What You Always Wanted to Know About the Tennessee Statewide Model Update, But Were Afraid to Ask

November 14, 2013

Vince Bernardin, RSG and Preston Elliott, RPM
Outline

Overview of the 25-Year Long Range Transportation Plan (Preston)
Phase 1 of the Statewide Model Update: Data Development (Vince)
Results of the MPO Survey (Preston and Vince)
Preview of Phase 2 of the Statewide Model Update (Vince)
The two main deliverables of this project:

- 25-Year Long-Range Transportation Policy Plan (*Policy Plan*)
- 10-Year Fiscally Constrained Strategic Investment Program

Other deliverables:

- An Updated Statewide Travel Demand Model
- An Updated Customer Satisfaction Survey
- A Financial & Revenue Forecasting Model
Tennessee’s 25-Year Long-Range Transportation Plan

- Address Growing and Changing Demands
- Action-Orientated Policy Plan
- Include a 10-Year Strategic Investment Program
- Drive TDOT’s 3-Year Transportation Program
Policy Papers

- **Topical Areas**
  - Demographic and Employment Changes & Trends: Population & Economic Conditions
  - Travel Trends & System Performance
  - Financial Revenues & Fiscal Outlook
  - Safety, Security, & Transportation Resilience
  - Freight Transportation: Movements & Infrastructure
  - Mobility: Public Transportation, TDM, & Non-Motorized Modes
  - Accessibility: Land Use Planning, Access Management, Complete Streets, and Health & Environment
  - Coordination, Cooperation, & Consultation
Tennessee’s 25-Year Long-Range Transportation Plan

Plan Development Process & Timeline

- **2013**
  - Understanding Needs & Changing Demands
  - Refining Vision, Goals, & System Performance Measures
  - Customer Satisfaction Research

- **2014**
  - Funding Options
  - Investment Scenarios

- **2015**
  - Development of 25-Year Statewide Long Range Transportation Policy Plan
  - Development of 10-Year Strategic Investment Program

Public & Stakeholder Engagement
Continuous Public Outreach

- Project Website
- Online Survey
- Book-a-Planner

TDOT's 25-Year Long-Range Transportation Plan

General Project Overview:

The Tennessee Department of Transportation (TDOT) is creating a new long-term vision for transportation in Tennessee and public input is needed. This 25-Year Long-Range Transportation Plan provides the foundation for prioritizing transportation investments across the State. The updated plan will aid in accomplishing TDOT's mission to serve the public by providing the best multimodal transportation system in the Nation.

TDOT has a long history of planning for multimodal transportation needs within the State. TDOT's 25-Year Long-Range Transportation Plan is an important document for the Department and its many stakeholders as the Plan allows TDOT to make key long-term funding and policy decisions about transportation investments throughout Tennessee today and in the future.

A major outcome of this two-year comprehensive effort is a mid-term, 10-Year Strategic Investment Program. The intent of the 10-Year Strategic Investment Program is to capture the insights gained during the development of the 25-Year Long-Range Transportation Plan to concurrently develop a program investment plan that is fiscally constrained that can be implemented over a 10-year horizon.

Over the course of the Plan process, an extensive public involvement program is in place to gather input from a variety of stakeholders, including the public, elected and appointed officials, and community groups located throughout the state.

www.tdot.state.tn.us/transportationplan
Phase 1 of the Statewide Model Update: Data Development
Statewide Model Update

Existing Statewide Model
• 2003 Base – 2030 Horizon
• Only Total Daily Traffic
• Limited Network Coverage
• Limited Sensitivity
  - Re-routing Only

New Statewide Model
• 2010 Base Year – 2040 Horizon Year
• Peak Hour and Daily Traffic
• Expanded Network Coverage
• New Sensitivity to:
  - Network changes
  - Induced demand
  - Alternative future land use scenarios
  - Population changes (aging, etc.)
Statewide Model Update: Phases 1 & 2

**Phase 1: Data Development (currently underway)**
- New, Expanded Network
- New, More Detailed Zone System
- Obtain & Process Socioeconomic Data
- New Socioeconomic Forecasts
- Obtain & Process ATRI Truck GPS Data
- Combine NHTS & MPO Household Travel Survey Data

