State-of-the Practice in Freight Transportation Modeling around the Country and the Applicability to Enhance ARC’s Freight Model

Presentation to:
Atlanta Regional Commission
Model Users Group (MUG)

June 14, 2019
Presenters

**Steve Cote, PE, AICP**
- Senior Planning Leader
- 20+ Years Freight Experience
  - Sub-area & Corridor Plans
  - Truck/Port Access
  - Truck Parking
  - State, MPO, County/City Plans

**Zahra Pourabdollahi, PhD**
- Freight Modeling Leader
- 10+ Years Freight Modeling Experience
  - Truck Touring & Behavior-Based Freight Models
  - Statewide Freight Models
- Serves on TRB Committees Standing Committees
  - Freight Planning and Logistics (AT015)
  - Travel Behavior and Values (ADB10)
Agenda

- Atlanta Regional Freight Challenges
- State-of-the Practice in Freight Modeling
- RS&H Applications
- Lessons Learned
Atlanta Regional Freight Challenges
Atlanta Regional Freight Challenges

» Geographic
  – Atlanta’s Vast and Growing Region
  – Savannah Port Explosive Growth
  – Existing & Emerging Freight Cluster Areas
  – Unauthorized Truck Parking
  – E-Commerce / Delivery Challenges

» Modal Challenges
  – Competition for Limited Road Capacity
  – Increasing Rail / Inland Port Development
  – Competition with “Complete Streets”

» Policy / Legislative
  – Local land use challenges
  – Public vs. private sector coordination

<table>
<thead>
<tr>
<th>TOP 100 LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Atlanta, GA</td>
</tr>
<tr>
<td>2. Fort Lee, VA</td>
</tr>
<tr>
<td>3. Chicago, IL</td>
</tr>
<tr>
<td>4. Louisville, KY</td>
</tr>
<tr>
<td>5. Cincinnati, OH</td>
</tr>
<tr>
<td>6. Los Angeles, CA</td>
</tr>
<tr>
<td>7. Aurora, IL</td>
</tr>
<tr>
<td>8. Houston, TX</td>
</tr>
<tr>
<td>9. Atlanta, GA</td>
</tr>
<tr>
<td>10. Seattle, WA</td>
</tr>
</tbody>
</table>
Atlanta Regional Freight Challenges

I-20 from the West: Perimeter

I-16 from the South: Region
What is the average time it typically takes you to find truck parking?

- Less than 15 minutes: 51%
- 15 – 30 minutes: 41%
- 30 minutes – 1 hour: 7%
- More than 1 hour: 1%

What are the top ways you find truck parking within the Atlanta Region?

- Continue driving until a safe parking location is found: 80%
- Smartphone Application: 20%
- I am aware of my destination in advance: 10%
Recent studies show deadly crashes involving large trucks are going up

By: Steve Gehlbach
Updated: May 17, 2019 - 7:15 AM
State-of-the-practice in Freight Modeling
State-of-the Practice in Freight Modeling

- Direct Facility Flow Factoring Method
- OD Factoring Method
- Three-step Trip-based (Truck) Model
- Tour-based Model
- Commodity-based Model
- Economic Activity (Agent-based) Model
- Hybrid Model

ARC Model
Tour-Based Freight Modeling

Traditional Trip-based Truck Model

- Aggregate (TAZ level)
- Limited ties to economic characteristics
- Disregard logistics decision making process
- Ignore temporal and spatial interrelations between truck trips

Tour-based Model

Tour Models
- Generation model
- Tour Purpose
- Start Time of Day Choice
- Vehicle Type Model
- Commodity Type

Stop Models
- Stop Frequency
- Stop Activity
- Stop Location
- Stop Duration

Trip Accumulation
- End of tour model
- Trip accumulation

Trip Assignment
Economic Activity Freight Modeling

Commodity-based Freight Model

- Aggregate (Zone level) or Disaggregate (Firm-level)
- Great ties to economic characteristics and Input-Output Tables
- Usually Multimodal
- Replicate logistics decision making process by modeling actors’ behavior

