A Quick Look at Freight Flow Modeling in the United States

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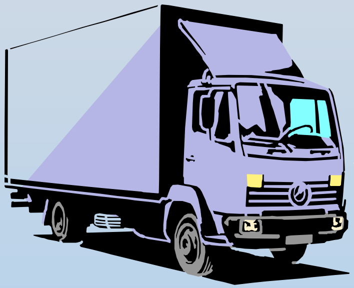
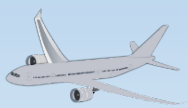
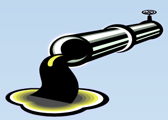
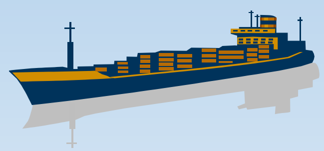


European Colloquium on Theoretical & Quantitative Geography 2017
Friday September 8th, York, England

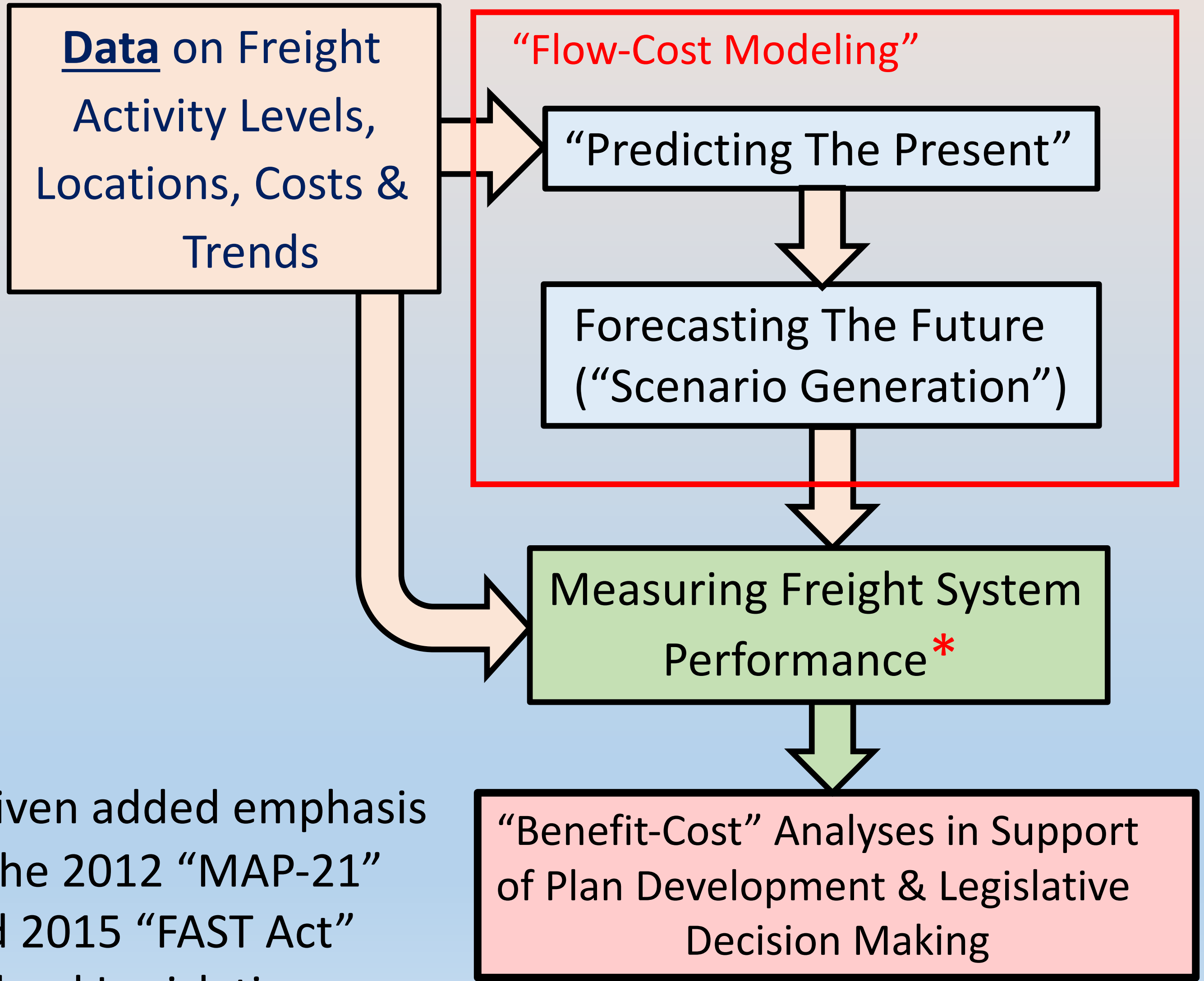
Talk Outline

- ❑ Current Public Sector Freight Modeling Practice
- ❑ Modeling Concerns
- ❑ “Top Down” Modeling Approaches
- ❑ “Bottom Up” Modeling Approaches
- ❑ Concluding Comments

1) Public Planning Agency Freight Flow Modeling: Emphasis on Measuring & Assessing Freight System Performance



Issues:

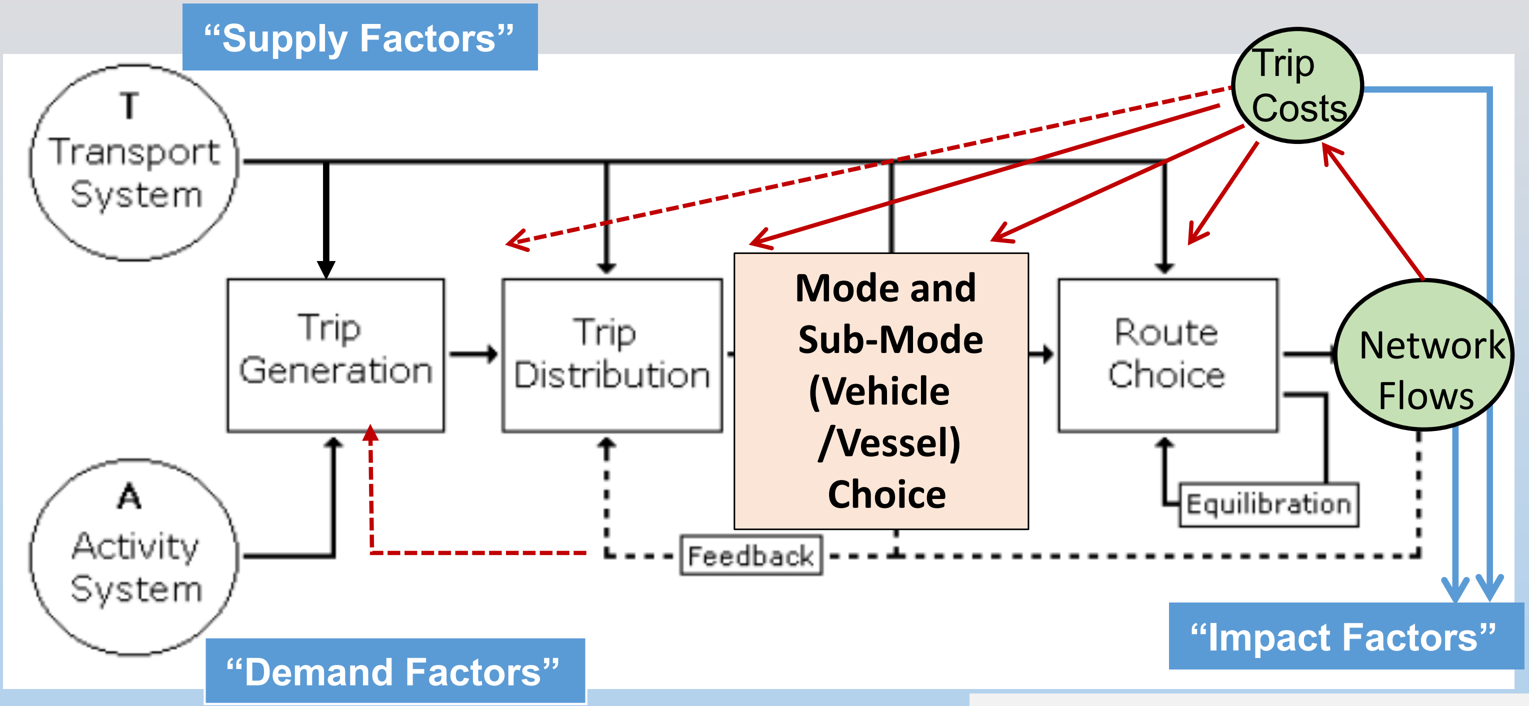
Safety & Security Levels
Fleet Operating Costs,
Infrastructure Costs,
Travel Times,
Congestion Impacts,
Place & Intermodal Connectivity ("Freight Fluidity"), Network Resilience,
"Sustainability",
Energy Supply,
Pollution Impacts

*Given added emphasis in the 2012 "MAP-21" and 2015 "FAST Act" Federal Legislation

FREIGHT PLANNING:

Traditional "Four - Step" Model Framework Used by Many State DOTs & MPOs (modified)

Capacities Associated with: Vehicles/Vessels, Labor, Fuels, Infrastructure (Networks, Terminals, Distribution Centers), Communications Systems, Freight Regulations



Commodity Volumes Associated With: Industrial/Economic Activity, Demographics

Direct: Freight Rates, Emissions, Accidents, On-Time Service Reliability

Adapted/E*tended from McNally, M.G. 2007 "The Four Step Model" UCI-ITS-WP-07-2.

2) Current Modeling Concerns

1) Limitations of Public Data Sources (Sample Sizes):-

- Limited Spatial (O-to-D) Detail (for Planning Purposes)
- Limited Logistical Detail (Especially 'Representative' Freight Costs)
- Mode Specific Data 'Silos"
  - Intermodal Network (Cost) Modeling

2) Limited Behavioral/Decision-Making Basis (Especially for Forecasting):-

- Freight Agent/Supply Chain Complexities

3) Rapid Growth & Change in Freight Volumes & in How They Are Being Moved

Forecasting Challenges: Continued Rapid Growth in Freight Volumes, As Well as Some Significant Changes in Commodity Mix.

