A Prototype NC Statewide Truck Network Model

Presented by Bing Mei, P.E.
ITRE @ NSCU
Research Project

☐ Sponsored by NCDOT
☐ PIs: John Stone, PhD
   (Leta Huntersinger)
   Bing Mei

☐ Project status:
   ◼ Fine-tuning
   ◼ Ending this June
Model Overview

- A commodity- and trip-based model
  - Commodity-based: FAF² trips
  - Trip-based: Local trips (non-FAF trips)

- Statewide

- Traffic analysis zones:
  - 139 internal zones – basically county-based
  - 42 buffer zones – county-based
  - 176 external zones – basically serve FAF² trips

- Highway network:
  - 13,425 miles of roadway inside NC
Trip Components to Model

- Freight Analysis Framework\(^2\) (FAF\(^2\)) Trips
- Local Truck Trips (non-FAF trips)
TAZ Structure

- Sub-county zones for Triangle, Triad, and Metrolina metropolitan areas
- County zones for other areas in NC and the buffer areas surrounding NC
- BEA zones for outside buffer areas
  - 179 BEA zones nationwide
  - 176 BEA zones in the model

* BEA: Bureau of Economic Analysis
TAZ Structure
Network Structure

- Based on National Highway Planning Network (NHPN) 2005
- Interstate highways outside the buffer areas
- Interstate highways plus US roads for the buffer areas
- Everything in NHPN for inside NC
Network Structure
Handling Local Truck Trips

- I-I trips
- I-E trips
What We Have

- FHWA Freight Analysis Framework (FAF) Trip Matrix
- Truck Traffic Count Data in NC
- VIUS Data
- Employment Data
- NHPN & NC Universe Network
What We Don’t Have

- Primary survey data that can be used to derive:
  - Trip rates by employment type
  - Trip length distribution
  - Time-of-day parameters
  - Truck routing characteristics
  - Etc.
FAF² Data

2002 Commodity Flow Survey (CFS)
- Comprehensive nationwide freight movement data source, providing tonnage and value of commodities between destination pairs
- The NAICS industries covered in the 2002 CFS

<table>
<thead>
<tr>
<th>NAICS code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>212</td>
<td>Mining (Except Oil and Gas)</td>
</tr>
<tr>
<td>311</td>
<td>Food Manufacturing</td>
</tr>
<tr>
<td>312</td>
<td>Beverage and Tobacco Product Manufacturing</td>
</tr>
<tr>
<td>313</td>
<td>Textile Mills</td>
</tr>
<tr>
<td>314</td>
<td>Textile Product Mills</td>
</tr>
<tr>
<td>315</td>
<td>Apparel Manufacturing</td>
</tr>
<tr>
<td>316</td>
<td>Leather and Allied Product Manufacturing</td>
</tr>
<tr>
<td>321</td>
<td>Wood Product Manufacturing</td>
</tr>
<tr>
<td>322</td>
<td>Paper Manufacturing</td>
</tr>
<tr>
<td>323</td>
<td>Printing and Related Support Activities</td>
</tr>
<tr>
<td>324</td>
<td>Petroleum and Coal Products Manufacturing</td>
</tr>
<tr>
<td>325</td>
<td>Chemical Manufacturing</td>
</tr>
<tr>
<td>326</td>
<td>Plastics and Rubber Products Manufacturing</td>
</tr>
<tr>
<td>327</td>
<td>Nonmetallic Mineral Product Manufacturing</td>
</tr>
<tr>
<td>331</td>
<td>Primary Metal Manufacturing</td>
</tr>
<tr>
<td>332</td>
<td>Fabricated Metal Product Manufacturing</td>
</tr>
<tr>
<td>333</td>
<td>Machinery Manufacturing</td>
</tr>
<tr>
<td>334</td>
<td>Computer and Electronic Product Manufacturing</td>
</tr>
<tr>
<td>335</td>
<td>Electrical Equipment, Appliance, and Component Manufacturing</td>
</tr>
<tr>
<td>336</td>
<td>Transportation Equipment Manufacturing</td>
</tr>
<tr>
<td>337</td>
<td>Furniture and Related Product Manufacturing</td>
</tr>
<tr>
<td>339</td>
<td>Miscellaneous Manufacturing</td>
</tr>
<tr>
<td>421</td>
<td>Wholesale Trade, Durable Goods</td>
</tr>
<tr>
<td>422</td>
<td>Wholesale Trade, Nondurable Goods</td>
</tr>
<tr>
<td>4541</td>
<td>Electronic Shopping and Mail-Order Houses</td>
</tr>
<tr>
<td>49310</td>
<td>Warehousing and Storage</td>
</tr>
<tr>
<td>551114</td>
<td>Corporations, Subsidiary, and Regional Managing Offices</td>
</tr>
</tbody>
</table>


FAF² Data

- **FAF2 Zones**
  - 131 freight analysis zones
  - 114 CFS freight OD zones
  - 17 major ports & border crossings
  - NC FAF zones
    - 71, 72, 73, and 74