Agent-based Freight Model

Agent Management
- Agent Synthesizer
- Activities
- Assign cost to activities
- Fleet Ownership
- Commodity Type

Freight Generation
- Commodity IO
- Tonnage/Value Estimation

Supply Chain
- Vendor Choice
- Buyer Choice
- Trade Partnership
- Shipper Choice
- Commodity Flow

Transport Choices
- Distribution Channel
- Intermediate Logistics Center
- Shipment Size
- Mode Choice

Trip Assignment
- Vehicle Choice
- Trip Accumulation
- Trip Assignment

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Advanced Freight Models

**Pros**

» Improved estimation of freight flows
» More accurate estimation of truck miles traveled
» Better forecast goods distribution and delivery patterns
» Disaggregate-level output
» Replicate logistics decision-making process
» Capture freight market behaviors
» High level of temporal resolution
» Support a wider range of regional planning, project and policy assessment

**Cons**

» Require more data
» Complicated formulation
» Longer development period
» Calibration and validation process
RS&H Project Applications
» RS&H Freight Modeling
  – Seven (7) Projects
  – Three (3) Clients

» Today’s Discussion
  – FDOT District Seven (Tampa Bay Region)
  – Maricopa Association of Governments (MAG)
Development of a Tour-Based Heavy-Truck Freight Model

FDOT – District Seven (Tampa Bay Region)

Geographical Coverage

Industry Coverage

<table>
<thead>
<tr>
<th>2012 NAICS Code</th>
<th>2012 NAICS Title</th>
<th>Modeled</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Agriculture</td>
<td>No</td>
</tr>
<tr>
<td>21</td>
<td>Mining, Querying, and Oil and Gas Extraction</td>
<td>Yes</td>
</tr>
<tr>
<td>23</td>
<td>Construction</td>
<td>No</td>
</tr>
<tr>
<td>31-33</td>
<td>Manufacturing</td>
<td>Yes</td>
</tr>
<tr>
<td>42</td>
<td>Wholesale Trade</td>
<td>Yes</td>
</tr>
<tr>
<td>44-45</td>
<td>Retail Trade</td>
<td>Yes</td>
</tr>
<tr>
<td>48-49</td>
<td>Transportation and Warehousing</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Data

- ATRI
- CFS Microdata (BTS)
- InfoGroup Data (FDOT)
- Freight Activity Center Data (FDOT)

Truck Classes

FDOT

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Development of a Tour-Based Heavy-Truck Freight Model

FDOT – District Seven (Tampa Bay Region)

Model Framework

Tour Generation
- Heavy truck tour rates by industry type & employment size

Tour Attributes
- Tour Purpose
- Tour Type

Start Time Of Day Choice
- AM Period
- Mid-day Period
- PM Period
- Evening Period

Stop Frequency Model
- Alternatives (intermediate stops)
- # of Alternatives based on ATRI data

Destination Choice
- Stop Location
  - Based on Land-use
    - Industrial
    - Warehousing & Transportation
    - Wholesaler
    - Retail
    - Service
    - Residential

Stop Purpose
# ATRI Data

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck ID</td>
<td>Vehicle Identifier (Dynamic IDs)</td>
</tr>
<tr>
<td>X</td>
<td>Degrees longitude</td>
</tr>
<tr>
<td>Y</td>
<td>Degrees latitude</td>
</tr>
<tr>
<td>Time/Date Stamp</td>
<td>Time and date</td>
</tr>
<tr>
<td>Spot Speed</td>
<td>Travel speed (mph)</td>
</tr>
<tr>
<td>Heading</td>
<td>Travel direction</td>
</tr>
</tbody>
</table>

## ATRI Data

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Coverage</td>
<td>Seven Counties + 10 mile external buffer</td>
</tr>
<tr>
<td>Temporal Coverage</td>
<td>Two Weeks (between 2015 and 2016)</td>
</tr>
<tr>
<td># of Records</td>
<td>96.4 Million</td>
</tr>
<tr>
<td># of Unique Truck IDs</td>
<td>110K</td>
</tr>
</tbody>
</table>
Development of a Tour-Based Heavy-Truck Freight Model