**Phase 2: Model Development (2014)**
- New Trip-based Model
- Time-of-Day Modeling (peak hour volumes)
- Destination Choice Models (greater accuracy)
- Possible Pivot-Point Structure (greater accuracy)
- Truck/Freight Modeling still being scoped
- Post-processing for Performance Measures (access to jobs, hospitals, etc.)
## Zone Size and Network Coverage

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<thead>
<tr>
<th></th>
<th>Ohio</th>
<th>Iowa</th>
<th>Indiana</th>
<th>Tennessee v1</th>
<th>Tennessee v2</th>
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<td>Population</td>
<td>11,500,000</td>
<td>3,100,000</td>
<td>6,500,000</td>
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<td>45,000</td>
<td>19,000</td>
<td>9,421</td>
<td>29,000</td>
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<td>TAZ in state</td>
<td>3,660</td>
<td>1,866</td>
<td>4,690</td>
<td>1,222</td>
<td>3,500</td>
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<td>Total TAZ</td>
<td>5,116</td>
<td>3,314</td>
<td>4,831</td>
<td>1,397</td>
<td>3,750</td>
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<td>Pop / TAZ*</td>
<td>3,200</td>
<td>1,600</td>
<td>1,400</td>
<td>5,300</td>
<td>1,800</td>
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<td>Acres / TAZ*</td>
<td>12.2</td>
<td>30.2</td>
<td>7.8</td>
<td>34.5</td>
<td>12.0</td>
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<tr>
<td>Miles / Acre</td>
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<td>0.8</td>
<td>0.5</td>
<td>0.2</td>
<td>0.7</td>
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<td>70</td>
<td>340</td>
<td>690</td>
<td>220</td>
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<tr>
<td>Miles / TAZ</td>
<td>11.5</td>
<td>24.1</td>
<td>4.1</td>
<td>7.7</td>
<td>8.3</td>
</tr>
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</table>

*in state

- TAZ and network for new Tennessee model are current estimates
- New model probably will have **triple** the network and zones
Network Development
Defining the Network

How do we decide what to include in the network?

**Old Model**
- Interstates & Principal Arterials

**New Model**
- Started with minimum criteria
  - Anything in the old model
  - Anything in the National Highway Planning Network (NHS, etc.)
  - All minor arterials
- Want network coverage one class lower than desired forecasts
- Began to look at TRIMS data, to consider volume thresholds, etc.
- Found the TRIMS Traffic layer (e.g., roads with TDOT traffic counts) has roughly the right level of network coverage
- Had to add ~100 links to minimum criteria
- May still remove a small number of roads to ensure good balance with TAZ
Defining the Network

New vs. Old Network

TRIMS Traffic Layer
Network Topology: Connectivity & Routing

Model Requirements
• Connected and routable network

Options
• Connect TRIMS GIS layers – Not enough time & budget
• TN OIR E99 layer – Not ready until 2014
• TeleAtlas network – Chosen

Issues
• How to connect with TRIMS
• TRIMS missing ramps
• Elevation (Z) data
Network Attributes

**Chosen Attributes**

- Design
  - Direction
  - Divided
  - Access Control
  - Lanes
  - Lane width
  - Shoulder width
  - Terrain
  - Speed Limit
- Traffic
  - AADT
  - Peak hour %
  - MU Truck %
  - SU Truck %
- Administrative
  - Functional Class
  - Ownership
  - County
- Intersection
  - Control Type

**Missing Attributes**

- Most attributes substantially complete
- 90% of roads with missing speed are rural minor arterials
- Speed is missing on roughly half of this class
- No volume / geographic pattern – ok to impute

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Missing</th>
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<tr>
<td>Speed Limit</td>
<td>15.94%</td>
</tr>
<tr>
<td>Divided</td>
<td>0.01%</td>
</tr>
<tr>
<td>Lanes</td>
<td>0.03%</td>
</tr>
<tr>
<td>AADT</td>
<td>0.05%</td>
</tr>
</tbody>
</table>
Network Development Process

Getting the TRIMS attributes on the routable TeleAtlas network…

• Develop a Least-Common-Denominator (LCD) TRIMS line layer network with a nodes anywhere a chosen attribute changes
• Get all the TRIMS attributes onto the single LCD layer
• Simplify and reduce the LCD representation above if possible
• Develop a common segmentation between LCD TRIMS and TeleAtlas
• Pass the TRIMS attributes over onto the newly segmented TeleAtlas layer
• Simplify the newly segmented TeleAtlas layer (remove unnecessary nodes)
A Good Lookin’ TAZ

What should a TAZ look like? What makes for a good TAZ?

