Modeling and Assessing the Cost of Delays on an Heavily Trafficked Intercity Truck Corridor

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Key Talking Points

**Project Motivation:** Growing Highway Demand vs Highway Supply Imbalance

- Forecast Continued & Rapid Growth in National/ South-Eastern Truck Traffic

**Project Objectives:**

- To develop and test a method that can be applied at the statewide, major corridor level for the purpose of deriving the monetary benefits of limiting within-corridor travel delays.

**Key Technical/Conceptual Challenges:**

- How Do We Determine The Types and Volumes of Commodities Moving Over Our Highly Trafficked Highway Corridors, and

- How Does This Commodity Mix Affect Delay Costs? (and by implication, How Should We Measure the Benefits of Reducing or Eliminating Such Delays)?

**Example Corridor Study (Some Preliminary Results):**

- I-85 Truck Freight Movements Through Georgia
Freight Traffic Is Expected to Grow Significantly in Georgia and the South-Eastern U.S. over the next 4 decades

Table ES.8  Freight and Economic Forecasts

<table>
<thead>
<tr>
<th>Source</th>
<th>Time Period</th>
<th>Tonnage Annual Growth Rate</th>
<th>Value Annual Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDOT Freight and Logistics Plan base forecast (TRANSEARCH Base Year Data w/FHWA FAF3 growth rates)</td>
<td>2007-2050</td>
<td>1.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Economy.com Georgia GDP</td>
<td>2007-2050</td>
<td>–</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

Table ES.9  Mode-Specific Forecasts

<table>
<thead>
<tr>
<th>Mode / Source</th>
<th>Time Period</th>
<th>CAGR</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Savannah Container Growth / GPA</td>
<td>2010-2050</td>
<td>4.5%</td>
<td>TEUs</td>
</tr>
<tr>
<td>Georgia Air Cargo / GDOT F&amp;L Plan</td>
<td>2007-2050</td>
<td>3.1%</td>
<td>Tons</td>
</tr>
<tr>
<td>National Air Cargo / Federal Aviation Authority</td>
<td>2010-2030</td>
<td>5.0%</td>
<td>Revenue ton-miles</td>
</tr>
<tr>
<td>Georgia Truck / GDOT F&amp;L Plan</td>
<td>2007-2050</td>
<td>1.5%</td>
<td>Tons</td>
</tr>
<tr>
<td>National Truck / American Trucking Assoc.</td>
<td>2009-2021</td>
<td>2.2%</td>
<td>Tons</td>
</tr>
<tr>
<td>Georgia Rail / GDOT F&amp;L Plan</td>
<td>2007-2050</td>
<td>1.0%</td>
<td>Tons</td>
</tr>
</tbody>
</table>

http://www.dot.ga.gov/Projects/programs/georgiafreight/logisticsplan/Pages/default.aspx
Example Truck Traffic Growth Forecast for the South-Eastern Region* - Rapid Growth

* Ton-miles of truck freight are projected to increase by 67% and truck cargo value to increase by 93% between 2015 and 2040

* Includes AL, FL, GA, NC, SC and TN  
Source: Federal Highway Administration – Freight Analysis Framework (Version 3)
Task 1: Defining a Study Corridor

Task 2: Generating a Suitably Disaggregated Matrix of Origin-Destination-Commodity-Truck Class (O-D-C-V) Flows based on Location Specific Economic Activity Data.

Task 3: Carrying out a Multi-Class, Origin-Based and Congestion Sensitive Assignment of Truck Trips to the Selected Corridor

Task 4: Estimating the Dollar Value of Recent and Future Year Truck Travel Time Savings (under different O-D disaggregation, different ton-to-truck conversions, different value of time assumptions)

Task 5: Writing the Draft and Final Project Reports
Task 1: Corridor Selection = I-85 /I-285 Through Georgia
Task 2: Spatial & Commodity Disaggregation of O-D Flows

Starting Point: Freight Analysis Framework (FAF3)

Spatial Resolution (based on 2007 U.S. Commodity Flow Survey regions):
123 domestic regions (74 metro/part metro area regions, 33 state remainders, and 16 entire state regions) + 8 foreign regions

Commodity Class Detail (for O-D Flows):
43 2-Digit Standard Classification of Transported Goods (=SCTG) Codes, as developed for 2007 U.S. Commodity Flow Survey.