ATRI Data Processing

Data QC & Cleaning → Tour & Stop Identification → Stop Filtering → Geo-spatial analysis: Land-use / Employment info for purpose inference → Tours and Trip Table by Purpose
## ATRI Data Processing

<table>
<thead>
<tr>
<th>Truck ID 104035</th>
<th>October 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS events (pings)</td>
<td>553</td>
</tr>
<tr>
<td>Identified Tours</td>
<td>5</td>
</tr>
<tr>
<td>Trucks</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Truck ID 104035 – One example Tour</th>
<th>October 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS events (pings)</td>
<td>194</td>
</tr>
<tr>
<td>Identified Tours</td>
<td>1</td>
</tr>
<tr>
<td>Identified Stops</td>
<td>5</td>
</tr>
<tr>
<td>Trips</td>
<td>6</td>
</tr>
</tbody>
</table>
Tour Summary

94.6 Million GPS records

1,710,493 Processed/Useable Records (first-stop-last)

94,928 Unique Truck IDs

325,615 Heavy Truck Tours

1,384,878 Heavy Truck Trips

Time of Day Choice

<table>
<thead>
<tr>
<th>AM</th>
<th>MD</th>
<th>PM</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>30%</td>
<td>10%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Main Stop Purpose Distribution

<table>
<thead>
<tr>
<th>Construction</th>
<th>External</th>
<th>Farming</th>
<th>Government</th>
<th>Industrial/Manufacturing</th>
<th>Residential/Other</th>
<th>Retail</th>
<th>Service</th>
<th>Warehousing/Transportation</th>
<th>Wholesale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
<td>30%</td>
<td>35%</td>
<td>40%</td>
<td>45%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Stop Frequency

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
<td>30%</td>
<td>35%</td>
<td>40%</td>
<td>45%</td>
<td>50%</td>
<td>55%</td>
<td>60%</td>
<td>65%</td>
<td>70%</td>
<td>75%</td>
</tr>
</tbody>
</table>

EXTERNAL | REGIONAL
### Most Visited Destinations

<table>
<thead>
<tr>
<th>Rank</th>
<th>TAZ</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Out of Region</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7-367</td>
<td>Port Tampa</td>
</tr>
<tr>
<td>3</td>
<td>1-265</td>
<td>Sam's Club Distribution Center and other</td>
</tr>
<tr>
<td>4</td>
<td>1-672</td>
<td>Walmart Distribution Center</td>
</tr>
<tr>
<td>5</td>
<td>1-467</td>
<td>CSX Winter Haven</td>
</tr>
<tr>
<td>6</td>
<td>1-665</td>
<td>Coca Cola</td>
</tr>
<tr>
<td>7</td>
<td>7-366</td>
<td>Port Tampa - APWU</td>
</tr>
<tr>
<td>8</td>
<td>7-2626</td>
<td>Walmart Distribution Center</td>
</tr>
<tr>
<td>9</td>
<td>1-379</td>
<td>Truck Rest Areas; Mobile Modular</td>
</tr>
<tr>
<td>10</td>
<td>1-3</td>
<td>Distribution Centers; Warehousing and Transportation Center</td>
</tr>
</tbody>
</table>
Development of a Behavioral Freight Model (MAG)

» Emphasis on freight data and data analysis  
  – Comprehensive review of freight data sources

» Data collection, acquisitions, and analysis

» Establishments/Firm Synthesis models  
  – Innovative state-of-the-art model

» Supply Chain models  
  – Innovative state-of-the-art model

» Transport, and mode choice models

» Truck tour models  
  – Separate models for different user classes

» Operational mega-regional multimodal behavioral freight model

C20 - Freight Demand Modeling and Data Improvement

The Phoenix Metro Area
Innovative model components within consistent agent-based behavioral framework—comprehensive review of freight data sources
Innovative Data: Large data collections and Purchases