Traditionally
• Zone boundaries conform to the network
• And other boundaries, maybe
• And homogenous land use, maybe

Travel Sheds
• Zones as catchment areas around network
• Borrowed from hydrology
• First used for TAZ in NW 20+ years ago
• Increasingly common in statewide models
• Clearer relationship to the network, less ambiguity about loading points / centroid connectors
• Better able to represent distinct rural and small urban zones
• Take other boundaries more seriously
Building Blocks

What are the statewide TAZ made of?

**Urban**
- Aggregations of MPO zones
- Mix of traditional and travel sheds

**Rural / Small Town**
- Aggregations of Census blocks? (Or overlay?)
- Less traditional, mostly travel sheds
Putting the Puzzle Pieces Together

How do you group MPO zones / Census blocks into SWM TAZ?

**Clustering**
- Groups nearby/similar blocks together
- Similarity / proximity can be defined
- Does not ensure contiguity (can have “islands”)
- Does not ensure compactness (can have “tentacles”)

**Partitioning**
- Takes clusters as input
- Ensures contiguous, compact, balanced zones
Matchmaking

So how do you cluster blocks? What does “nearby” or “similar” mean?

**Distance Function**

- Combines various measures of proximity and similarity into a single measure

“Distance” = TT + aD + bC + cP + dHX + eWX + fRR + gMX

- TT: travel time (from TeleAtlas)
- D: Simpson’s D dissimilarity statistic calculated from pop, ind emp, com emp
- C: Different County (binary)
- P: Different Census Designated Place (binary)
- HX: Major (access controlled) highway crossings (# of)
- WX: Major water crossings (# of)
- RR: Railroad crossings (# of)
- MX: Ridge line (Mountain) crossings (# of)

a, b, c, d, e, f, g: weights (minutes of penalty per unit of variable)
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  P: Different Census Designated Place (binary)
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  MX: Ridge line (Mountain) crossings (# of)

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Easy Criteria

Counties

Places
Harder Criteria

Slopes, Ridgelines and Water Features

- Plenty of water layers, but how to define “major”
- No canned “ridgeline” layers
- Created ridgelines by processing DEMs
- Tried to define “internal” criteria
- Instead, used visual inspection against TeleAtlas, looking for network gaps
- Found slopes more a barrier than ridges in some areas
Diversity vs. Homogeneity

How do you measure “homogenous land use”?

Diversity or Dissimilarity Statistics

- Lieberson’s (1969) D statistic
  - Measures the probability that two items drawn at random from two different samples will belong to the same category
    \[ d_{ij} = 1 - \sum_c [P_i(c)][P_j(c)] \]
  - Defined on the interval [0,1]
  - Two zones with all items of only one category have \( d = 0 \)
  - Two zones with no category with an item in both zones have \( d = 1 \)
  - For “land use” we simply take each household, commercial job and industrial job as an item
Socioeconomic Data Development
Demographics

Decennial Census
- Population, Households, Children, Seniors
- Block level data

American Communities Survey
- Workers, Vehicles, Income
- Block group level available
- Disaggregate to blocks proportionally to households
Employment Categories

Industry Categories

• Using standard 20 two digit NAICS categories for data development
• May combine categories later if not needed for the model