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Table 2.1 FAF3 2-Digit SCTG* Commodity Classes

<table>
<thead>
<tr>
<th>SCTG</th>
<th>Commodity</th>
<th>SCTG</th>
<th>Commodity</th>
<th>SCTG</th>
<th>Commodity</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Live animals-fish</td>
<td>15</td>
<td>Coal</td>
<td>29</td>
<td>Printed products</td>
</tr>
<tr>
<td>02</td>
<td>Cereal grains</td>
<td>16</td>
<td>Crude petroleum</td>
<td>30</td>
<td>Textiles/leather</td>
</tr>
<tr>
<td>03</td>
<td>Other agricultural products</td>
<td>17</td>
<td>Gasoline</td>
<td>31</td>
<td>Nonmetal mineral products</td>
</tr>
<tr>
<td>04</td>
<td>Animal feed</td>
<td>18</td>
<td>Fuel oils</td>
<td>32</td>
<td>Base metals</td>
</tr>
<tr>
<td>05</td>
<td>Meat/seafood</td>
<td>19</td>
<td>Natural gas and petroleum prod.</td>
<td>33</td>
<td>Articles-base metal</td>
</tr>
<tr>
<td>06</td>
<td>Milled grain prod.</td>
<td>20</td>
<td>Basic chemicals</td>
<td>34</td>
<td>Machinery</td>
</tr>
<tr>
<td>07</td>
<td>Other foodstuffs</td>
<td>21</td>
<td>Pharmaceuticals</td>
<td>35</td>
<td>Electronics</td>
</tr>
<tr>
<td>08</td>
<td>Alcoholic beverages</td>
<td>22</td>
<td>Fertilizers</td>
<td>36</td>
<td>Motorized vehicles</td>
</tr>
<tr>
<td>09</td>
<td>Tobacco prod.</td>
<td>23</td>
<td>Chemical prod.</td>
<td>37</td>
<td>Transport equipment</td>
</tr>
<tr>
<td>10</td>
<td>Building stone</td>
<td>24</td>
<td>Plastics/rubber</td>
<td>38</td>
<td>Precision instruments</td>
</tr>
<tr>
<td>11</td>
<td>Natural sands</td>
<td>25</td>
<td>Logs</td>
<td>39</td>
<td>Furniture</td>
</tr>
<tr>
<td>12</td>
<td>Gravel</td>
<td>26</td>
<td>Wood products</td>
<td>40</td>
<td>Misc. mfg. products.</td>
</tr>
<tr>
<td>13</td>
<td>Nonmetallic minerals</td>
<td>27</td>
<td>Newsprint/paper</td>
<td>41</td>
<td>Waste/scrap</td>
</tr>
<tr>
<td>14</td>
<td>Metallic ores</td>
<td>28</td>
<td>Paper articles</td>
<td>43</td>
<td>Mixed freight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>99</td>
<td>Commodity unknown</td>
</tr>
</tbody>
</table>

* Standard Classification of Transported Goods
1. Develop Spatially Disaggregated (County/Sub-County) Commodity Productions & Attractions

2. Develop O-D-Commodity Flow Estimates

3. Convert to O-D-Vehicle Trips (Including Empty Trips)


5. Compute O-D-V-(C) Trip Costs = Function (Money + Travel Time + Travel Time Unreliability)

* Includes CFS, CBP/ZBP, BEA, EPA, DOE, USDA data sources
**Using TransCAD’s OUE Assignment Routine
Six-State South-Eastern County Disaggregations of O-D Flows (Preliminary)

Number Of O-D Flows Modeled

- **External-External (EE) Flows**: $102 \times 102$ O-D Flows
- **Internal-External (I-E) and External-Internal (E-I) Flows**: $534 \times 102$ O-D Flows
- **Internal-Internal (I-I) Flows**: $534 \times 534$ O-D Flows
Task 2a. Conversion of Commodity Tons to Truck Trips

- Tonnage Allocation Factor (by: distance, truck type)
- Truck Equivalency Factor (by: commodity, truck type, body type)
- Empty Truck Factors (by: truck type, body type)
- Total Trucks (across all body types for each truck type)

- # of Single Unit Trucks by Body Type
- # of Truck Trailer Trucks by Body Type
- # of Comb Semi Trucks by Body Type
- # of Comb Double Trucks by Body Type
- # of Comb Triple Trucks by Body Type
- # of Empty Single Unit Trucks by Body Type
- # of Empty Truck Trailer Trucks by Body Type
- # of Empty Comb Semi Trucks by Body Type
- # of Empty Comb Double Trucks by Body Type
- # of Empty Comb Triple Trucks by Body Type
- Total # of Single Unit Trucks
- Total # of Truck Trailer Trucks
- Total # of Comb Semi Trucks
- Total # of Comb Double Trucks
- Total # of Comb Triple Trucks
- Total # of Convoy Trucks