Firm Synthesizer –
» NETS data

Supply Chain Model –
» FAF4.1
» TRANSEARCH
» BEA Make and Use Tables
» Economic Census Data 2007 (CFS 2007)
» Economic Census Data 2012 (CFS 2012 microdata for AZ)
» Sun Corridor IMPLAN data

Mode and Path Choice Model –
» Economic Census Data 2012 (CFS 2012 microdata for AZ)

Tour-based Model –
» ATRI (Heavy trucks)
» StreetLight (Medium and Light trucks)

Utilization of the 2016 commercial vehicles survey

Selected Best Data Fusion Application in the Country By TRB at 1st Innovations in Freight Data Workshop 2017 from among 20 submissions
Supply Chain Model Overview Framework

1. **Freight Generation:**
   - Production/Consumption Rates per employee by industry class

2. **Supplier Selection:**
   - Form supplier-buyer pairs
   - Determine amount of traded commodity

3. **Transport, Mode, and Path Choice Model:**
   - Mode Choice, Shipment size, Transload location, external stations

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**MAG Behavioral Freight Model**

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**TMIP Webinar November 15, 2017: Presentation 1 - MAG Behavioral Freight Model**
Model Overview

- **Study Area:**
  - Arizona Sun Corridor Megaregion (MAG+PAG Modeling Area)

- **Variable Zone System:**
  - MAG-PAG megaregion: TAZ
  - Rest of Arizona: County
  - Rest of the US: FAF zones

- **8.5 million establishments/firms with 6-digit NAICS industry classification**
  - Partitioned to 398,385 firm clusters (decision-making agents)

- **42 Commodity Groups (2-digit SCTG)**
(1) Freight Generation
Output: Supplier & Buyer Firms Database

- Firms characteristics
- SCTG
- Supply/Demand K-ton

Freight Generation Results for Articles of Base Metal (SCTG 33)

<table>
<thead>
<tr>
<th>Total National Supply &amp; Demand</th>
<th>18,040,435 k-ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAG-PAG Supply</td>
<td>125,029 k-ton</td>
</tr>
<tr>
<td>MAG-PAG Demand</td>
<td>163,861 k-ton</td>
</tr>
<tr>
<td>Simulated Supplier Agents</td>
<td>137,328</td>
</tr>
<tr>
<td>Simulated Buyer Agents</td>
<td>4,177,042</td>
</tr>
</tbody>
</table>

TMIP Webinar November 15, 2017: Presentation 1 - MAG Behavioral Freight Model

RSH
MAG Behavioral Freight Model

(2) Supplier Selection
Agent Modeling Constructs

- Multiple agents (actors) interact in the market
- Firms buy commodities, produce using them and other commodities, and then sell and transport these goods.
- Agent model is a simplified portion of this “enterprise” model, focusing on the buyers and sellers in individual commodity markets
(2) Supplier Selection
Market Clearing Model - Roth & Peranson Algorithm

- A pareto-optimal and stable market-clearing mechanism to matches buyers to sellers.
- Only needs an ordinal ranking of who each buyer would like to purchase from, and an ordinal ranking of whom each seller would like to sell to.
- Selection Utility/Score is calculated for each buyer and seller.

```java
public static enum SellerScoreFactor {
    INVERSE_DISTANCE,
    AVG_PRODUCTION,
    AVG_EMPLOYEE_SIZE,
    INVERSE_SSELLER_PRICE,
    SELLER_PRODUCTION;
}

public static enum BuyerScoreFactor {
    BUYER_AVG_EMPLOYEE_SIZE,
    BUYER_AVG_DEMAND,
    BUYER_EMPLOYEE_SIZE,
    BUYER_DEMAND
}
```

(3) Transport, Mode and Path Choice Model

Overview

- Disaggregate Logistics Choice Model
- Evaluates alternatives for each buyer-supplier pair
- Joint Mode and Shipment Size Choice
- Main estimation source: 2012 Commodity Flow Survey (CFS) Microdata Sample
- Determine external stations for highway mode and Selected Intermodal Yard for Rail shipments
(3) Transport, Mode and Path Choice Model
Data Sources: 2012 CFS Microdata