FAF4 Baseline Scenario: Using a 1.2% CAGR for **2012 to 2045** produces a total tonnage increase from 17 billion tons ($22.8 trillion) in 2012to 25.3 billion tons ($37.1 trillion) in 2045 **(≈ 49% increase in tonnage, and 68% increase in value).**

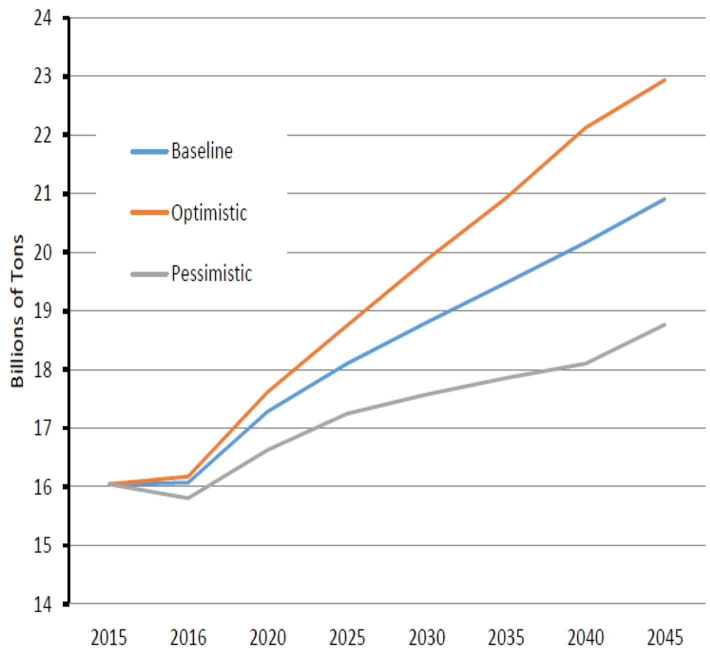
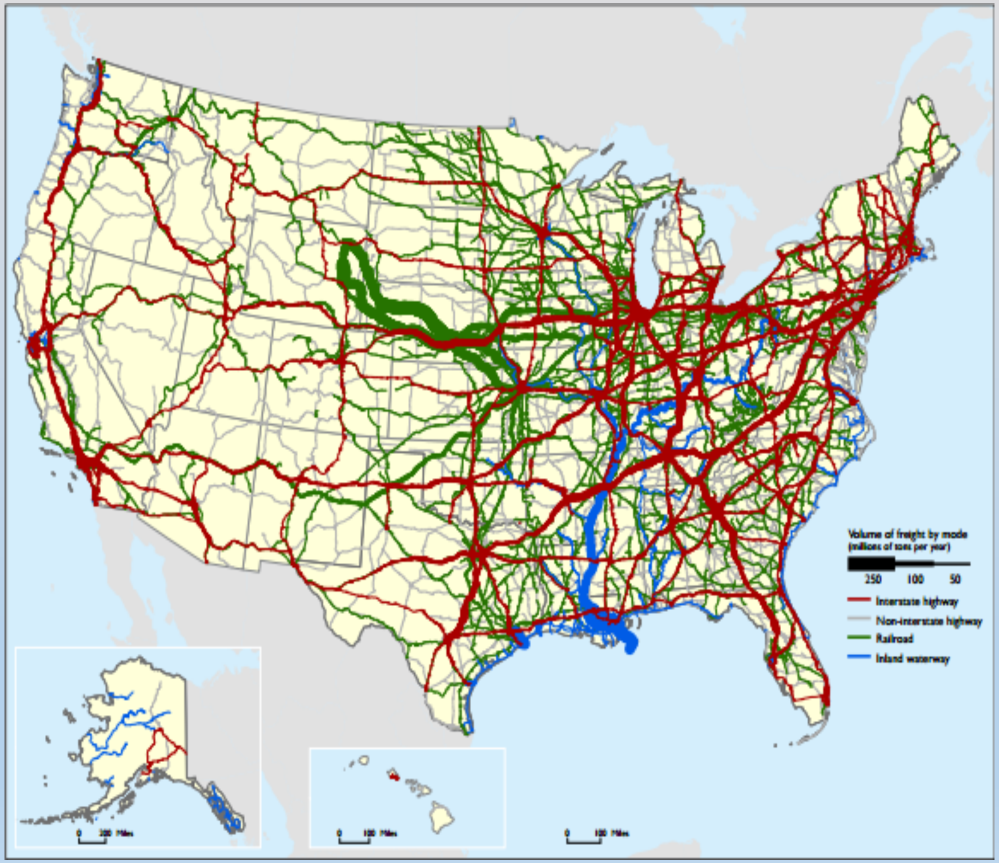
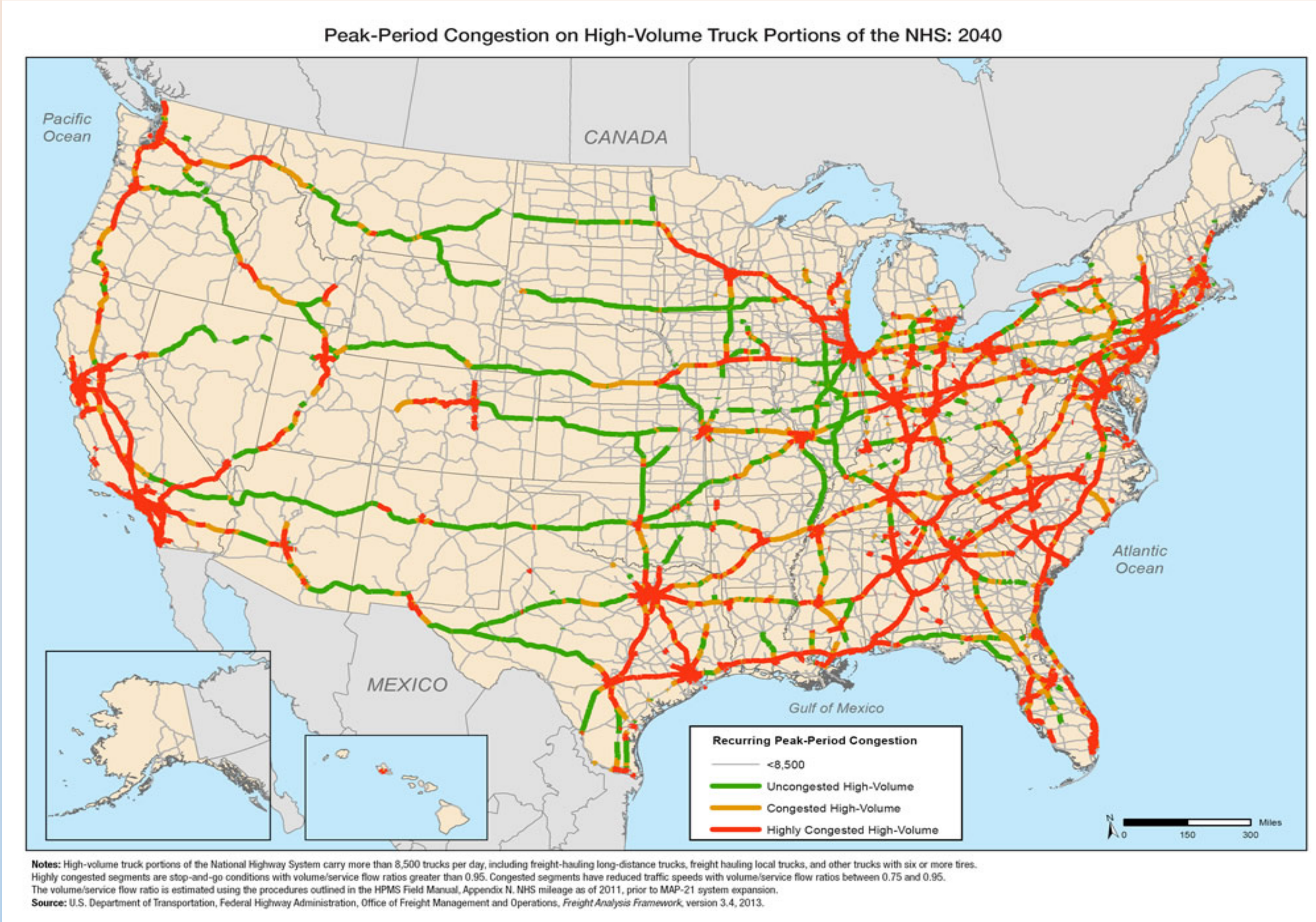


Figure 11. Graph Domestic Tonnages – Baseline, Optimistic, and Pessimistic Scenarios, 2015 – 2045



Source : See https://ops.fhwa.dot.gov/publications/fhwahop16043/index.htm

Costs to the Trucking Industry of Highway Congestion



*** Estimated Annual Truck Ton-Miles: 2.0 trillion in 2015 -> 3.6 trillion in 2045 (≈74.8% INCREASE).**https://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/

*** Estimated trucking industry congestion tops $63.4 Billion in 2015, with over 996 million hours of lost productivity. (ATRI Insider , Vol 13.1, August 2017). For a truck driven 100,000 mi. a year this equates to an average annual congestion cost of $22,676 (approx. $0.23/Vehicle Mile Travelled).**

Current Status of Freight Flow Data For Analysis Purposes

"Currently, public sector freight decision-making is largely reliant on datasets that are incomplete, outdated, insufficient, too highly aggregated to permit localized analyses, or simply unavailable".
(FHWA Freight Operations Research & Development (R&D) Plan Webinar, July 30, 2015)

And what data is available is delivered in a variety of largely mode-specific and agency specific reporting styles and metrics

Problem Statement:

How do we overcome these limitations?

3) "Top Down" Freight Flow Modeling Approaches

National (inc. Intercity & Interstate) & International Flows

Statewide Freight Flows

High Volume Freight Corridor Flows

Metropolitan Area-wide Flows

Intra-City or -County Flows

Disaggregations

Data Driven Log-Linear Modelling with Gap Filling (FAF)

Interregional Input-Output (I-O) Modeling

Direct Demand (DD) and Structural Equation Modeling (SEM)

Location (including Facility)-Specific Flows

High Level FAF (Nationwide) Freight Flow Data & Estimation Process*

US Commodi
(CFS) (1993,
2007, 2012
Sampled Dat

Out-of-Scope
Flow Data
(Various Carrie
Administrative
Commodity or
Specific Data S
(Farm-based a
Fishery, Loggi
Natural Gas, C
Materials and
Municipal Soli
Household/Bu
Retail, Service
Trades, International Air Trades,
Waterborne Commerce Trades