STUDY AREA:
• Georgia plus 5 surrounding states (AL, FL, NC, SC, TN)

STUDY CORRIDOR:
• Portion of I-85 in Georgia
• 180 miles
• 182 links

PRELIMINARY RESULTS:
• Average trucks per link: 4,876
• Truck miles traveled: 966,051
• Truck hours traveled: 240,750
• Average tons per link: 79,925
• Total ton-miles: 16,289,083
Model Estimated Daily Truck Trips Volumes on I-85 (in 2007) by Truck Type (Preliminary)

Distribution of Average Daily Truck Trips Originating in Georgia and Using I-85
- Destinations Outside GA

Distribution of Average Daily Truck Trips Terminating in Georgia and Using I-85
- Originations Outside GA
- GA Originations

I-85 Average Daily Truck Trips
- Other Trips
- Other SE Regional Trips
- Within Georgia Trips

Originations Outside GA
- GA Originations

Destinations Outside GA
- GA Destinations

Within Georgia Trips
- Other Trips
- Other SE Regional Trips
Model Estimated Top 5 Commodity Classes Moving On I-85 in 2007 by Weight (Ktons) and Value ($Millions) (Preliminary)
Task 4: Calculating The Costs of Trucking Delay

Measurement Issues:

1) What Are The Relevant Delay-Induced Costs?
   a) Direct Vehicle O&M Costs: Labor, Fuel, Administrative, Maintenance, Insurance, etc. per mile or per hour costs)
   
b) Other Travel Time-Based Costs: Extra Unloading Costs, Extra In-Transit Inventory Holding Costs, Cargo Lost Value Costs, Lost Cargo Consolidation Savings
   

2) How Do We Value? What Factors Impact Such Delay Costs?
   
d) Vehicle Configurations: carrying capacity, body type, fuel use, service area, IT use..
   
e) Commodity Characteristics: perishability, unit value, special carriage needs,…
   
f) Supply Chain Considerations: scheduling sensitivity, customer sensitivity/satisfaction, industrial sector, company size, use of outsourcing,…

3) Who Pays (Which) Delay Costs?
   
g) Shippers/Carriers/Receivers/Final Customers…..
Task 4: Calculating The Costs of Trucking Delay

Transportation Cost = (\(\alpha_1\) * Money) + (\(\alpha_2\) * Travel Time) + (\(\alpha_3\) * Travel Time Reliability)

for a set of model calibrated cost sensitivity parameters \(\alpha_1 - \alpha_3\), and where “Money” costs is broken down as follows:

\[
\text{Money} = \text{Labor Costs (mainly Driver Wages and Benefits)} + \text{Vehicle O&M Costs}
\]

where O&M refer to the marginal (per mile or per hour) costs of vehicle operation and maintenance, including fuel costs, vehicle repair, maintenance and insurance costs, lease or purchase payments, permits and licenses, and tolls.

*E.G. Using Standard Deviation in Truck O-D Travel Times*
Task 4: Estimating the Dollar Value of Truck Travel Time Savings

** Truck Transport and Logistics Cost Modeling Concept **

- **Vehicle Type**
- **Commodity Class**
  - Average Load (Tons or Units /Vehicle)
  - Average Speed (mph)
  - Average Fuel Consumption (Gallons/Mile)
  - Average Fuel Cost ($/Gallon)
  - Average Loading/Unloading Cost ($/Vehicle Load)
  - Average Storage Cost ($/Load/Hour)
  - Fuel Cost Per Trip ($)
  - Storage & Handling Cost Per Trip ($)
  - # of Vehicle Trips Per O-D Pair

** From Assignment Algorithm **

- Labor Cost Per Trip ($)
- Per Trip ** Travel Time **
- O-D Trip Distance (Miles)**
- Vehicle O & M Cost Per Trip ($)
- Average Vehicle O&M* Cost ($/Mile)
- Average $ Cost Per Vehicle Trip
- Transport & Handling Costs ($)
- # of O-D Pairs

* Vehicle O&M cost includes costs associated with tires, oil, parts maintenance and replacement, insurance and licenses
Task 4: Calculating The Costs of Trucking Delay