- **FAF2 Network**
  - NHPN version 2005.10
  - 450,000 miles of roadway nationwide
  - 11,053 miles NC statewide
FAF² Zones - NC

- 71 Charlotte-Gastonia-Salisbury
- 72 Greensboro--Winston-Salem--High Point
- 73 Raleigh-Durham-Cary
- 74 Remainder of North Carolina
FAF² Network - NC
FAF² Disaggregation

- Disaggregate FAF² O-D to County Level
  - Disaggregate FAF zone totals (in tonnage) to county totals based upon county truck VMT
  - Use gravity model to distribute O’s and D’s based on FAF¹ observed truck trip length distribution (year 1998)
  - So county-to-county FAF² flows are estimated rather than observed
Table showing example of FAF$^2$ Zonal Total Disaggregation:

<table>
<thead>
<tr>
<th>CFIPS</th>
<th>FIPS</th>
<th>FAF Zone</th>
<th>Truck VMT/Day</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>01007</td>
<td>1</td>
<td>1</td>
<td>81,991</td>
<td>0.026</td>
</tr>
<tr>
<td>01009</td>
<td>1</td>
<td>1</td>
<td>129,757</td>
<td>0.040</td>
</tr>
<tr>
<td>01021</td>
<td>1</td>
<td>1</td>
<td>259,398</td>
<td>0.081</td>
</tr>
<tr>
<td>01043</td>
<td>1</td>
<td>1</td>
<td>366,189</td>
<td>0.114</td>
</tr>
<tr>
<td>01073</td>
<td>1</td>
<td>1</td>
<td>1,467,601</td>
<td>0.457</td>
</tr>
<tr>
<td>01115</td>
<td>1</td>
<td>1</td>
<td>312,747</td>
<td>0.097</td>
</tr>
<tr>
<td>01117</td>
<td>1</td>
<td>1</td>
<td>352,185</td>
<td>0.110</td>
</tr>
<tr>
<td>01127</td>
<td>1</td>
<td>1</td>
<td>242,103</td>
<td>0.075</td>
</tr>
<tr>
<td>04013</td>
<td>4</td>
<td>4</td>
<td>6,233,498</td>
<td>0.824</td>
</tr>
<tr>
<td>04021</td>
<td>4</td>
<td>4</td>
<td>1,335,447</td>
<td>0.176</td>
</tr>
</tbody>
</table>
Vehicle Inventory and Use Survey (VIUS) 2002
- provides physical and operational characteristics of trucks
- Primary source for developing commodity flow tonnage to truck trip conversion factors (payload factor)

Payload factors derived based on
- Commodity type
- Vehicle group
  - straight trucks
  - straight truck + trailer
  - tractor + single trailer
  - tractor + multiple (double and triple) trailer
- Truck body type
  - automobile, livestock, bulk, flatbed, tank, van, reefer, logging, & other
## Average Payloads (tons): Example

<table>
<thead>
<tr>
<th>Commodity Code</th>
<th>Body Type</th>
<th>Truck Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Straight Trucks</td>
</tr>
<tr>
<td>1</td>
<td>1-Automobile</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Livestock</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Flatbed</td>
<td>7.283</td>
</tr>
<tr>
<td>5</td>
<td>Tank</td>
<td>12.531</td>
</tr>
<tr>
<td>6</td>
<td>Van</td>
<td>9.946</td>
</tr>
<tr>
<td>7</td>
<td>Reefer</td>
<td>12.531</td>
</tr>
<tr>
<td>8</td>
<td>Logging</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

Source: FHWA Peer Review Meeting, Washington, DC, 8/22/2006
Regional Payload Factor

- Differences in State TSW regulations
- Reflected in truck configurations, body types, and populations
- 5 regions considered demonstrating regional variability
Trip Length Frequency Distribution of FAF² Truck Trips (in miles)

- Only include FAF² truck trips from, to, and within NC
- Average trip length = 240 miles
Truck Traffic Count Data

- 724 locations in total
- 460 locations in the network
- Counts by vehicle type:
  - Motor Cycles
  - Autos
  - Trucks:
    - 2-axle 4-tire
    - single-unit: 2-, 3-, and 4-axle
    - single-trailer: 4-, 5-, and 6-axle
    - multi-trailer: 5-, 6-, and 7-axle
Employment Data

- North Carolina Employment and Security Commission (NCESC) employment data are used for estimating local truck trips
- 260,711 employers in the records
- 3,775,976 employees in NC in 2006
# Synthesized Speed Table

- **Speed look-up table**
  - Functional Class
  - Speed Limit
  - Two-lane or Multi-lanes
  - Terrain Type

<table>
<thead>
<tr>
<th>Terrain Type</th>
<th>Functional Class</th>
<th>Average Travel Speed (mph)</th>
<th>2 lanes speed limit (mph)</th>
<th>3 lanes or more speed limit (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;=20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>1 (Flat)</td>
<td></td>
<td>59</td>
<td>62</td>
<td>59</td>
</tr>
<tr>
<td>2 (Rolling)</td>
<td></td>
<td>58</td>
<td>61</td>
<td>59</td>
</tr>
<tr>
<td>3 (Mountain)</td>
<td></td>
<td>49</td>
<td>55</td>
<td>57</td>
</tr>
</tbody>
</table>

