Holguin-Veras, Rensselaer Polytechnic Institute
Charles E. Howard, Jr., Puget Sound Regional Council
Barbara Ivanov, Washington State Department of Transportation
Thomas J. Kane, Thomas J Kane Consulting
Rebekah Karasko, North Central Texas Council of Government
Michael D. Meyer, Parsons Brinckerhoff
Gordon Proctor, Gordon Proctor & Associates, Inc.
Joseph L. Shofer, Northwestern University
Edward Strocko, Federal Highway Administration

Guest Judges

Rolf Schmitt, U.S. DOT
Jakub Rowinski, NJTPA
Selected Project Team Members
Selected Task Group Members