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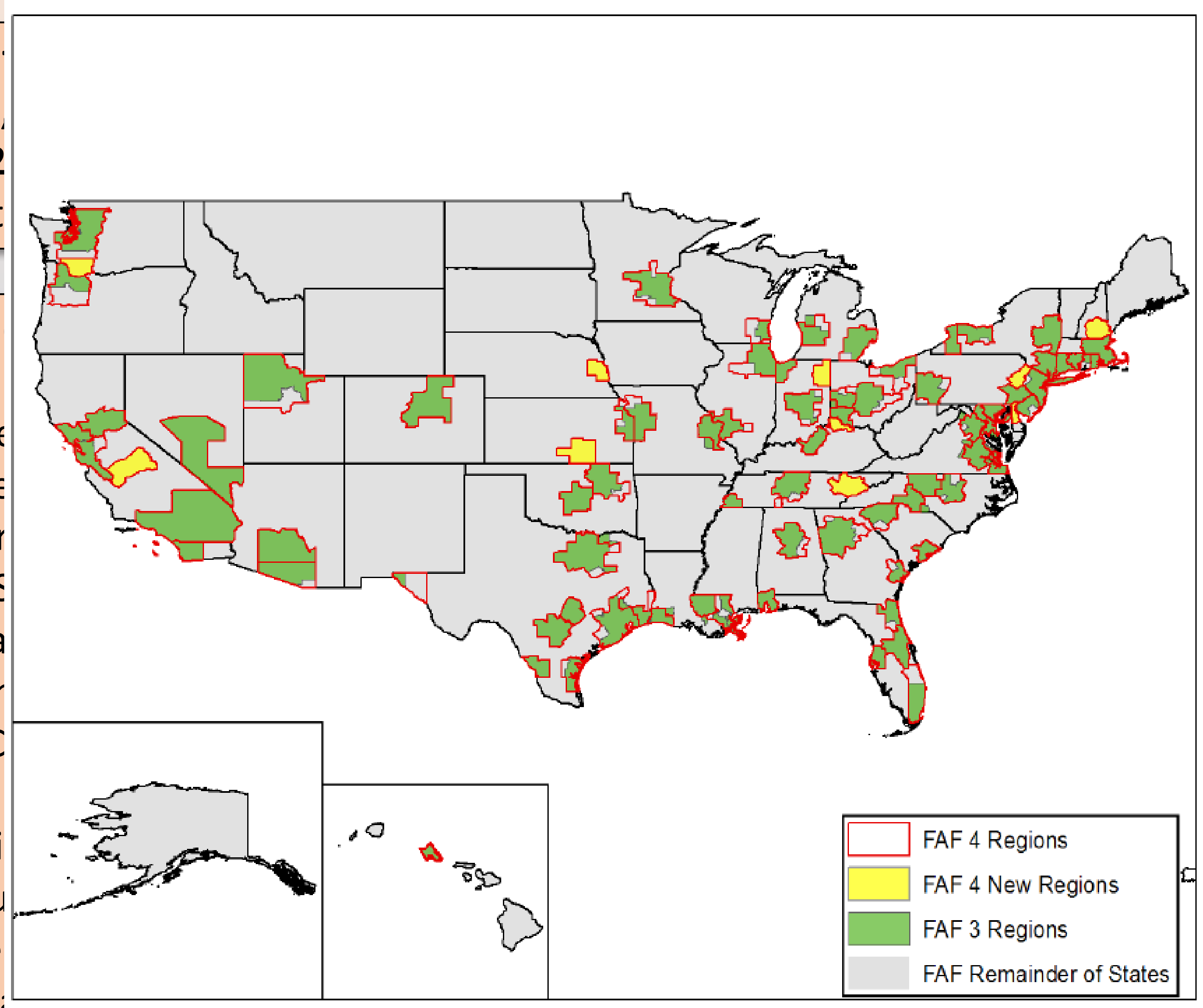


5,244,624 data cell
Freight Flow Matrix

*** See ORNL/TM-2016/489 "Building the FAF4 regional Database: Data Sources and Estimation Methods**

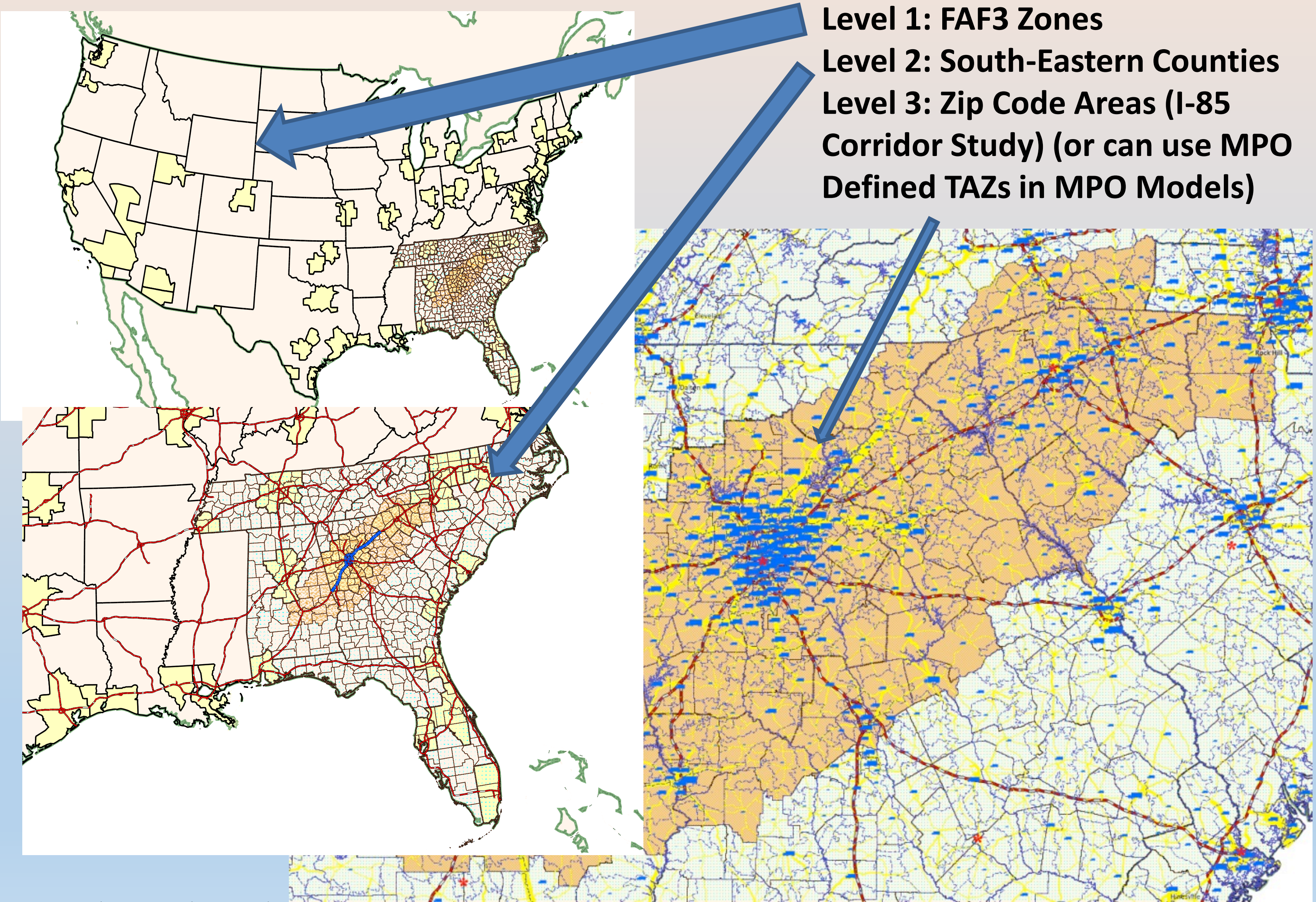
In Practice A combination of log-linear modeling (LLM) and iterative proportional fitting (IPF)was Used in FAF3 to Fill In Missing Flow Cell Values:

$$Ln(F^{ODCMUS}) = \lambda_0 + \lambda^{O} + \lambda^{D} + \lambda^{M} + \lambda^{C} + \lambda^{U} + \lambda^{S} + \lambda_j^{OD} + \lambda^{OC} + \lambda^{OM} + \lambda^{OU} + \lambda^{DC} + \lambda^{DM} + \lambda^{DU} + \lambda^{CM} + \lambda^{CU} + \lambda^{MU} + \lambda^{OS} + \lambda^{DS} + \lambda^{CS} + \lambda^{MS} + \lambda^{US} + \lambda^{ODC} + \lambda^{ODM} + \lambda^{ODU} + \lambda^{OCM} + \lambda^{OCU} + \lambda^{OMU} + \lambda^{DCM} + \lambda^{DCU} + \lambda^{DMU} + \lambda^{CMU} + \lambda^{ODS} + \lambda^{OCS} + \lambda^{OMS} + \lambda^{OUS} + \lambda^{DCS} + \lambda^{DMS} + \lambda^{DUS} + \lambda^{CMS} + \lambda^{CUS} + \lambda^{MUS} + \lambda^{ODCM} + \lambda^{ODCU} + \lambda^{ODCS} + \lambda^{ODMU} + \lambda^{ODMS} + \lambda^{ODUS} + \lambda^{OCMU} + \lambda^{OCMS} + \lambda^{OCUS} + \lambda^{OMUS} + \lambda^{DCMU} + \lambda^{DCMS} + \lambda^{DCUS} + \lambda^{DMUS} + \lambda^{CMUS} + \lambda^{ODCMU} + \lambda^{ODCMS} + \lambda^{ODMUS} + \lambda^{ODCUS} + \lambda^{OCMUS} + \lambda^{DCMUS} + \lambda^{ODCMUS}$$

where λ^{O} = origin O effect ; λ^{D} = destination D effect; λ^{M} = mode M effect; λ^{C} = commodity class C effect; λ^{U} = unit of measurement effect (tons, $ values); λ^{S} = a data source effect, and λ_j^{OD} + = an origin-mode effect, etc… and λ_0 = a "grand mean" scaling parameter.

Example FAF-Based Hierarchical Freight Traffic Analysis Zoning (TAZ) System*

Level 1: FAF3 Zones
Level 2: South-Eastern Counties
Level 3: Zip Code Areas (I-85 Corridor Study) (or can use MPO Defined TAZs in MPO Models)



* F. Southworth and D. A. Smith. (2016) *Estimating the Monetary Benefits of Reducing Delays on a Heavily Trafficked Truck Freight Corridor*

