How Truck and Rail Compete in Commodity Movement in the U.S.?

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Background

- A direct comparison of shipment costs was the primary method (Cunningham, 1982).
- Reliability, flexibility, safety, and some other non-cost factors entered the analysis when the random utility models emerged (Norojono and Young, 2003).
- Hensher and Figliozzi (2007) argued that new supply chain concepts are adopted by many companies, which subsequently influenced the shipping preferences and required fundamental revision in the models.
Objectives

- To introduce a large-scale behavioral freight modeling framework with a focus on modal split.
- To utilize publicly available freight data in the U.S. for the framework.
- To conduct a survey and satisfy the data needs.
- To introduce a behavioral freight mode choice model.
- To run a microsimulation freight model for the U.S.
Technical challenges

- Rapid changes in the supply chain management strategies,
- Lack of an acceptable freight modeling framework,
- Freight data scarcity.
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Supply Chain Replication

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Four types of data are required for FAME:

- Information on Business Establishments,
- Aggregate Freight Movements,
- Information on Individual Shipments,
- Specifications of the Transportation Networks.
A person with comprehensive knowledge of the firm's supply chain and transportation activities was asked for this online survey.

Around 9.3% of those clicked on the survey link.

316 establishments participated in the survey providing information on 881 shipments across the country.

- PART I: Establishment Information.
- PART II: Shipment Information.
- PART III: Contact Information.
### Biasness

Value and weight share of each mode:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Dollar Value</th>
<th>Weight</th>
<th>Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CFS</td>
<td>UIC</td>
<td>CFS</td>
</tr>
<tr>
<td>Truck</td>
<td>68%</td>
<td>67%</td>
<td>60%</td>
</tr>
<tr>
<td>Rail</td>
<td>3%</td>
<td>4%</td>
<td>10%</td>
</tr>
<tr>
<td>Water</td>
<td>1%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Air, air &amp; truck</td>
<td>5%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Intermodal</td>
<td>15%</td>
<td>12%</td>
<td>7%</td>
</tr>
<tr>
<td>Pipeline &amp; unknown</td>
<td>9%</td>
<td>-</td>
<td>20%</td>
</tr>
</tbody>
</table>
MODELS

Models that are used in FAME:

- Supplier selection,
- Shipment size,
- Mode Choice.
Supplier Selection

A Bi-Level Supplier Selection Model:

- List all the candidate suppliers,
  - FAF industry to commodity crosswalk,
  - Make and use tables in the 2002 Benchmark Input-Output Account.
- Suitability assessment?
  - A fuzzy rule-based system.
Distribution of the size of the shipments by commodity type and by shipping distance was obtained from the CFS 2002,

- 3 categories for size: <1000 lbs., 10000-50000, 50000<.
- 43 categories for commodity: 2Digit-SCTG
Initialization:

- For a given commodity and distance, define the following matrix:

  \[
  \begin{array}{cccc}
  \vdots & \vdots & \vdots & \vdots \\
  x_{ij} & \vdots & \vdots & \vdots \\
  \vdots & \vdots & \vdots & \vdots \\
  Total & Total & Total & Total \\
  \end{array}
  \]

- Initialize in a way that larger supplier and buyers tend to ship their commodity in larger shipments.
Shipment Size

- Iterative Proportional Fitting (IPF),
- Determining factors in shipment size:
  - Establishment size of the supplier,
  - Establishment size of the buyer,
  - Shipping distance,
  - Commodity type.
# Mode Choice

## Variables and Definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODE</td>
<td>1: truck / 0: rail or any combination of that with truck</td>
<td>0.924843</td>
<td>0.263919</td>
</tr>
<tr>
<td>GCD</td>
<td>Great circle distance (miles)</td>
<td>616.563</td>
<td>640.328</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>Weight of the shipment (lbs)</td>
<td>23457.6</td>
<td>28959</td>
</tr>
<tr>
<td>IMPEDANCE</td>
<td>= EXP (H_IMP/R_IMP)</td>
<td>6.1866</td>
<td>3.33839</td>
</tr>
<tr>
<td>H_IMP</td>
<td>Highway impedance</td>
<td>897.702</td>
<td>4589.48</td>
</tr>
<tr>
<td>R_IMP</td>
<td>Rail impedance</td>
<td>1176.16</td>
<td>9082.08</td>
</tr>
<tr>
<td>CONTAINERIZED</td>
<td>1: if the shipment is containerized / 0: otherwise</td>
<td>0.02296</td>
<td>0.149947</td>
</tr>
<tr>
<td>COMMODITY</td>
<td>1: if the commodity is agricultural, chemical, pharmaceutical, gravel, natural sands, cement, machinery, metal, mixed freight, miscellaneous, or prepared foodstuffs / 0: otherwise.</td>
<td>0.655532</td>
<td>0.475691</td>
</tr>
</tbody>
</table>
# Mode Choice

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>t-ratio</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>4.832713742</td>
<td>8.170</td>
<td>-</td>
</tr>
<tr>
<td>GCD</td>
<td>-.1042385818E-02</td>
<td>-4.856</td>
<td>2.0786606</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>-.2543805528E-04</td>
<td>-5.075</td>
<td>1.0296476</td>
</tr>
<tr>
<td>IMPEDANCE</td>
<td>-.9889771944E-01</td>
<td>-1.978</td>
<td>2.0211493</td>
</tr>
<tr>
<td>CONTAINERIZED</td>
<td>-1.271052643</td>
<td>-2.612</td>
<td>1.0550726</td>
</tr>
<tr>
<td>COMMODITY</td>
<td>-.9403044651</td>
<td>-2.985</td>
<td>1.0463709</td>
</tr>
</tbody>
</table>

## Fit Measures

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Log likelihood</td>
<td>-58.56742</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Model Chi-squared</td>
<td>138.4382</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Akaike I.C.</td>
<td>0.26959</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td>0.54168</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Correctly Predicted (%)</td>
<td>95.615866</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Correctly Predicted (%) – rail</td>
<td>58.33333</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
SIMULATION

- A total of 46,243 firm-types were generated,
- In all the domestic FAF zones,
- Based on County Business Patterns (CBP) 2002,
- For each firm-type:
  - Location (FAF),
  - Industry (NAICS),
  - Size (8 clusters),
  - Number of actual firms
Modal Split Validation:

- CFS02
- CFS07
- FAF
- FAME

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Research Contribution:

- FAME is heavily based on public freight data in the U.S. and therefore data collection costs are substantially low.
- It is one of the early efforts in freight demand modeling that has a separate component for supply chain configuration.
- It has an open structure and could accept other components that may be available later.
CONCLUSION

Research Contribution:

- Almost all the industry classes are covered in FAME.
- FAME has a unique geographic coverage and to the best of the author’s knowledge, it is the first comprehensive nationwide freight microsimulation in the U.S.
CONCLUSION

Future Works:

- Obtain more information on supplier selection preferences, and expand the second module,
- Develop a robust model to estimate the probability of a shipment being containerized,
- Consider international shipments as well,
- Implement econometrics models or logistic cost minimization approaches for shipment size,
- Network analysis.
Q/A