



BEHAVIORAL/AGENT-BASED SUPPLY CHAIN MODELING RESEARCH SYNTHESIS: MODEL APPROACHES

BACKGROUND AND CHALLENGE

A handful of public agencies in the United States are in the process of developing—or have already developed—behavioral/agent-based models of supply chain decisions and freight movements. The uptick in development of these new models is largely attributable to the planning need for better freight forecasts. Federal Highway Administration (FHWA) Broad Agency Announcement awards and the Strategic Highway Research Program (SHRP2) C20 program provided funding for these new approaches to designing and implementing freight demand modeling. These include agent-based supply chain freight models currently in use in Baltimore Metropolitan Council (BMC), Chicago Metropolitan Agency for Planning (CMAP), Florida Department of Transportation (FDOT), Metro (Portland, Oregon), Phoenix’s Maricopa Association of Governments (MAG), and Wisconsin Department of Transportation (WisDOT). A number of these agencies additionally funded their own efforts, including Metro who added funding for data collection, and CMAP who added funding beyond the initial research.

MODELING NEEDS

Agencies expressed the need to answer questions posed as part of their planning processes that were beyond the capabilities of their current freight and truck modeling tools. For example, the following policy analysis needs and issues were identified by one or more agencies as a reason for implementing a supply chain freight model:

- Understanding the economic impacts of freight and the relationship between changes in the economy and changes in demand for freight transportation.
- Understanding the relationships between freight movement and land-use and spatial development in a study area.
- Understanding current freight movements to identify mobility needs and deficiencies in the transportation system.
- Evaluating complex freight-related policies and freight-related infrastructure improvements.
- Understanding the environmental impacts of freight and truck movements.

Table 1. Summary of Freight Modeling Needs, By Type

Type	Economic Forecasts	Growth Rates by Industry	Logistics Practices	Roadway Congestion	Private Sector Operations	Logistics Terminals	Ports	Truck Volumes
Economic Impact	●	●	●	●	●	●	●	
Land Use		●			●	●	●	
Policies	●	●	●			●	●	
Infrastructure				●		●	●	●
Environmental				●	●	●	●	●

In most cases, the freight models used by agencies were designed to support the needs of multiple stakeholders in large and complex regions, which added to the diversity of policy needs and issues. For example, several of the freight models were designed to cover megaregions with multiple metropolitan areas, or large single-MPO regions, or were jointly developed by state and regional agencies. In several cases, modal agencies, such as port authorities, were involved in the development of the freight models. This expansion beyond a more historically typical highway-focused use of travel models added to the need to cover all freight transportation modes rather than, for example, a truck-only model. Agencies' freight modeling needs (economic impact, land use, policies, infrastructure, and environmental) and their freight modeling elements are summarized in Table 1.

APPROACHES

Approaches to freight travel demand modeling in the United States range from conventional 4-step planning models to more advanced integrated supply chain, economic-based, and tour-based models. The traditional 4-step freight demand modeling approach is defined by its four sequential stages of trip generation, trip distribution, modal split, and traffic assignment. In these models, the demand modeling process is aggregate and trip-based or commodity-based with limited analysis of individual trip behavior.

Four-step models are relatively weak in terms of behavioral foundation, which often leads to limited model capabilities and model accuracy issues. These models fail to model the underlying economic behaviors from which the demand is derived. The main drawback of these aggregate models is their inability to capture

the complexity of freight policy systems and their failure to replicate the supply chains and logistics decisions made by individual players in the freight supply chain.

In recent years, to address some of the limitations mentioned above, advanced freight demand forecasting models have been proposed. Disaggregate freight models are also termed advanced models, since they provide more capabilities than aggregate models to evaluate policies and investments. These advanced models are disaggregate models that incorporate supply chain or truck touring procedures.