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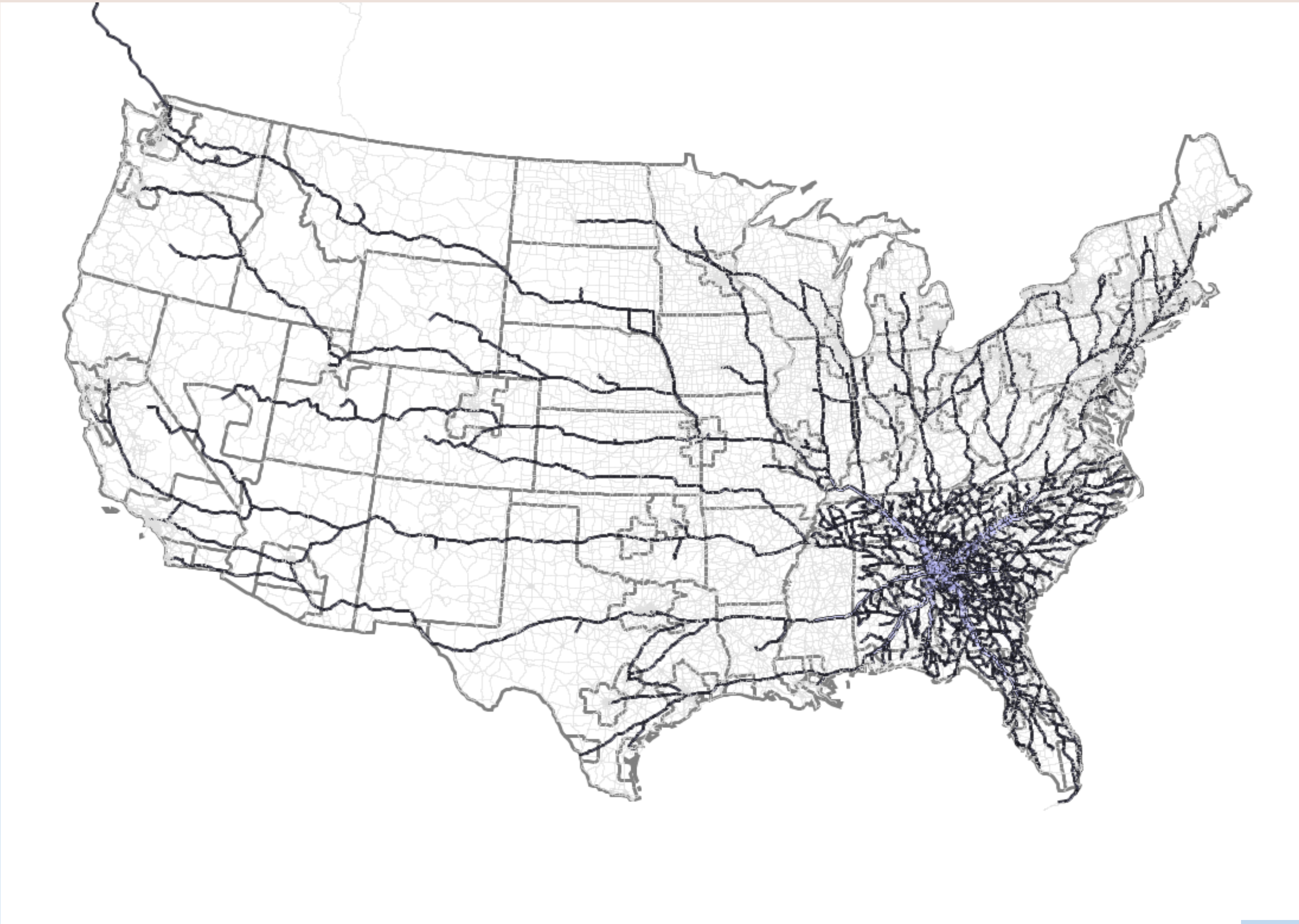
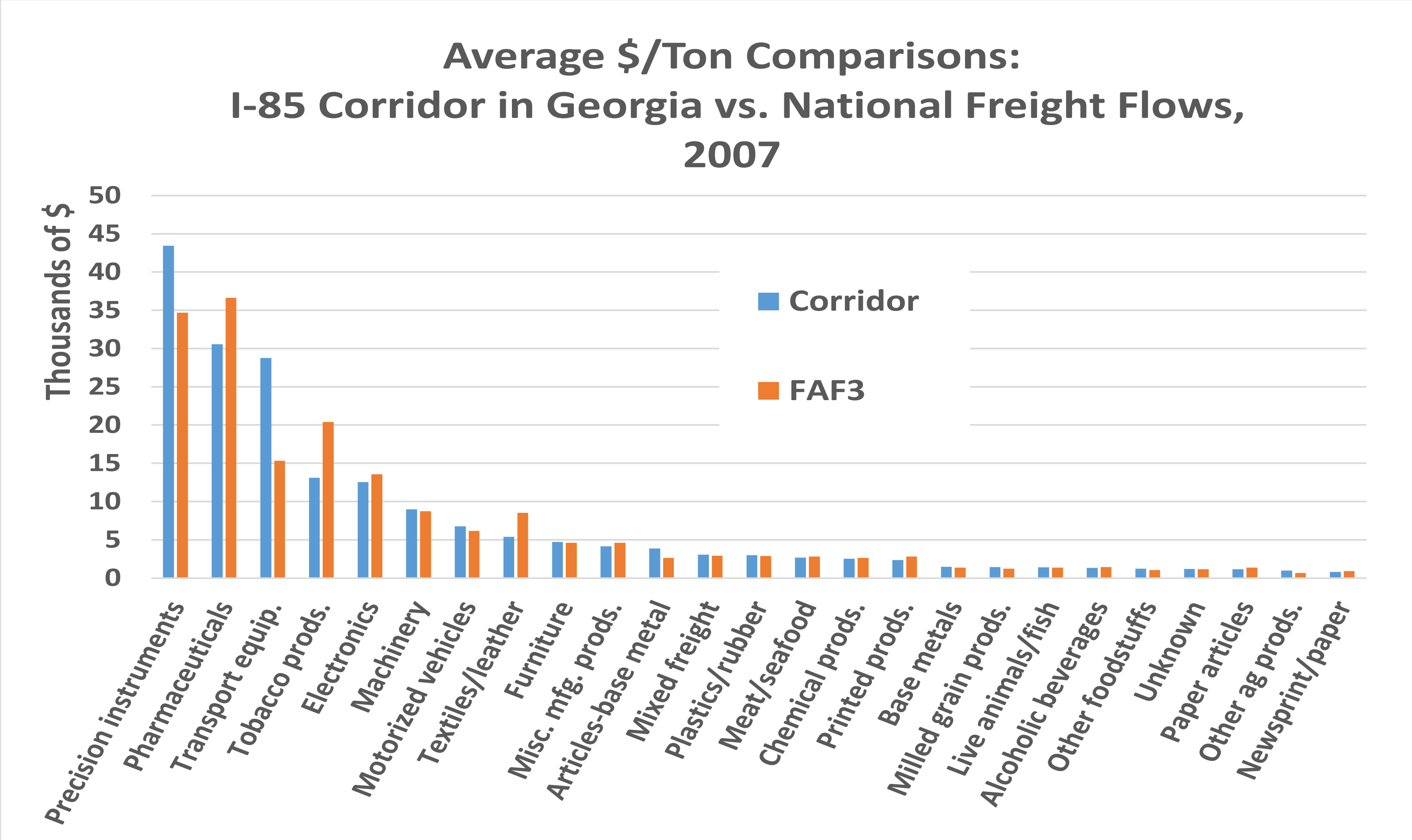
Example Mapping of 2007 Truck Flows That Use I-85/I-285 within Georgia*



* F. Southworth and D. A. Smith. (2016) ibid.

Example Freight Flow Modeling Outputs*:

Corridor vs Statewide and Corridor vs National Comparisons



Using A Multi-Class, Origin User Equilibrium Assignment Model and a Select Link Analysis to convert and assign O-D-C Flows to Truck Trips over the U.S. Highway Network

* F. Southworth and D. A. Smith. (2016) ibid.

4) “Bottom Up” Freight Flow Modeling Approaches

Some Recent (and Increasingly Related) Trends:

- **Agent-Based (Decision-Maker Oriented) Freight Demand Modeling**
- **Supply Chain Logistics (Especially Logistics Cost) Modeling**
- **Microsimulation and Re-Aggregation of Individual Freight Moves Including:**
  - **Multi-Stop, Tour Based Urban Goods Movements**
  - **Long-Haul Intermodal Deliveries, with First Mile- Last Mile Details**
- **Use of Non-Intrusive, IT-Based (GPS, Cellular, RFIDs, Bar Codes….)**