<table>
<thead>
<tr>
<th>NAICS Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Agriculture, Forestry, Fishing and Hunting</td>
</tr>
<tr>
<td>21</td>
<td>Mining, Quarrying, and Oil and Gas Extraction</td>
</tr>
<tr>
<td>22</td>
<td>Utilities</td>
</tr>
<tr>
<td>23</td>
<td>Construction</td>
</tr>
<tr>
<td>31-33</td>
<td>Manufacturing (31, 32, 33)</td>
</tr>
<tr>
<td>42</td>
<td>Wholesale Trade</td>
</tr>
<tr>
<td>44-45</td>
<td>Retail Trade (44 &amp; 45)</td>
</tr>
<tr>
<td>48-49</td>
<td>Transportation and Warehousing (48 &amp; 49)</td>
</tr>
<tr>
<td>51</td>
<td>Information</td>
</tr>
<tr>
<td>52</td>
<td>Finance and Insurance</td>
</tr>
<tr>
<td>53</td>
<td>Real Estate and Rental and Leasing</td>
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<tr>
<td>54</td>
<td>Professional, Scientific and Technical Services</td>
</tr>
<tr>
<td>55</td>
<td>Management of Companies and Enterprises</td>
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<tr>
<td>56</td>
<td>Administrative and Support and Waste Management and Remediation Services</td>
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<tr>
<td>61</td>
<td>Educational Services</td>
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<tr>
<td>62</td>
<td>Health Care and Social Assistance</td>
</tr>
<tr>
<td>71</td>
<td>Arts, Entertainment, and Recreation</td>
</tr>
<tr>
<td>72</td>
<td>Accommodation and Food Services</td>
</tr>
<tr>
<td>81</td>
<td>Other Services, except Public Administration</td>
</tr>
<tr>
<td>92</td>
<td>Public Administration</td>
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</table>
Employment Data Sources

**InfoGroup**
- Purchased data for all Tennessee
- Individual business with lat, long locations
- Based on phone surveys, aggregated data

**LEHD**
- Freely available federal data
- Employment by NAICS category by Census block
- Based on administrative (tax) records, with some ‘fuzziness’ added to preserve privacy

**BEA**
- Freely available federal data
- **Total** employment by NAICS category at County level

**Woods & Poole**
- Purchased data including employment forecasts consistent with BEA
Using InfoGroup and LEHD Together

Cleaning
• Compare differences and correlations look for outliers

Combining
• Both InfoGroup and LEHD account for roughly 85% of BEA
• If they are independent, together they would account for 98% of BEA
• Research in Ohio suggests they are close to independent
Using InfoGroup and LEHD Together

Cleaning
Socioeconomic Forecasts
County Control Totals

Sources of Forecasts

- UT’s Center for Business and Economic Research (CBER) – population only
- Woods & Poole
- MPO forecasts
- Historic growth rates and trends

Anderson County Population Projections
Allocation to TAZ

**MPO areas**
- Use MPO growth allocations
- Absolute growth may not match exactly if control totals differ, but same pattern will be assumed

**Non-MPO areas**
- Allocate future growth near/where growth has occurred historically
  - Population: Census 2000 & 2010
  - Employment: LEHD 2002-2012
ATRI Truck GPS Data
ATRI Truck GPS Data

What’s ATRI?

**American Transportation Research Institute (ATRI)**

- non-profit funded by the trucking industry
- Receives over 4 Billion GPS truck positions annually from member organizations
- Cannot disclose the individual raw truck traces, but can provided processed data products which avoid disclosure
- Basis of FHWA’s Freight Performance Measures Webtool
- Used for major corridor studies, I-95, I-70
- Incorporated in Indiana & Iowa’s statewide models
- Now in the process of acquiring data for Tennessee
24 Hours
48 Hours
72 Hours
5 Days
7 Days
Indiana Experience

Data
• Eight week sample
• 16 million records
• 305,000 trucks
• 2 million truck trips

Results

<table>
<thead>
<tr>
<th>Model</th>
<th>2006 Model</th>
<th>2010 Model</th>
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<tr>
<td>Observations</td>
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<td>Avg. Count</td>
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<td>1,264</td>
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<td>RMSE</td>
<td>69.3%</td>
<td>60.6%</td>
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<tr>
<td>Avg Error</td>
<td>5.4%</td>
<td>-0.1%</td>
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<tr>
<td>MAPE</td>
<td>74%</td>
<td>42%</td>
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</table>

Method
• Used existing commodity-flow based model to pivot off of expanded ATRI data
Data Processing

What constitutes a stop?