<table>
<thead>
<tr>
<th>A. European Studies*: Value of Travel Time (Dollar/Hour):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle VTT</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>2015 Dollars/Hour</td>
</tr>
</tbody>
</table>

Reliability Ratio (Travel Time) = Value of SD of Travel Time / Value of Travel Time

TTRR (Shippers and Carriers)

<table>
<thead>
<tr>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>1.24</td>
</tr>
</tbody>
</table>

* See De Jong (2014), Tables 9.2 and 9.4

B. U.S. Studies: **

<table>
<thead>
<tr>
<th>Vehicle VTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Dollars/Hour</td>
</tr>
</tbody>
</table>

ATRI (2014 Update):

$1.676/Mile $76/Hour


Summary- Project Innovations

The R&D looks to improve current planning practice through:

- The Use of **alternative spatial and industrial sector disaggregation** methods.

- The Use of **recent advances in origin-based network route assignment modeling** to connect detailed O-D-Commodity specific flow estimates to specific corridor movements.

- The Use of the latest theoretical developments in **value of time modeling** to produce monetized benefits estimates grounded in travel behavior and spatial economic theory.

- Combining All of The Above Within A Single **Data-Driven Modeling Framework**
Task 2: Generating a Disaggregated Matrix of Origin-Destination-Commodity-Truck Class (O-D-C-V) Flows


**1. Freight Generation / Attraction (Os & Ds)**
- Proportional Weighting (based on zonal employment, payrolls, populations,...)
- Regression Models
- Input-Output (Use & Make) Based Models
- Simultaneous / Structural Equation Models (SEMs)
- Special Freight Generators
  - Direct Demand Commodity Flow Models (Os, Ds, and O-Ds)

**2. O-D Commodity Flows**
- Bi-Proportional Matrix Balancing Methods
- Spatial Interaction (Gravity, Entropy, Utility..) Models

**3. Ton-to-Truck to-PCE conversion methods (including empty trucks)**

**4. Multi-Class Truck to Highway Traffic Assignment**
- All-or-Nothing Route Assignment
- Wardrop User Equilibrium (WUE)
- Stochastic User Equilibrium (SUE)
- Origin-Based (Multi-Class) UE......

* Some 30 Past Studies Reviewed
Download FAF OD Tables

Perform Spatial Disaggregation

Identify and Specify Flow Type

External-External Flows
- Perform Tons to Trucks Procedure
- Combine OD Tables for All Commodities

EI/IE Flows
- Perform Distribution
- Perform Tons to Trucks Procedure
- Combine OD Tables for All Commodities

Internal-Internal Flows
- Aggregate I-I Flows from FAF OD’s to FAF P’s and A’s
- Perform Distribution
- Perform Tons to Trucks Procedure
- Combine OD Tables for All Commodities

Combine all flow types in one table and import into one matrix file

Run Multi-Class, OUE Traffic Assignment

Create Map in TransCAD
Connect Centroids to Network
Create Network TransCAD

Update Link Cost
Coal Production and Imports: The amount of coal mined and shipped does not correlate well with either employment or payroll data, and its spatial disaggregation was therefore treated separately. There is a limited amount of coal production in the six state south-eastern region, most of it concentrated in just 10 Alabama and 3 Tennessee counties. Annual coal plant production data for these counties, reported in kilotons, was created from individual coal plant data reported by the Energy Information Administration (EIA, 2014). To this data were added FAF3 seaport region-specific imports, extracting only those moved inland by truck. Over 94% of these within-region shipments came in through the five ports Charleston SC, Jacksonville and Tampa FL, Mobile AL, Savannah GA, with a small volume also entering through the port district covering the Remainder of North Carolina: a result found to be consistent with the EIA’s 'Monthly Report IM 145' data series for 2007. This combined production and import data was then used to share internal coal originating shipment volumes across study area counties in a manner that matched the volumes reported by FAF3 truck shipments.
2.1b County Level Freight Attraction (Commodity Consumption) Modeling

Preferred Approach = A “Supply-Side Input-Output Model”

Let \( V(C,g) \) = the dollar value of commodity \( C \) used in industry \( g \), then:

\[
U(C,g) = \frac{V(C,g)}{\sum C V(C,g)}
\]

which = the share of commodity \( C \) used in the total ($ valued) output of industry \( g \). With this we then compute:

\[
T(C,j) = T(C,F) \times \left( \frac{\sum g \epsilon G(U(C,g)) \times [E(j,g)/\sum E(j,g)]}{j \epsilon F} \right)
\]

where \( T(C,j) \), \( T(C,F) \) = the tons of commodity \( C \) destined for county \( j \) and for FAF region \( F \), respectively, \( E(j,g) \) = the annual employment in industry \( g \) in county \( j \) receiving commodity \( C \); and the summation is over all industries that consume commodity \( C \).