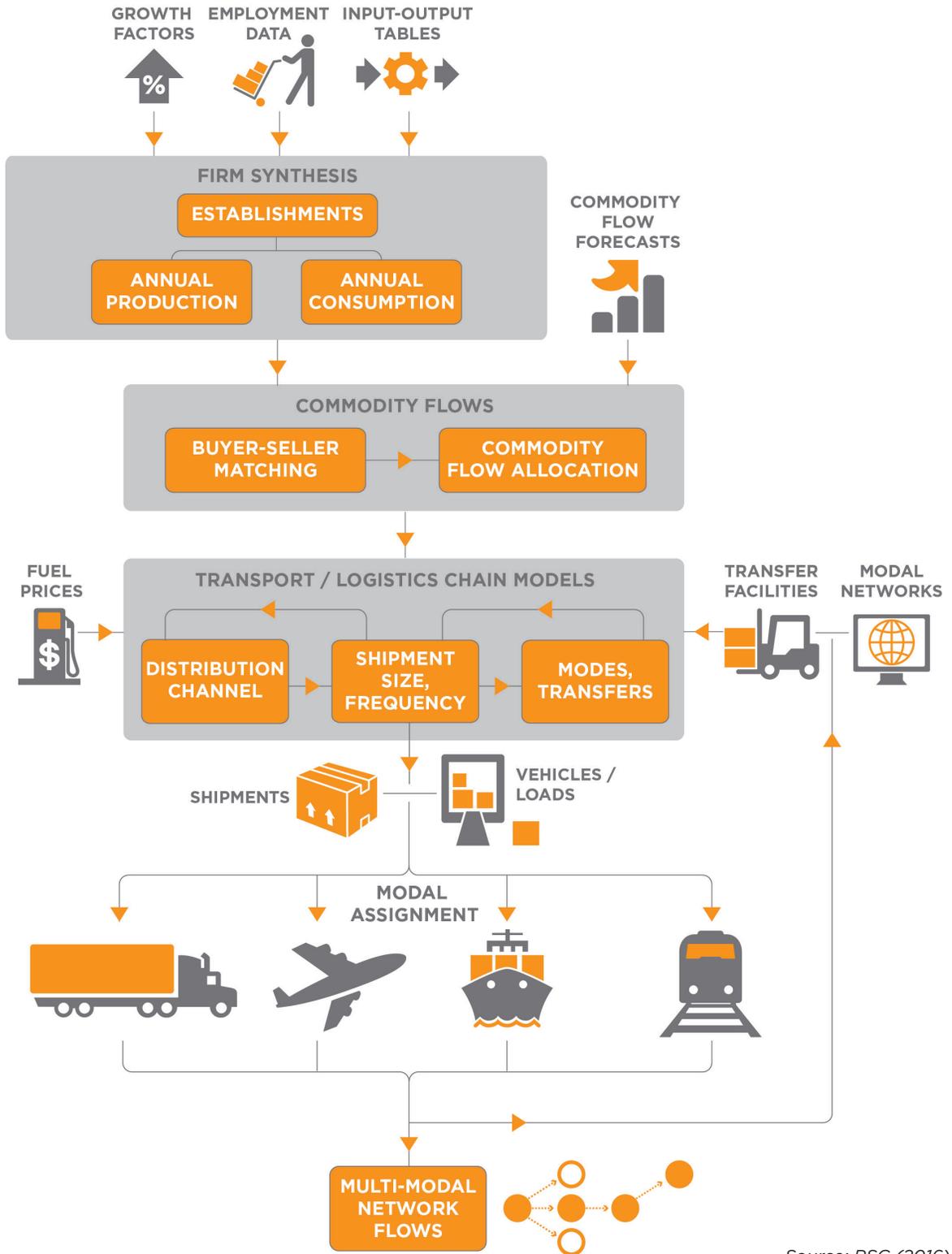
Figure 1 shows the supply chain modeling process including firm synthesis, buyer-supplier matching, distribution channel and vehicle choice, shipment size, mode choice, and truck touring models. The models in Chicago, Florida, Baltimore, Oregon, Portland, and Phoenix are summarized in Table 2.

FREIGHT MODEL DESIGN

An agency's decision to transition to a more advanced freight model structure must weigh the investment cost of transitioning against the importance of answering detailed policy and planning questions. The models of agencies examined as part of this synthesis were relatively limited trip-based models that analyzed—at most—grouped commodities and often represented only trucks. In these cases, the models provided little of the market coverage and policy sensitivity required to answer complex policy questions.

Most supply chain model components reviewed as part of this synthesis were based on multinomial or nested logit choice model formulations. The first step of these supply chain models is an

Figure 1. Behavioral Supply Chain Modeling Process



Source: RSG (2016)

Table 2. Review of Freight Forecasting Models

Model	Firm Synthesis (model type)	Buyer-Supplier Matching (model type)	Supply Chain Allocation (model type)	Mode and Shipment Size (model type)	Tour-based Truck (model type)
Chicago	Establishment enumeration	Game theory	MNL ¹ model	Ben-Akiva and de Jong ² utility equation, MNL model	MNL ¹ models, greedy algorithm
Florida	Establishment enumeration	Fuzzy logic	MNL ¹ model	Ben-Akiva and de Jong ² utility equation, MNL model	N/A
Baltimore/Maryland	Establishment enumeration	Fuzzy logic	MNL ¹ model	Ben-Akiva and de Jong ² utility equation, MNL model	MNL ¹ models, TSP ³ algorithm, hurdle/count models
Portland	Establishment enumeration	Fuzzy logic	MNL ¹ model	Ben-Akiva and de Jong ² utility equation, MNL model	MNL ¹ models, TSP ³ algorithm, hurdle/count models
Phoenix	Establishment evolution	ACE ⁴	ACE ⁴	Nested Logit	MNL ¹ models
Oregon	N/A ⁵	N/A ⁵	N/A ⁵	Monte Carlo process	TSP ³ algorithm
Wisconsin	Establishment enumeration	Fuzzy logic	Ben-Akiva and de Jong ² utility equation	Ben-Akiva and de Jong ² utility equation	Gravity models

enumeration of establishments, typically called firm synthesis, based on iterative proportional fitting methods. The buyer-supplier matching

model component is based on different methods, with the most advanced being a game theory application. Buyers consider several transportation, logistics, risk, capacity, and productivity factors for sellers when selecting a seller. Tour-based truck models primarily use the multinomial logit choice approach. In several cases, the stop-sequencing element of the truck-touring models used a different approach, such as the greedy algorithm and the hurdle/count model.

¹ Multinomial Logit

² de Jong, G., Ben-Akiva, M. 2007. "A micro-simulation model of shipment size and transport chain choice." *Transportation Research Part B* 41 950-965.

³ Travelling Salesman Problem

⁴ Agent-based Computational Economic

⁵ An input/output approach is used to link regions and goods flows. This is handled by modules other than the Commercial Travel module and use an economic input/output model to allocate dollar flows among commodities and employees.

FOR MORE INFORMATION

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Learn more about the SHRP2 program, its Capacity focus area, and Freight Demand Modeling and Data Improvement (C20) products at www.fhwa.dot.gov/GoSHRP2/



The second Strategic Highway Research Program is a national partnership of key transportation organizations: the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Transportation Research Board. Together, these partners conduct research and deploy products that help the transportation community enhance the productivity, boost the efficiency, increase the safety, and improve the reliability of the Nation's highway system.



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