Anonymized GPS records converted to ODs

- Criteria based on speed and time
- Duration of a stop necessary to avoid counting traffic stops as destinations

<table>
<thead>
<tr>
<th>from TAZ</th>
<th>to TAZ</th>
<th>distance</th>
<th>time</th>
<th>elapsed time</th>
<th>speed</th>
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<th>status2</th>
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<td>18023</td>
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<td>5.0</td>
<td>5.0</td>
<td>0.0</td>
<td>stopped</td>
<td>stopped</td>
</tr>
</tbody>
</table>
Data Expansion

It’s a big sample, but it’s still a sample.

**Simple Scaling**
- Single uniform expansion factor
  - sample truck VMT to HPMS truck VMT

**Complex Weighting**
- Varying weights by
  - Region
  - Trip length
- Weights developed by analyzing results of ODME
Household Survey Data
Combining NHTS & MPO Surveys

Datasets
- NHTS Add-On for Tennessee
  - Oversampled rural areas
- MPO surveys
  - Complete/complement NHTS
  - May not use all MPO surveys

Re-weighting and combining
- Controls
  - Region
  - Household size by vehicles
  - Person age
- Iterative Proportional Fitting
Results of the MPO Survey
TN MPO Travel Demand Model Survey

- Online Survey
- Conducted between Sept to Oct 2013
- 20 Questions
- Completed by all 11 TN MPOs
What counties does your travel demand model cover?

- MPO models cover 42 counties (29 in TN and 8 in other States)
- Other States include: Georgia, Kentucky, Virginia, & Mississippi
- MPO models range from 1 county to 10 counties in size
What is the **Base Year** of your currently approved model?

- Base Years range from 2004 to 2010
- Six models have a Base Year of 2010

What is the **Last Horizon Year** of your currently approved model?

- Future Years range from 2035 to 2040
- Future Year - 4 have 2035 - 7 have 2040

What other **interim horizon years** are part of your model?

- Most models have interim horizon years
TN MPO Travel Demand Model Survey Results

When are you looking to update your model?

- Four are currently updating their model (Bristol, Chattanooga, Nashville, & Memphis)
- Five in 2016

What will be the Base Year of the new model?

- Three are looking at 2010
- Others range from 2012 to 2017
TN MPO Travel Demand Model Survey Results

What data was used for your Base Year POPULATION control totals?

• 2000 and 2010 US Census data most cited

What data was used for your Future Year POPULATION control total projections?

• 9 of the 11 used Woods & Poole for the future year population projections
• 4 referenced UT's population projections
What data was used for your Base Year EMPLOYMENT control totals?

- 7 MPOs referenced Woods & Poole
- Other sources: InfoGroup, Dun & Bradstreet, Bureau of Labor Statistics

What data was used to allocate your Base Year EMPLOYMENT to the TAZ?

- 8 MPOs referenced using InfoGroup data

What data was used for your Future Year EMPLOYMENT control total projections?

- 9 MPOs referenced Woods & Poole data
TDOT is considering several options for other data that could be available to MPOs; which of the following are you interested in:

**Woods & Poole Economics (Economic & Demographic Data)**
- 7 would Love to Have
- 4 would be Nice to Have

**InfoGroup (Locational Employment Data)**
- 8 would Love to Have
- 3 would be Nice to Have
What type of freight data was used in your current travel demand model?

- 6 MPOs referenced TRANSEARCH data
- 4 MPOs referenced FAF Commodity Flow data

What freight data are you likely to use in the future?

- TRANSEARCH data: 2 Certain / 4 Likely / 5 Possibly
- ATRI Truck GPS data: 3 Certain / 1 Likely / 7 Possibly
- FAF data: 2 Certain / 3 Likely / 6 Possibly

TDOT is considering several options for freight data; which of the following are you most interested in?

- 9 MPOs used Woods & Poole for the future year population projections
- 4 MPOs referenced UT's population projections
TDOT is considering several options for freight data; which of the following are you most interested in:

TRANSEARCH data
• 3 - 1st Choice, 5 - 2nd Choice, 3 - 3rd Choice

ATRI Truck GPS data
• 4 - 1st Choice, 5 - 2nd Choice, 2 - 3rd Choice

FHWA FAF data
• 4 - 1st Choice, 1 - 2nd Choice, 6 - 3rd Choice
TN MPO Travel Demand Model Survey Results

How best can TDOT and their consultant involve you in the update of the statewide travel demand model?