<table>
<thead>
<tr>
<th>Mode</th>
<th>Use in Model Estimation and Application</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>Yes (combine)</td>
<td>1</td>
</tr>
<tr>
<td>For-hire truck</td>
<td>Yes (combine)</td>
<td>35,038</td>
</tr>
<tr>
<td>Private truck</td>
<td>Yes (combine)</td>
<td>28,805</td>
</tr>
<tr>
<td>Rail</td>
<td>Yes (combine)</td>
<td>501</td>
</tr>
<tr>
<td>Truck and rail</td>
<td>Yes (combine)</td>
<td>161</td>
</tr>
<tr>
<td>Air (incl truck &amp; air)</td>
<td>Yes (combine)</td>
<td>2,863</td>
</tr>
<tr>
<td>Parcel, USPS, or courier</td>
<td>Yes (combine)</td>
<td>34,107</td>
</tr>
<tr>
<td>Mode suppressed</td>
<td>No - unknown mode</td>
<td>5</td>
</tr>
<tr>
<td>Single mode</td>
<td>No - unknown mode</td>
<td>221</td>
</tr>
<tr>
<td>Multiple mode</td>
<td>No - unknown mode</td>
<td>135</td>
</tr>
<tr>
<td>Truck and water</td>
<td>No - water not included</td>
<td>1</td>
</tr>
<tr>
<td>Non-parcel multimode</td>
<td>No - unknown mode</td>
<td>4</td>
</tr>
<tr>
<td>All Shipment Records</td>
<td></td>
<td>101,842</td>
</tr>
<tr>
<td>Shipment Records with Complete Mode Information</td>
<td></td>
<td>101,476</td>
</tr>
</tbody>
</table>
### (3) Transport, Mode and Path Choice Model

**Nested Logit structure**

<table>
<thead>
<tr>
<th>Mode Alternatives</th>
<th>Shipment Size Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail Carload / IMX</td>
<td>SMALL &lt; 150 lbs. Not included</td>
</tr>
<tr>
<td>Truck</td>
<td>Modeled</td>
</tr>
<tr>
<td>Parcel / Air</td>
<td>Modeled</td>
</tr>
</tbody>
</table>
(4) Model Calibration/Replication: Commodity Flows

MODELED VS. OBSERVED TOTAL DIRECTIONAL FLOWS

(a) Modeled Flows

<table>
<thead>
<tr>
<th>Direction</th>
<th>Flow (kton)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>II (Internal)</td>
<td>103,945</td>
<td>56%</td>
</tr>
<tr>
<td>EI (Inbound)</td>
<td>59,916</td>
<td>32%</td>
</tr>
<tr>
<td>IE (Outbound)</td>
<td>21,083</td>
<td>12%</td>
</tr>
<tr>
<td>Total</td>
<td>184,944</td>
<td></td>
</tr>
</tbody>
</table>

(b) FAF Flows

<table>
<thead>
<tr>
<th>Direction</th>
<th>Flow (kton)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>II (Internal)</td>
<td>104,836</td>
<td>56%</td>
</tr>
<tr>
<td>EI (Inbound)</td>
<td>60,038</td>
<td>32%</td>
</tr>
<tr>
<td>IE (Outbound)</td>
<td>21,548</td>
<td>12%</td>
</tr>
<tr>
<td>Total</td>
<td>186,423</td>
<td></td>
</tr>
</tbody>
</table>
Lessons Learned
The analytical needs and policy/planning questions at regional and state agencies determine the most suitable modeling methodology.

More robust and complicated modeling approaches are required to replicate and forecast the evolving freight transportation and logistics market.

The advanced models’ capabilities and nice properties make them intuitively more appealing, and reliable in forecasting freight trips and policy assessment.

Data scarcity is still a problem and considerable data acquisition, fusion and analysis are required.

Good results when model development is a pooled effort with support from multiple agencies/stakeholders.