An Update to SCAG’s External Heavy Truck Model using Firm Synthesis and Supply Chain Modeling Techniques

SCAG Modeling Task Force
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Outline

• Freight and truck modeling concepts
• External model design: introduction to model components
• Software design and visualization
• Discussion of model sensitivity
Design Overview
Behavior-Based Freight Models: 3 Types Emerging

Supply Chain Models
• Tend to be National in scope
• Some examples at State and Regional levels

- Focused on modeling commodity flows
- Includes components such as firm synthesis and supply chain models
- Mode and path selection
Supply Chain Models
• Tend to be National in scope
• Some examples at State and Regional levels

Tour-based Models
• Tend to be Regional in scope
• Some examples at State and National levels

- Focused on modeling truck movements
- Includes components such as tour generation, vehicle type models, and time of days models
- Many build tours incrementally
Supply Chain Models

Tour-based Models

Hybrid Models
- Combined supply chain and tour-based models
- For Regional/Statewide planning, but with a National component

- Models shipments using the supply chain framework
- Regional pick up and delivery of shipments is handled by touring trucks
What is Firm Synthesis?

• A model that creates a complete set of “agents” that represent firms
• The model embodies each of those firms with individual characteristics that affect the behavior that we are interested in modeling:
  – Where are they located?
  – How large is the firm?
  – What industry do they operate in?
  – Which commodities do they consume?
  – Which commodities do they produce?

• Concept is similar to population synthesis used in activity-based models
  – In this case, households are the agents that are created
  – They are described in terms of location, size, etc.
Producer Locations and Characteristics for Commodity 2122A0

**Producer Locations**

A map of the United States showing the locations and sizes of producers for Commodity 2122A0.

**Establishments by Size**

A bar chart showing the number of establishments by size. The chart indicates that the majority of establishments are small, with less than 20 employees per establishment.

**Employment by Establishment Size**

A bar chart showing the sum of employment by establishment size. The chart indicates that the majority of employment is in small establishments, with less than 20 employees per establishment.
What are Production – Consumption Models?

• Given a set of firms with production capacity and consumption requirements, these models
  – Simulate trading between firms
  – Allow buyers to identify preferred suppliers
  – Estimate the amount (tons and value) of a commodity traded
  – Aggregated results are analogous to commodity flow origin-destination data (e.g. Freight Analysis Framework)

• Several approaches
  – Rule based approach (based on UIC’s FAME work)
  – Procurement market games (game theory)
All Attempted Trades and Final Trades for One Buyer

Sellers That Buyer 851828 Attempted to Trade With Quantity Traded, All Iterations

Sellers That Buyer 851828 Attempted to Trade With Quantity Traded, Last Iteration
What are Logistics – Chain Models?

- This family of models simulate decisions made on how to move a commodity between supplier and buyer:
  - How often will shipments by made?
  - How large will the shipments be?
  - Which mode(s) will carry the shipments?
  - Which route will the shipments take?
  - Where will intermodal/within mode transfers take place?

- Model forms include Multinomial Logit Models and logistics cost equations
Model Design
Model Design Overview

• **Overall Model Structure**
  – Integrates data from multiple sources
  – Designed for integration within the rest of the SCAG Travel Demand Model

• **Firm Synthesis Model**
  – Synthesizes a set of business establishments that ship and receive freight in the region

• **Supply Chain Model**
  – Models annual commodity movements and shipment flows to and from the region by truck

• **External Truck Trips Model**
  – Allocates shipments to trucks to produce truck trip tables
Overall Model Design

- SCAG Travel Demand Model
  - Freight Model
    - Firm Synthesis
    - Supply Chain Model
    - Synthetic Firms
    - Shipments
    - Other Truck Components (Internal, Port)
    - External Truck Trips
    - Truck Trip Tables
  - Assignment to Regional Highway Network
  - Passenger Vehicle Trip Tables
  - Passenger Model
Multiple Geographic Levels

• **National Supply Chain Model**
  – Include all of U.S, Canada, and external foreign zones
  – Uses FAF4 regions as zone system
  – Static travel times and distances (model input) to and from each TAZ to each SCAG external stations

• **California**
  – Use smaller zone system than FAF4 zones, the California Statewide Travel Demand Model TAZs.
  – Static travel times and distances (model input) to and from each TAZ to each SCAG external stations

• **SCAG Model Area**
  – Uses SCAG model network and zones
Firm Synthesis Data Needs

• **SCAG Region Data**
  – Point business locations – InfoUSA
  – TAZ control data for base and future years – SCAG model
  – Spatial data – TAZ system