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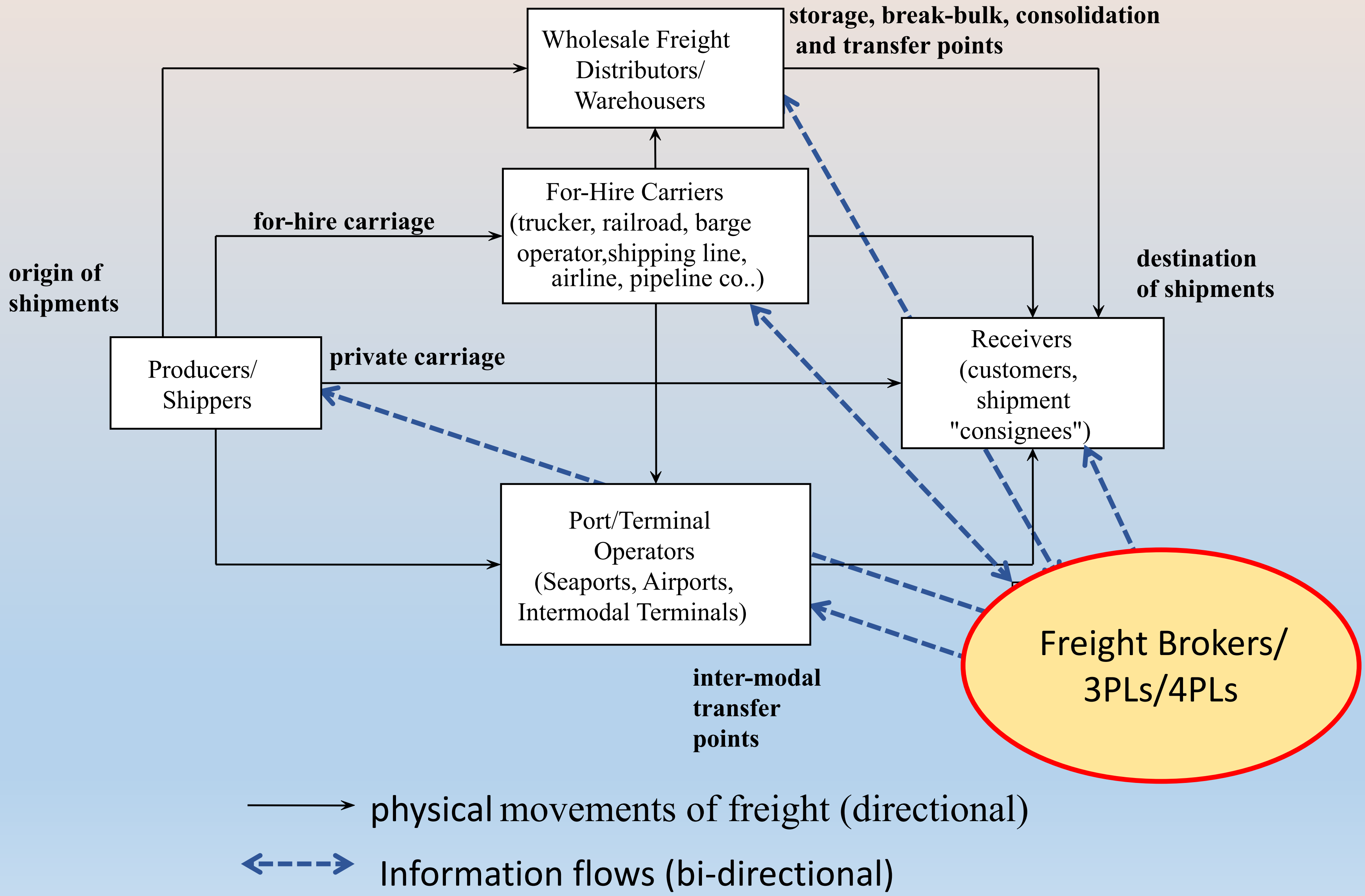
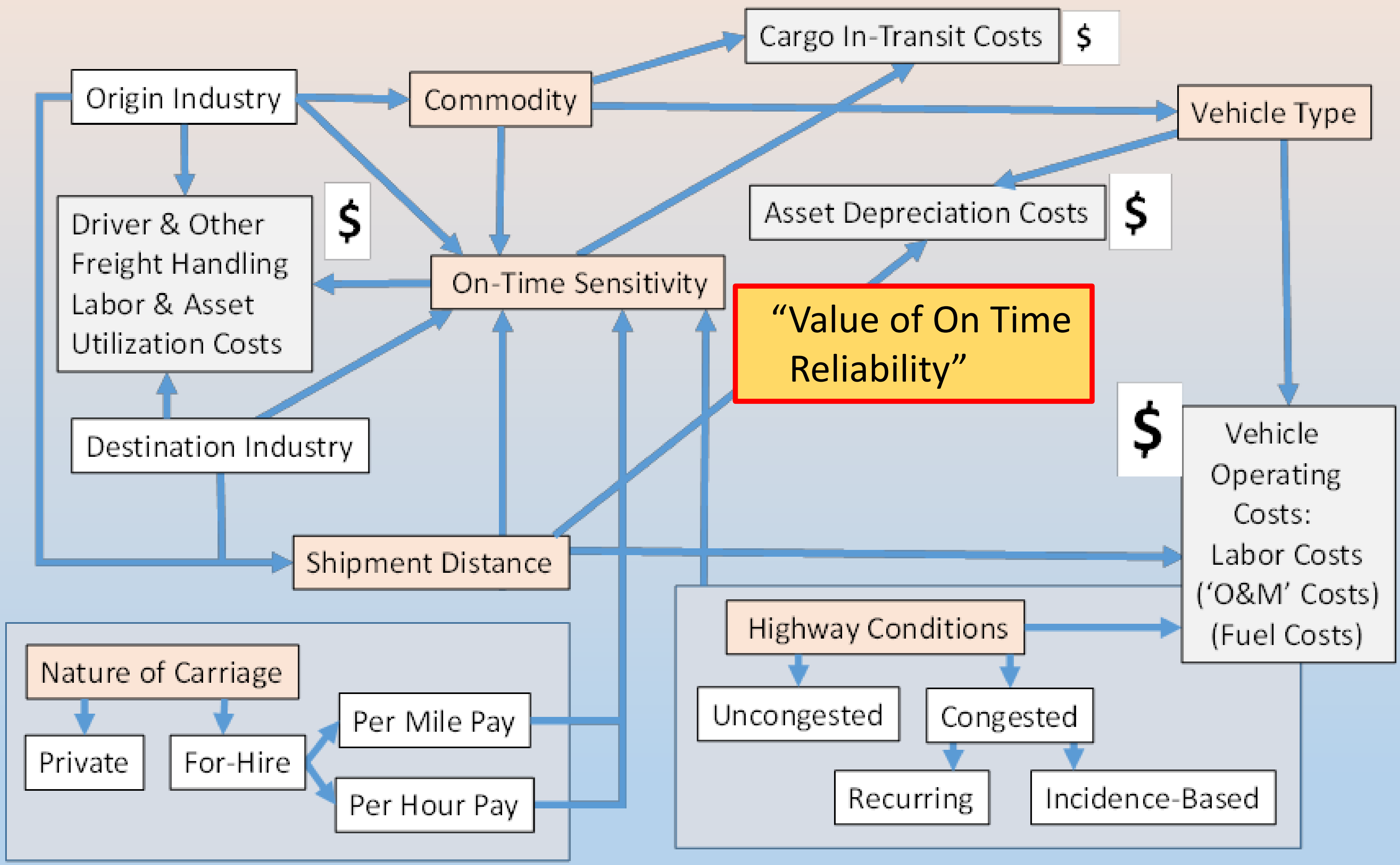
- **Use of Non-Intrusive, IT-Based (GPS, Cellular, RFIDs, Bar Codes….) Data Sources (e.g. for validation purposes)**

Freight Agents Involved in The Supply Chain
(+ Who/How Should We Survey?)



Example Estimation of Freight "Value of Time Costs"*



* F. Southworth (2016) *A Review of Truck Freight Value of Travel Time and Travel Time Reliability Studies*

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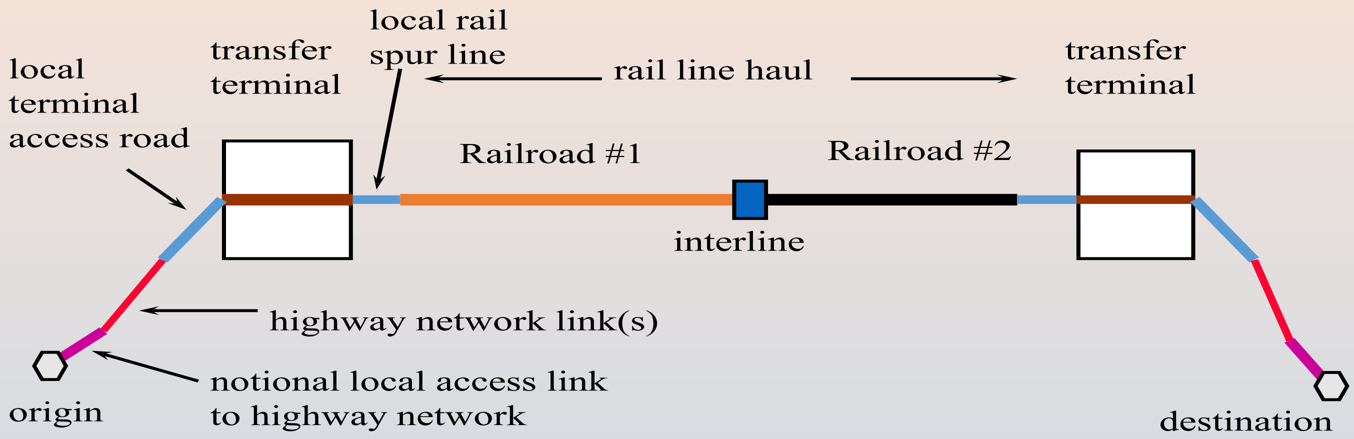
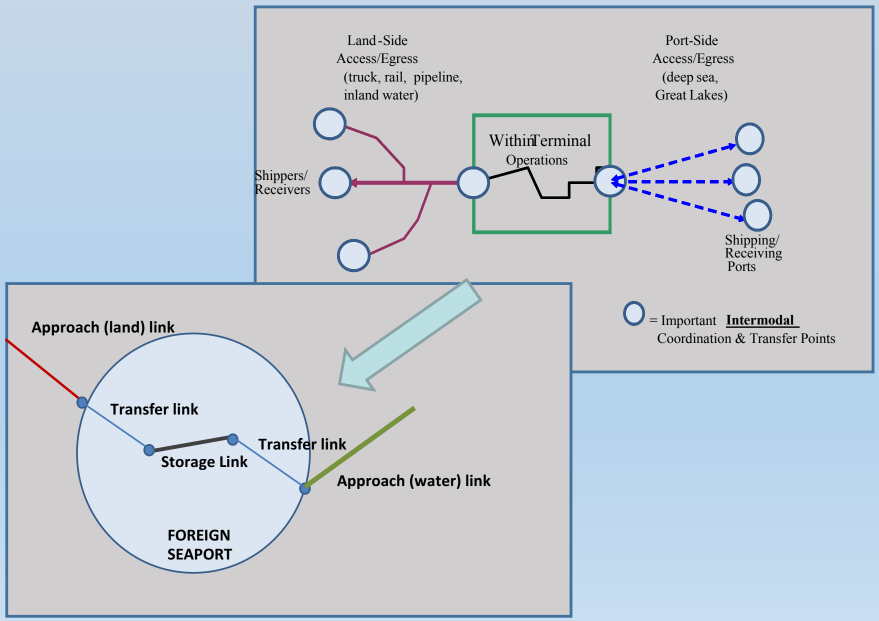
Example Long-Haul Intermodal Network Data Model Structures

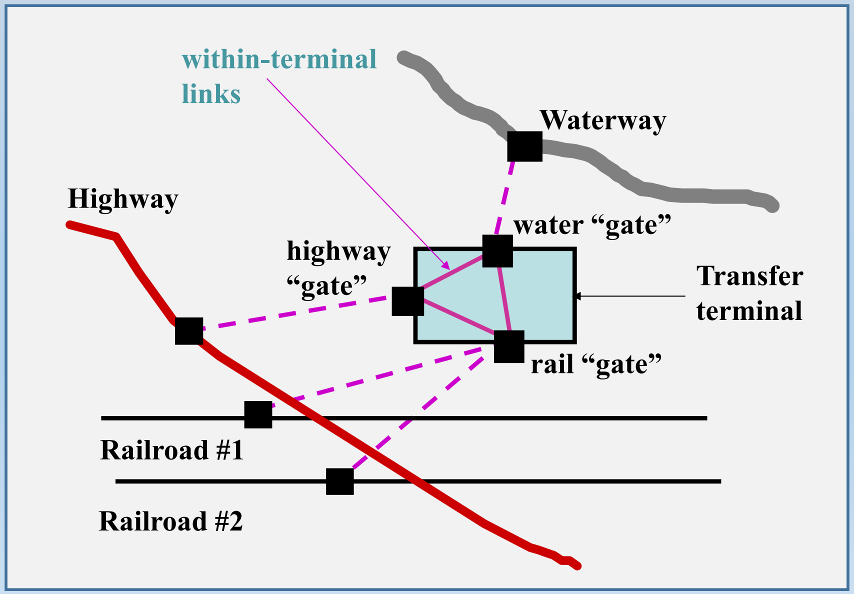


Route Impedance = modal line-haul travel costs
\+ intra-terminal transfer costs
\+ inter-carrier (interlining) costs
\+ local network access and egress costs
\+ network-to-terminal local access costs