- Email
- TNMUG Meetings
- Periodic Conference Calls
Preview of Phase 2 of the Statewide Model Update
Phase 2: Model Development

Advanced Trip-based Passenger Model
• Advanced trip generation
• Destination choice models
• Peak hour models

Truck / Freight Model
• Still being scoped

Validation

Post-processing
• Traffic statistics
• Post-processing
Advanced Trip Generation

Non-linear Regression Models
- Allow multiple explanatory variables
  - Effect of area type / accessibility
  - Effect of seniors / children
- Capture both rational non-linearities
  - Diminishing returns to scale
  - Interaction effects

Poisson Distributed Household Variables
- Reduces aggregation as in cross-class
- But don’t require stratification curves, etc.

Source: Wikimedia Commons
Destination Choice Models

**Account for More Factors**
- Number of Attractions
- Travel Time / Impedance
- Effect of Residence Location on Willingness to Travel
- Psychological Boundaries
  - River Crossings
  - Ridgeline Crossings
  - Major Highway Crossings
  - State / County Line Crossings
- Walkability of Destination
- Mixture of Land Uses at Destination
- Convenience for Trip-Chaining
- Spatial Auto-correlation Effects

Trip Chaining in Knoxville

Fewer, Longer Rural Trips
More, Shorter Urban Trips
Peak Hour Models

Nested Logit Models

• Must account for duration of long trips
• Upper nest determines at least some portion of the trip occurs in the AM peak hour, PM peak hour or both
• Lower nest determines how much of the trip occurs in the peak hour
• Will consider differences in peak hour factors related to
  – area type / accessibility of origin and destination
  – trip length
  – region
Truck / Freight Model Options

Three Options
- ATRI-based Truck Models
- Commodity flow-based Freight Models
- Supply Chain Logistics & Truck Tour Simulation Models

Considerations
- Budget
- Schedule for Long Range Plan
- Availability of Required Data
- Ability to Evaluate Potential Projects
Truck Models

Model Structure
• Three step, like traditional passenger models
• Segmentation
  – by vehicle type
    light commercial vehicles
    single unit trucks
    multi-unit trucks
  – by trip type
    commercial passenger trip
    service delivery trip
    freight delivery trip

Can be developed based on ATRI data, pivot off of ATRI data
New truck-rail intermodal facilities can be handled by special diversion module
Inexpensive and quick to develop
Commodity Flow-based Models

**Model Structure**
- Commodities produced, consumed & exchanged
- Four step, like traditional passenger models
- Must be used together with truck models since only long-haul freight movements included

**Other Modes**
- Can provide information on freight movements by modes other than truck
- Limited ability to model freight mode shifts
- Rail assignment still experimental

**Commodity Flow Data**
- Transearch requires considerable cleaning
- FAF requires considerable disaggregation

**Moderately Expensive to Develop**
**Moderately Time Consuming to Develop**
Supply Chain Logistics & Truck Tour Simulation Models

Model Structure
- Firm synthesis (like population synthesis in ABMs)
- Simulated negotiations between shippers, carriers, 3PLs
  - agent-based computational economics & game theory
- For truck mode, simulation of tours as in ABMs

Most Realistic Freight Mode Choices
Data Hungry
Expensive to Develop
Time Consuming to Develop
Validation

Demand Validation
• Generation Rates
• Trip Lengths
• JTW Patterns

Assignment Validation
• Will produce similar statistics as for MPO models
• Different criteria for statewide models

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%RMSE for Statewide Models from NCHRP 08-36-91
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Palette (save me)

The palette must be saved by EACH computer using the template. Go to Design> Colors> Create new theme color. The default colors will be the RSG colors. Give it a name and SAVE. Otherwise, the first time you change colors you will lose the palette.

- **Main colors**
  - Red: 246
  - Green: 139
  - Blue: 31
  - Red: 72
  - Green: 72
  - Blue: 764

- **Pop/accents colors**
  - R: 0
  - G: 100
  - B: 148
  - R: 136
  - G: 202
  - B: 222
  - R: 101
  - G: 179
  - B: 96
  - R: 233
  - G: 214
  - B: 101
  - R: 81
  - G: 77
  - B: 133
  - R: 156
  - G: 18
  - B: 43

- **Neutrals of grey and light warm yellow**
  - R: 127, G: 127, B: 127