• **Business/Industry Data**
  – BEA input/output data
Firm Synthesis Model Outputs
Firm Synthesis Model Outputs

606,148 Synthesized Firms

8,479,827 Synthesized Employees
Supply Chain Framework

- **Firm Synthesis**: Synthesizes a list of businesses in the model region.
- **Supplier Selection**: Connects suppliers to buyers based on the commodities produced by the supplier and consumed by the buyer.
- **Goods Demand**: Distributes commodity flows amongst the paired suppliers and buyers.
- **Distribution Channel**: For each buyer/supplier pair, selects whether shipments are direct or involve intermediate handling (intermodal, distribution center).
- **Shipment Size**: For each buyer/supplier pair, converts an annual commodity flow to shipments by size and frequency.
- **Mode and Transfers**: Identifies the mode for each leg of the trip from supplier to buyer and the transfer locations.
Supply Chain Data Requirements

- **Commodity Flow Data**
  - Base Year Commodity Flows (Freight Analysis Framework Data)
  - Forecasted Commodity Flow Data (Transearch, FAF)
  - Shipment Size Data (Commodity Flow Survey)
Supply Chain Model Outputs

1,191,410,361
Annual Shipments

263,897,675
Annual Shipments (X by Truck)

761,088,166
Annual Shipments (T by Truck)

180,630,281
Annual Tonnage

66,873,034
Annual Tonnage (X by Truck)

58,630,594
Annual Tonnage (T by Truck)
External Truck Trip Data Needs

• **Payload and empty factors**
  – Based on VIUS data by commodity
  – Regional (California) specific where sample supports, national otherwise

• **Calibration**
  – ATRI describing locations served by trucks to/from each external (as well as proportion that is external to external traffic)
  – Count data by truck class and time of day at each external station
External Trip Model Outputs
Software Design and Visualization
Software Design

• **Self contained component:** External Heavy Duty Truck model is a self contained model component that reads inputs, simulates the truck trips, and writes outputs (trip lists and summaries)

• **Programming platform:** Written in R, and leverages several R packages to support applying models and visualizing results

• **Non compiled code:** Code is open to read and modify
Overall Model Design

SCAG Travel Demand Model

Freight Model

- Firm Synthesis
- Supply Chain Model
- Synthetic Firms
- Shipments
- Other Truck Components (Internal, Port)
- External Truck Trips
- Assignment to Regional Highway Network
- Truck Trip Tables

Passenger Model

- Passenger Vehicle Trip Tables
rFreight Application Structure

rFreight R package: library of functions used throughout the model

Main.R: controller file that manages model flow

R script – model component

Inputs: tabular, network skims

Outputs: trip tables, reporting via “freightviz”

Other Model Components: GISDK Scripts for Skimming and Assignment
Visualization Dashboard

• **In one place:** A tool that provides a summary of a set of model results (or data analysis, etc.)

• **Visually Compelling:** Data are presented in a way that is readily digestible

• **Up to date:** Results are updated without work required by the user

• **Interactive:** Users can query, select, filter, pan, zoom, etc.
Dashboard Technology

- **Single HTML file** that is produced at the end of each model run
  - Can be linked directly to a website, or
  - Distributed by email and opened in a web browser

- **Interactive tabulations, charts, and maps embedded directly into the HTML file**
  - Uses client-side interactivity or publicly available web-resources, e.g. Open Street Map.
  - No need for hosting on a webserver
Dashboard Landing Page
Results in Charts, Maps, and Tables

606,148
Synthesized Firms

8,479,827
Synthesized Employees
Discussion of Model Sensitivity
Model Sensitivity

• **Firm Synthesis Model**
  – Location and growth of business establishments that ship and receive freight in the region
  – Controlled to regional forecasts, but override ability for specific businesses as scenario tests

• **Supply Chain Model**
  – Forecasts of annual commodity movements by consumption in the SCAG region and also changes in external production and consumption locations
  – Mode choices by commodity and other logistics behavior such as use of distribution and warehousing

• **External Truck Trips Model**
  – Travel times within the region (to and from external stations)
  – Capacities and loading of trucks
  – Diurnal profile of trucks entering and leaving the region
Summary

• The updated external heavy duty truck model
  – Incorporates new freight modeling techniques
  – Includes components that simulate firms and supply chains that lead to shipment and truck movements to and from the region

• Modeling software
  – Developed as a standalone component for integration with the SCAG travel demand model
  – Includes a visualization dashboard

• Status
  – Currently completing the project and transferring final models and documentation to SCAG staff