Example of Modeling Seaport Throughput Flows and Costs

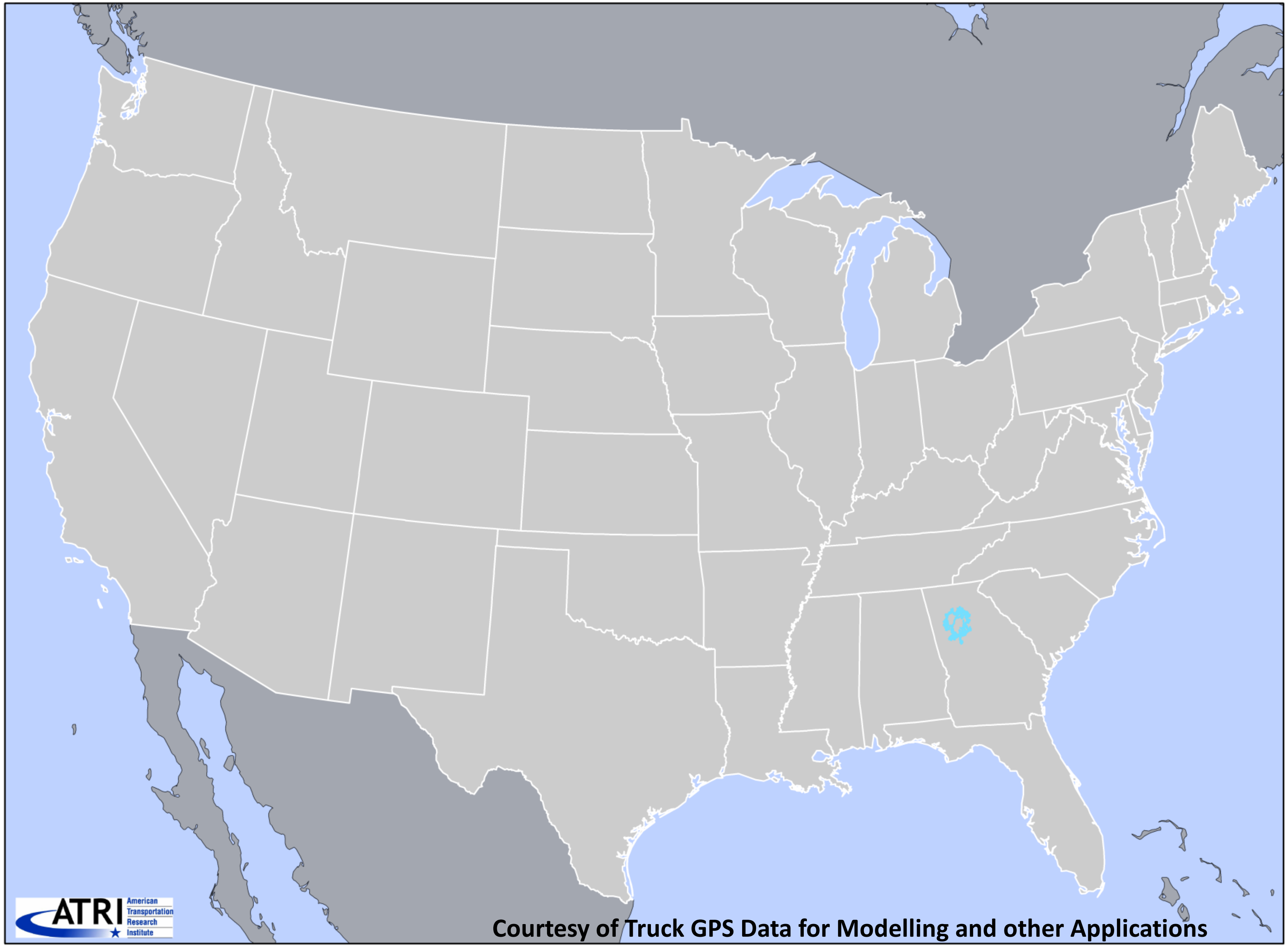


Example of Modeling Inland Intermodal Terminals Flows



How Can We Make Use of GPS and Other Non-Intrusive Survey Data?

Atlanta 2,000 ATRI Truck Sample



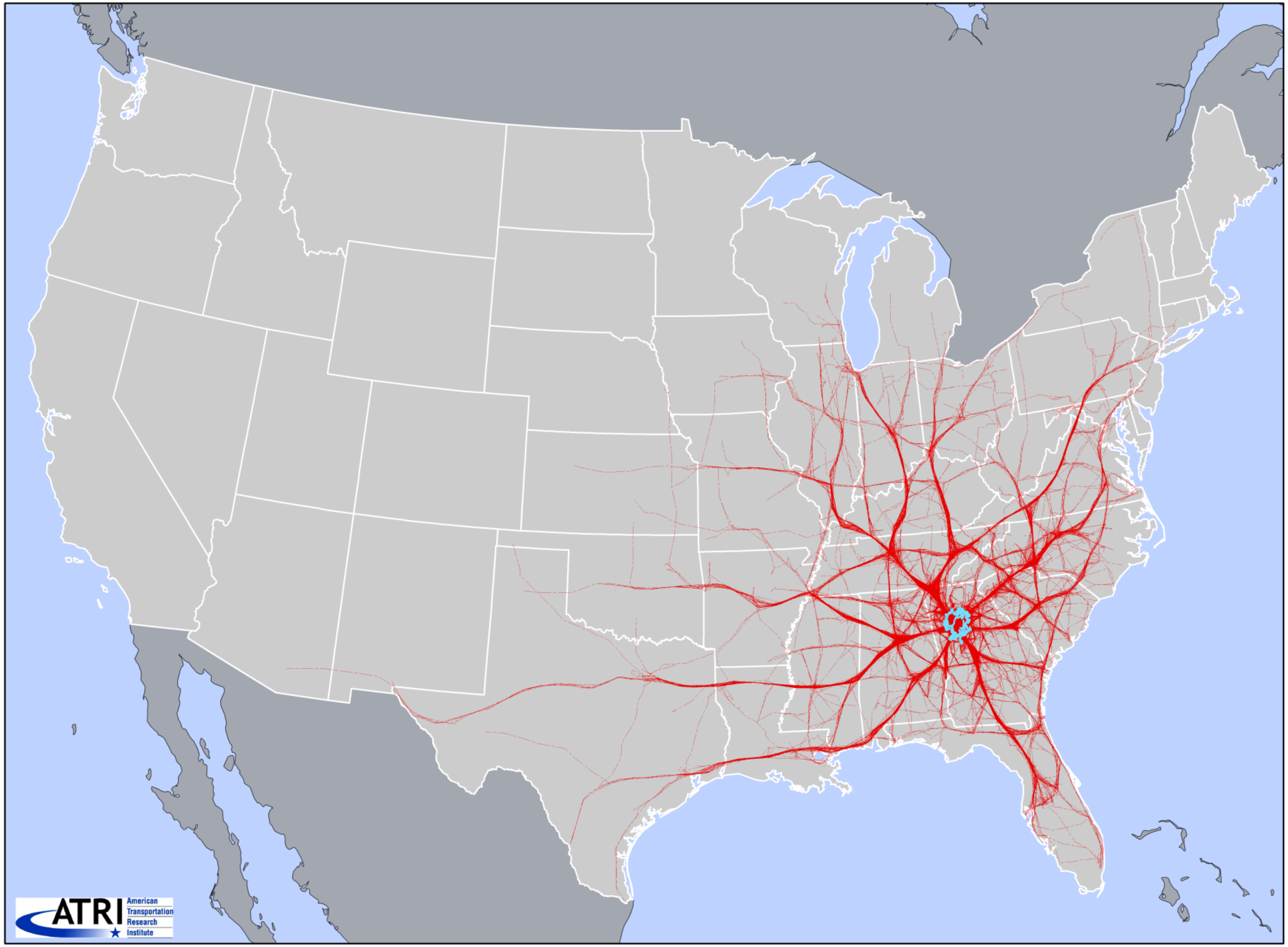
Courtesy of Truck GPS Data for Modelling and other Applications

Jeff Short American Transportation Research Institute (ATRI)

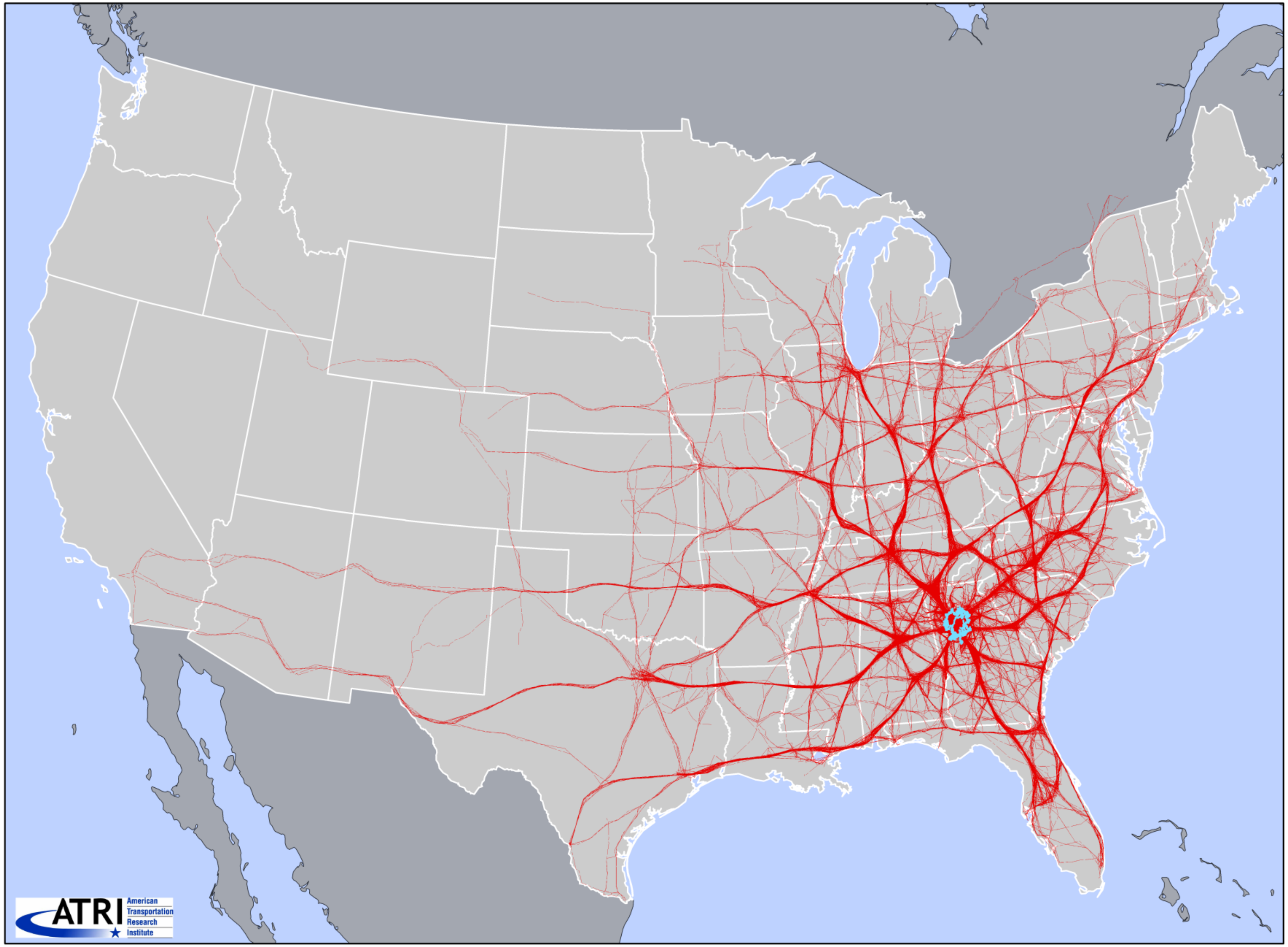
August 25, 2017, Atlanta Regional Commission Modelling Group