- The table provides speed limits for different functional classes and terrain types.
Adding Empty Truck Trips to FAF2

- 30% empty truck trips were assumed based on
  - Global Insight Recommendations
  - VIUS
  - Literature about empty truck percentage in other states
- 30% of back-haul trips
- Zonal origins and destinations are not balanced in original FAF2 trip matrix
- Must make sure after adding empty trips zonal origins and destinations are balanced
  - A method has been developed by the team
Model Calibration

- Iterating between trip rates adjustment and trip distribution parameters to find the best fit to:
  - Truck traffic counts; AND
  - VIUS trip length distribution
- Gravity model with exponential function for trip distribution
- Calibrated truck trip rate = 1.2 trips/employee
- Local trips account for 83% of total truck trips
- FAF\(^2\) trips account for 17%, including empty truck trips.
Trip Length Frequency Distribution of Local Truck Trips (in minutes)
VIUS vs. Modeled Range of Operation

- FAF2 + Local Truck Trips

<table>
<thead>
<tr>
<th>Range of Operation</th>
<th>VIUS</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 miles or less</td>
<td>65.5%</td>
<td>69.3%</td>
</tr>
<tr>
<td>51 to 200 miles</td>
<td>25%</td>
<td>23.8%</td>
</tr>
<tr>
<td>201 miles or more</td>
<td>9.5%</td>
<td>6.9%</td>
</tr>
</tbody>
</table>
Traffic Assignment

- Multi-path Stochastic Assignment
  - Dial’s algorithm
  - Demonstration with a simple example

- Why not UE?
  - No passenger traffic modeled, which account for
    - 70 – 90% on interstate highways
    - 80 – 90% on rural arterials
    - 85 – 95% on other lower level roads
  - Don’t want to apply growth factors to HPMS auto traffic volumes
Demonstration of Dial’s Algorithm
How much assignment approach matters?

- Of 460 counts, daily
  - v/c ratio >= 1: 3 (0.6%)
  - 0.5 < v/c ratio < 1: 25 (5.4%)
  - 0.1 < v/c ratio <= 0.5: 193 (42%)
  - v/c ratio <= 0.1: 239 (52%)

- After applying 30% increase, daily
  - v/c ratio >= 1: 9 (2%)
  - 0.5 < v/c ratio < 1: 39 (8.5%)
  - 0.1 < v/c ratio <= 0.5: 216 (47%)
  - v/c ratio <= 0.1: 196 (42.5%)

- TRM Daily (2005)
  - 5%
  - 31%
  \[64\%\]
How much assignment approach matters?

Conical Volume-Delay Function
Performance Measures

- Screenlines & Cordon lines
- R-squared
- VMT comparison
- Scatter Plots
- Etc.
## VMT & Volume Comparisons

<table>
<thead>
<tr>
<th>NC Region</th>
<th>Truck Counts Based VMT</th>
<th>Model Estimated Truck VMT</th>
<th>% Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain</td>
<td>1,254,866</td>
<td>1,168,637</td>
<td>- 7%</td>
</tr>
<tr>
<td>Coastal</td>
<td>1,329,124</td>
<td>1,386,750</td>
<td>+ 4%</td>
</tr>
<tr>
<td>Central</td>
<td>1,967,652</td>
<td>2,113,502</td>
<td>+ 7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,551,642</strong></td>
<td><strong>4,668,889</strong></td>
<td><strong>+ 2.5%</strong></td>
</tr>
</tbody>
</table>

\[ R^2 = 0.8 \]
Modeled Truck Volumes on the Network
Work in Progress

- Trip matrix estimation based on ground counts
  - Approach 1: use the trip matrix developed from the gravity model as a seed matrix and estimated local truck trips based on counts
  - Approach 2: combine FAF2 matrix with the trip matrix developed from the gravity model, use the combined matrix as a seed matrix, and estimated all truck trips based on counts
  - Trying different weights on the seed matrix
Use of the Model

- It is a statewide model with strengths in:
  - Intercity / inter-region travel forecasting
  - Rural area travel forecasting
  - I-E travel forecasting for a study area
  - E-E travel forecasting for a study area

- More sophisticated urban models handle commercial vehicle travel for urban areas.
Use of the Model

☐ Intercity corridor studies
☐ Through traffic forecasting for MPO models
☐ Other special applications:
  ■ NC truck profiles project
  ■ Commercial vehicle monitoring
  ■ Etc.
Future Improvements

- Input-Output Modeling
  - Better reflecting the relationship between economy and freight
- Multi-modal Freight Modeling
  - Highway, Rail, Air, and Water Modes
- A Full-blown Statewide Model:
  - Passenger Trips
    - Long trips: business, tourism, & other long trips
    - Daily short trips: HBW, HBO, & NHB
  - Commercial vehicle trips
    - Freight
    - Service
  - Intercity & intra-city trips
  - Multi-modal
  - Time-of-day