* BEA I-O Tables for 377 detailed NAICS industrial classes

**Coal Consumption and Exports.** To obtain the likely destination county for coal shipments, a surrogate for annual coal delivery data was obtained from the [EPA's eGrid website](https://www.epa.gov/eGRID), in the form of utility plant-specific and coal-based net electricity generation, reported in megawatt-hours, or MWh (EPA, 2014). According to FAF3, coal exports resulting from truck trips into a port county were limited in 2007, principally through Mobile AL, with a small volume also passing through Miami FL.

FAF3 regional coal truck freight destination totals were then shared to these utility plant-located counties using the MWh data, again rectified to match FAF3 intra-regional truck destination totals. The most likely error introduced by this method is the assumption that truck mode shares are similar across within-region counties.
2.2 Inter-County (O-D) Commodity Flow Modeling

Approach 1: Cross-Product Multiplication. For each Commodity Class C:

\[ \text{Tons}(i,j) = \text{FAF}(I,J) \times \left[ \frac{O(i)}{\text{OFAF}(i)} \times \frac{D(j)}{\text{DFAF}(j)} \right] \]

where \( \text{Tons}(i,j) \) = the annual tons of the commodity being flowed moving between counties \( i \) and \( j \); \( O_i \) = county \( i \) production (originations), \( D_j \) = county \( j \) attraction (destinations), and \( \text{OFAF}(i) \) and \( \text{DFAF}(j) \) = the county aggregated FAF3 regional activity totals for the commodity being flowed.

Approach 2 (Preferred): Cost Sensitive Spatial Interaction Modeling: For each Commodity Class C

\[ \text{Tons}(i,j) = O(i) \times D(j) \times G[\text{Cost}(i,j)] \times A(i) \times B(j) \]

where the \( A(i) \) and \( B(j) \) = the usual iteratively derived balancing factors* (after Wilson, 1967); and where \( G[\text{Cost}(i,j)] \) = a function of marginal cost of inter-county transportation; and where each \( i \)-to-\( j \) cost element is itself a multi-component function of the form:

\[ \text{Transportation Cost} = \alpha_1 \times \text{Money} + \alpha_2 \times \text{Travel Time} + \alpha_3 \times \text{Travel Time Reliability} \]

* i.e. \( A(i) = \frac{1}{\sum_j B(j)D(j)G[\text{Cost}(i,j)]} \) for all \( i \); and \( B(j) = \frac{1}{\sum_i A(i)O(i)G[\text{Cost}(i,j)]} \) for all \( j \).
First, identify O-D shipment distance and assign to a distance interval range. Distribute truck types $v=1,2,..5$ across 5 distance intervals (based on VIUS).

Truck type $v (=1,2,...5)$ trips are then assigned to each distance-bin specific O-D-C flow as:

\[
Y_v = \sum_{k=1}^{k=9} \frac{X_{Cv} \beta_{Cvk}}{\omega_{Cvk}}
\]

where,

- $Y_v$ = number of trucks of truck type $v$
- $X_{Cv}$ = tons of commodity C moved by truck type $v$
- $\beta_{Cvk}$ = the proportion of commodity C moved by truck type $v$ with body type $k$
- $\omega_{Cvk}$ = the average payload of truck type $v$ with body type $k$ transporting commodity C

And:

\[
E_v = \sum_{k=1}^{k=9} \frac{X_{Cv} \beta_{Cvk}}{\omega_{Cvk}} E_{vk}
\]

where,

- $E_v$ = number of empty trucks of truck type $v$
- $X_{Cj}$ = tons of commodity C moved by truck type $v$
- $\beta_{Cvk}$ = the percent of commodity C moved by truck type $v$ with body type $k$
- $\omega_{Cvk}$ = the average payload of truck type $v$ with body type $k$ transporting commodity C
- $E_{jk}$ = empty truck factor for truck type $v$ with body type $k$

Distance Intervals (1,2,..5):
- < 51 mi.,
- 51-100 mi.,
- 101-200 mi.,
- 201-500 mi.,
- > 500 miles.

Truck Body Types (k=1..9):
- auto,
- livestock,
- bulk,
- flatbed,
- tank,
- dry van,
- reefer,
- logging
- other.