Same 2,000 Trucks After 24 Hours

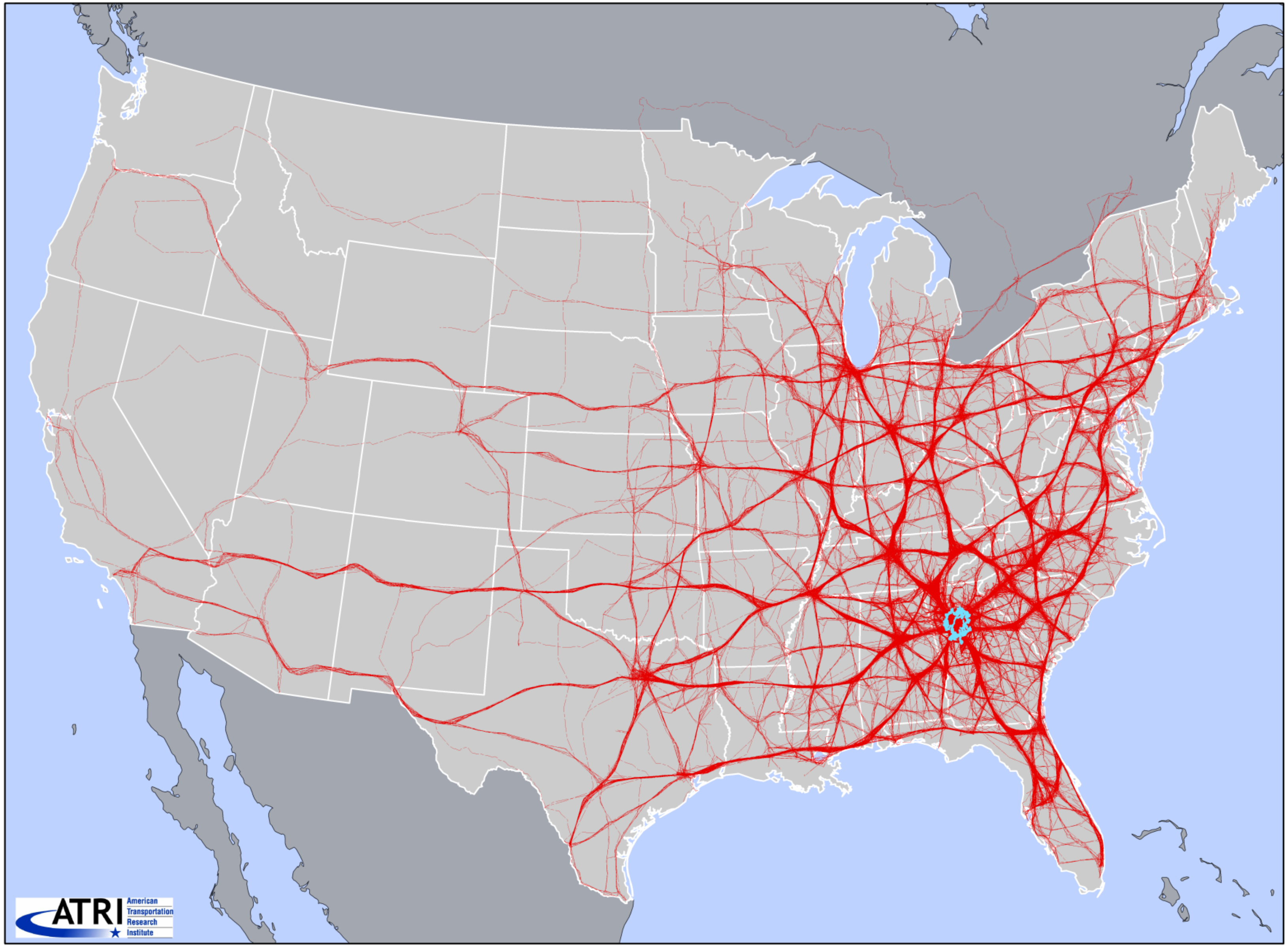
Same 2,000 Trucks After 48 Hours



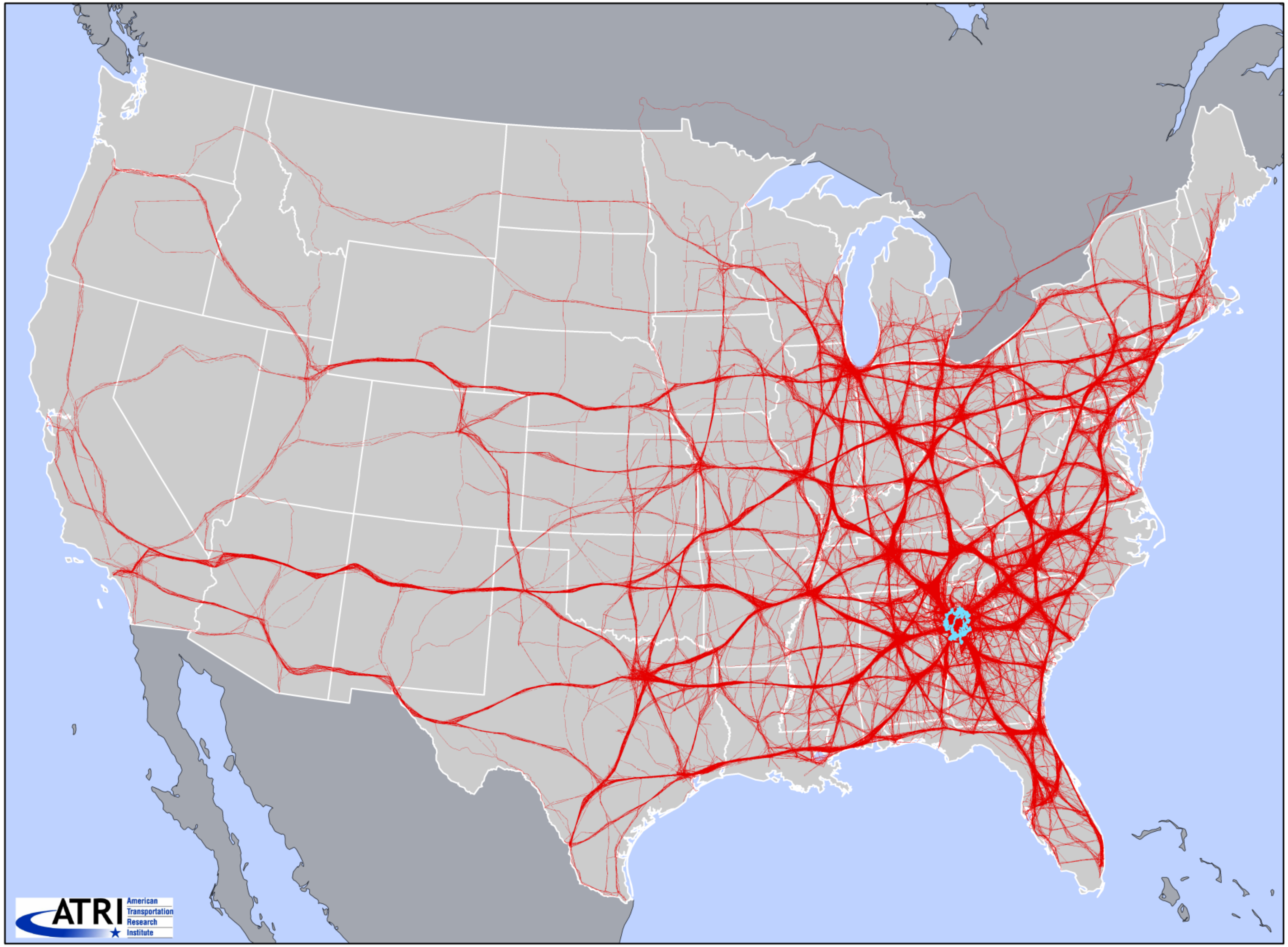
Same 2,000 Trucks After 72 Hours



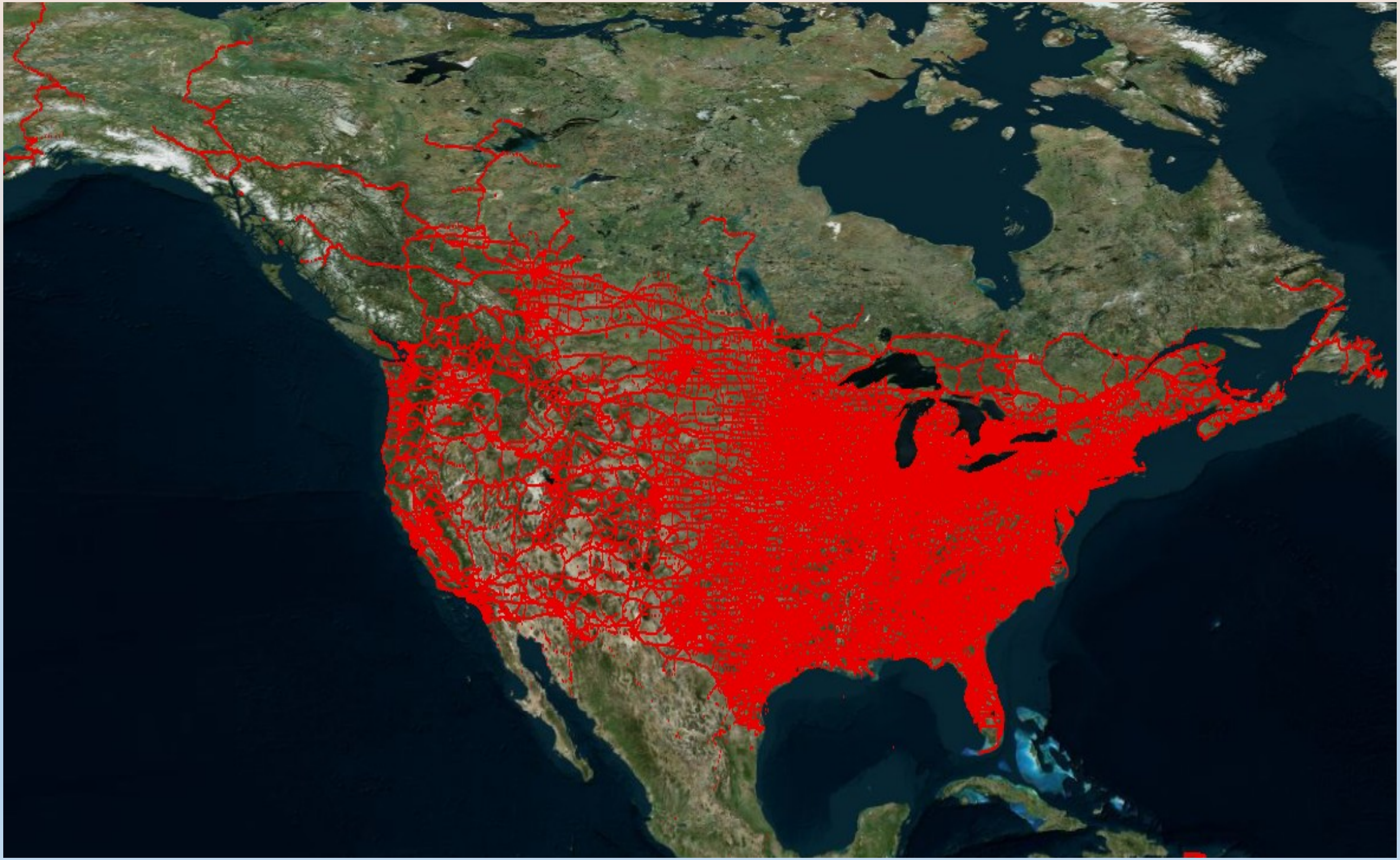
Same 2,000 Trucks After 5 Days



Same 2,000 Trucks After 7 Days

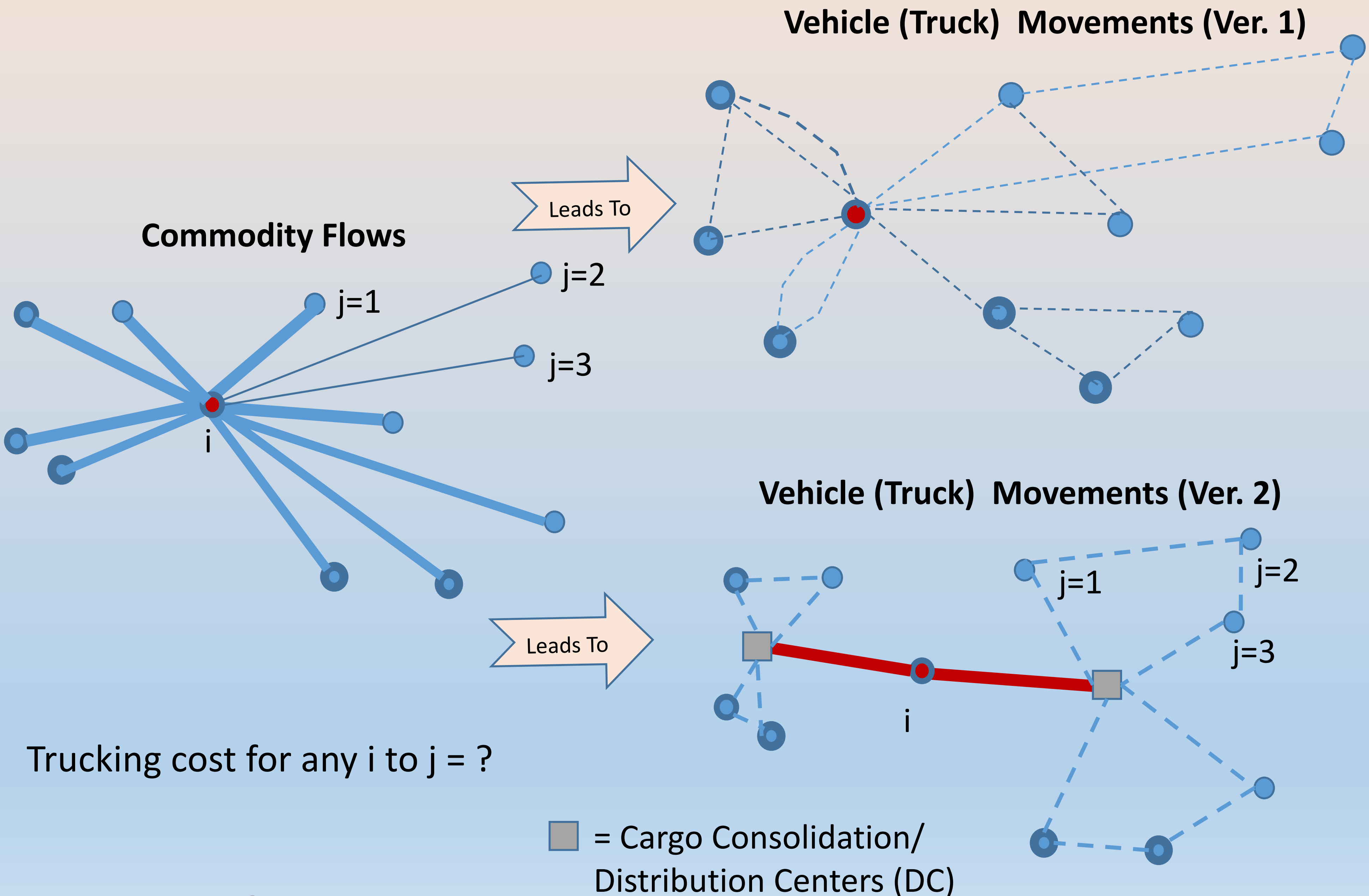


ATRI Truck GPS Dataset – One Day



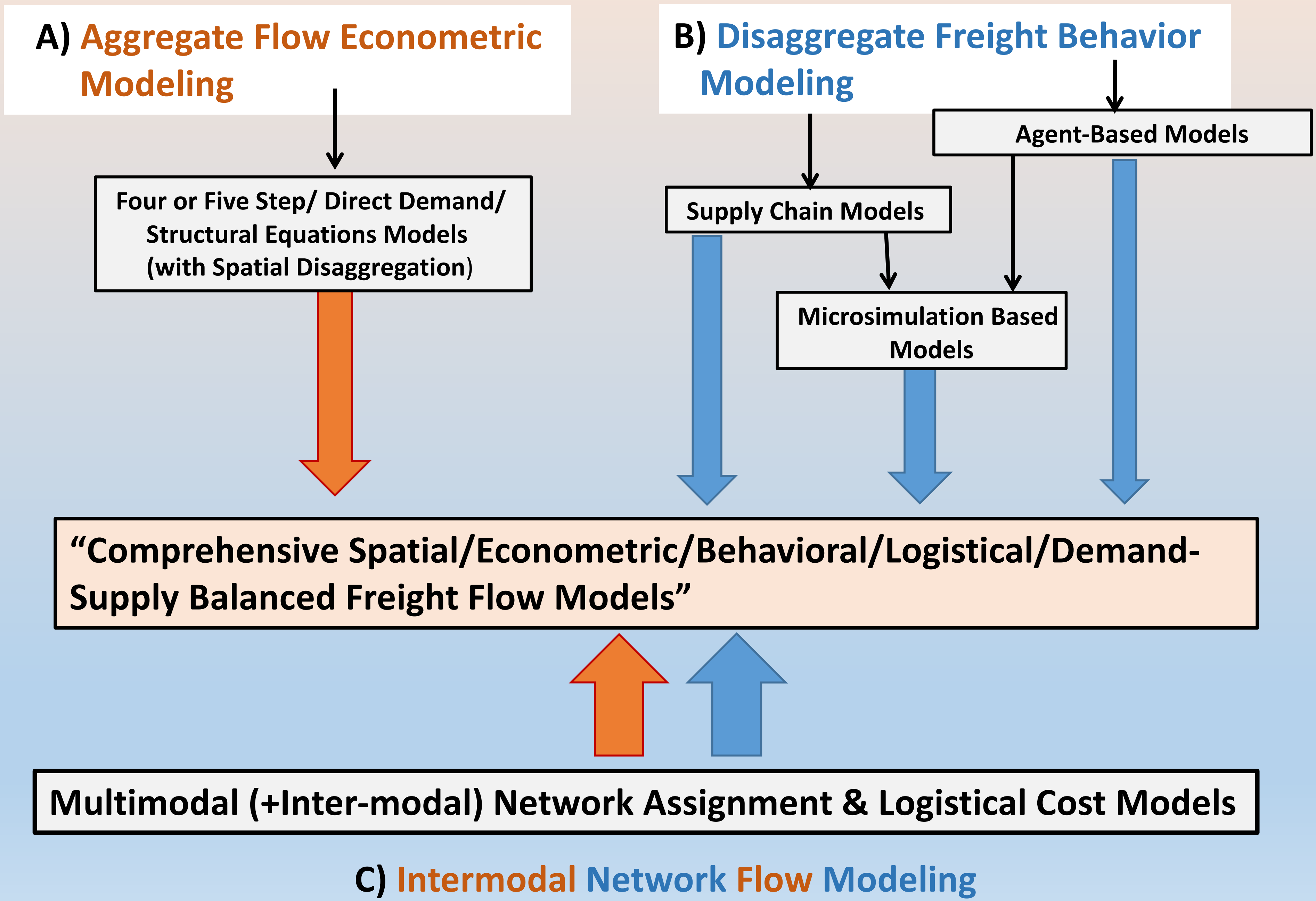
Short, J. ATRI Ibid.

Urban Truck Freight Modeling: Multi-Stop Pickup and Delivery Tours



Trucking cost for any i to j = ?

Can We Pull It All Together?



And Finally: Some Emerging Issues To Think About.

How Do We Model…..

- "New Mode" Impacts
  - Including:
    - Drones (for Rural Freight)
    - Autonomous Connected Truck Platoons (On Interstates)
    - Megaships

- New Energy Source (Generation, Storage) Impacts
  - Including:
    - Vehicle-based and Roadway-based Electric Power Options

- New Production Method Impacts
  - Including:
    - 3-D Printing (Changes in Household as well as Industry Production Patterns)

A Look at Freight Demand Modeling in the United States

Abstract

This presentation overviews the different approaches to estimating and forecasting the demand for freight services in the United States, pointing out the most common in-practice approaches and how recent and on-going research efforts are likely to move this practice towards new, improved, and increasingly involved model applications, making using of a variety of data sources. These developments are discussed in the context of bringing more detail into the freight planning process: by adding industry, commodity, modal, network, behavioral and logistical details to freight activity models at a number of different regional scales. The discussion is centered on the interplay between freight volumes and freight costs. Emerging methods include the introduction of supply-chain considerations into freight activity models, the use of microsimulation techniques, notably in support of behaviorally motivated agent-based freight modeling, and the inclusion of an expanded range of freight cost factors, including delivery time reliability and other inventory related carrying costs. Supporting these efforts are parallel developments in newly available data sources. Driving much of this modeling effort today is the search for policy-relevant and plan-sensitive freight performance measures, at a time when the condition and carrying capacity of the nation's multi-modal freight networks are coming under increased scrutiny.